**GEOVision**
*geophysical services*
*a division of Blackhawk Geometrics*

# GEOPHYSICAL INVESTIGATION

## Aerial Photographic Anomaly Area 46
## Marine Corps Air Station, El Toro, California

GEOVision Project No. 0260

Prepared for

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June 13, 2000

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June 16, 2000

Contracting Officer
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Southwest Division
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San Diego, CA 92132-5187

Attention: Ms. Lynn Hornecker

**Subject: Geophysical Survey Report for APHO 46**
**Contract N68711-93-D-1459, Delivery Order 070,**
**Remediation of Various UST, AOC and RFA Sites, MCAS El Toro, California**

Dear Ms. Hornecker:

The attached report from GEOVision Geophysical Services, details their survey efforts and results at Aerial Photograph Anomaly Area 46 (APHO 46). The survey identified one area of some potentially near-surface contacts that might bear field verification, and clearly demarcated the area of IRP Site 5 where it intersects the APHO vicinity.

As we discussed by telephone, there is a linear feature that runs parallel to the Site 5 boundary, which could be an old pipeline, or possibly some guard rail feature associated with the landfill. However, it does not appear to be associated with the APHO site.

If you have any questions or need additional information or copies please call or e-mail me.

Sincerely,

William Sedlak, P.E.
Sr. Project Manager

cc: L. Holloway, COTR 1C/1E
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**Location:** MCAS EL TORO

**FROM:** [signature] FOR
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# TABLE OF CONTENTS


1 INTRODUCTION ..... 1

2 GEOPHYSICAL TECHNIQUES ..... 2

2.1 MAGNETIC METHOD ..... 2
2.2 ELECTROMAGNETIC INDUCTION METHOD ..... 3
2.3 GROUND PENETRATING RADAR METHOD ..... 4

3 FIELD PROCEDURES ..... 6

3.1 SITE PREPARATION ..... 6
3.2 MAGNETIC SURVEY ..... 6
3.3 GEONICS EM-31 SURVEY ..... 7
3.4 FIELD VERIFICATION AND GPR SURVEY ..... 7

4 DATA PROCESSING AND INTERPRETATION ..... 8

4.1 DATA PROCESSING ..... 8
*4.1.1 Magnetic and Geonics EM-31 Data Processing ..... 8*
*4.1.2 Ground Penetrating Radar Data Processing ..... 9*
4.2 INTERPRETATION ..... 9

5 CONCLUSIONS ..... 12

6 CERTIFICATION ..... 13

APPENDIX A GEOPHYSICAL TECHNIQUES FOR SHALLOW ENVIRONMENTAL INVESTIGATIONS


# LIST OF FIGURES


FIGURE 1 SITE LOCATION MAP
FIGURE 2 SITE MAP WITH GEOPHYSICAL INTERPRETATION
FIGURE 3 CONTOUR MAP OF TOTAL MAGNETIC FIELD INTENSITY
FIGURE 4 CONTOUR MAP OF GEONICS EM-31 CONDUCTIVITY RESPONSE
FIGURE 5 CONTOUR MAP OF GEONICS EM-31 IN-PHASE RESPONSE
FIGURE 6 GROUND PENETRATING RADAR PROFILES 5095 AND 5098

# 1 INTRODUCTION

A geophysical investigation was conducted on April 20 to May 10, 2000 in an approximate 12-acre area encompassing Aerial Photographic Anomaly Area 46, Marine Corps Air Station (MCAS), El Toro, California. The purpose of the investigation was to screen the site for buried metallic and/or construction debris and fill soils.

The geophysical survey area consisted of an open dirt field located northeast of the eastern portion of the golf course. A chain link fence parallel to the adjacent Perimeter Road runs along the southeastern edge of the survey area. The location of the survey area is shown on Figure 1.

There was no surficial evidence of disposal activities at the site. The only surficial cultural features within the survey area that could adversely affect the geophysical data included monitoring wells, the fence, and sparse scattered surface debris.

Geophysical techniques used during this investigation included magnetic, electromagnetic (EM) induction, and ground penetrating radar (GPR) methods. These techniques complement one another as each responds to different physical properties or subsurface materials and has different strengths and limitations. The magnetic method was applied to this investigation because it has the greatest depth of investigation of the geophysical methods typically applied to mapping buried metallic debris. However, this greater depth of investigation comes at the expense of lateral resolution. The EM induction technique was applied to this investigation because it can map both shallow buried metallic debris and variations in soil conductivity. Changes in soil conductivity may be used to infer the presence of fill soils, providing the fill has a different composition than native soils. The GPR method was applied to this investigation primarily to better characterize significant magnetic and EM anomalies.

Geophysical techniques used during the investigation are discussed in Section 2. Field procedures are described in Section 3. Data processing and interpretation are discussed in Section 4. Conclusions are presented in Section 5, and our professional certification is presented in Section 6.

# 2 GEOPHYSICAL TECHNIQUES

This section presents background information on the magnetic, EM and GPR methods used during this investigation. A description of the geophysical methods used during this investigation, common applications of the methods, photographs of the instruments, and example applications are included in Appendix A.

## *2.1 Magnetic Method*

The magnetometers used during this investigation consisted of a Geometrics G858 optically pumped cesium-vapor magnetometer (G858) and a GEM GSM-19 base station magnetometer. These instruments measure the intensity of the earth's magnetic field in nanoteslas (nT).

The earth's magnetic field is believed to originate in convection currents in the earth's liquid outer core. The magnetic field varies in intensity from about 25,000 nT at the equator, where it is parallel to the earth's surface to about 70,000 nT at the poles where it perpendicular to the earth's surface. The intensity of the earth's magnetic field in North America varies from about 45,000 to 60,000 nT, and has an associated inclination that varies from about 60 to 75 degrees. The earth's magnetic field undergoes low-frequency diurnal variations (drift) caused by the earth's rotation. The magnetic field can also undergo short-period, high-amplitude variations during periods of sunspot activity called magnetic storms. Often magnetic field intensity can be so variable during a magnetic storm that meaningful magnetic data cannot be acquired. When necessary to correct for magnetic drift a base station magnetometer is set up in a quiet portion of the site and programmed to record total magnetic field intensity at fixed increments (i.e. 5-second intervals) throughout the day. This base station data is then used to remove the effects of drift from the field data. In small survey areas where the data is acquired over a small amount of time and the anomalies have large amplitudes correction for magnetic drift is not necessary.

Buried ferromagnetic objects give rise to local perturbations (anomalies) in the earth's magnetic field. In North America, these anomalies are often dipolar with a positive response south and a negative response north of the object. The dimensions and amplitude of a magnetic anomaly are a function of the size, mass, depth and magnetic properties of the source. Magnetometers can typically locate a metallic object the size of a 55-gallon drum to a depth of about 10 feet providing background noise levels are not too high and the object is not significantly corroded. Larger metallic objects can be located to greater depths. The magnetic anomaly due to an object the size of a 55-gallon drum is expected to have dimensions of greater than 10- by 10-feet. Magnetometers are not able to detect nonferrous metals such as aluminum or brass.

Typical applications of the magnetic method include:

- Locating pits and trenches containing ferrous metallic debris
- Locating buried drums, tanks and pipes
- Delineating boundaries of landfills containing ferrous debris
- Locating abandoned well casing
- Detecting unexploded ordnance
- Mapping basement faults and geology

- Mapping archeological sites.

Some advantages of magnetic surveys are:

- Rapid – modern instruments can acquire up to 10 readings per second as the operator walks down survey lines
- Depth of investigation – magnetometers can often locate buried ferrous metallic objects to greater depths than other methods
- Anomalies are much larger than the source allowing for larger line spacing in some situations

Some limitations of the magnetic surveys are:

- Unable to detect nonferrous metals such as aluminum or brass
- Magnetic anomalies are unsymmetrical and much larger than the source and it can, therefore, be difficult to determine the precise locations and size of the source
- Ineffective in areas having extensive metallic debris at the surface as no distinction can be made between anomalies caused by surface and buried debris
- Metallic structures such as buildings, fences, reinforced concrete, and light posts interfere with the measurements
- High voltage powerlines can often strongly interfere with the measurements
- Data can be very noisy in areas containing volcanic rock, specifically basalt

## 2.2 Electromagnetic Induction Method

EM induction equipment used during this investigation consisted of a Geonics EM-31 terrain conductivity meter (EM-31) coupled to a digital data logger. The EM-31 consists of a transmitter and receiver coil, one at each end of 12-foot long boom. An alternating current is applied to the transmitter coil, causing the coil to radiate a primary EM field. This primary EM field generates eddy currents in subsurface materials, which give rise to a secondary EM field. The EM-31 measures the components of the secondary EM field both in-phase and 90-degrees out-of-phase with the primary EM field. The out-of-phase component is converted to apparent conductivity in millisiemens per meter (mS/m) and the in-phase component is measured as parts per thousand of the primary EM field. A negative EM-31 response with positive shoulders is generally observed over shallow, buried metallic objects. The EM-31 can locate both ferrous and nonferrous metallic objects and can locate a metallic object the size of a 55-gallon drum to a maximum depth of about 5 feet. The EM-31 must pass directly over or immediately adjacent to a buried metallic object to detect it. Because of the 12-foot separation between the transmitter and receiver coils, the EM-31 cannot detect very small, buried metallic objects. The EM-31 can also map changes in the electrical conductivity of subsurface soils caused by certain types of conductive contaminants (i.e. brines, drilling muds, chloride, metals, etc.) or simply a change in soil type (i.e. low conductivity sand to high conductivity clay).

Applications of EM Induction methods include:

- Locating buried tanks

- Locating pipes and utilities
- Locating pits and trenches containing metallic and/or nonmetallic debris
- Delineating landfill boundaries
- Delineating oil production sumps and mud pits
- Mapping conductive soil and groundwater contamination
- Mapping soil salinity in agricultural areas
- Characterizing shallow subsurface geology
- Mapping buried channel deposits
- Locating sand and gravel deposits
- Mapping conductive fault and fracture zones
- Mapping lateral variation in subsurface soil type

Strengths of EM Induction Methods include:

- Rapid – data can be acquired at a slow walking pace
- Locate both metallic and some nonmetallic targets
- Better resolution than magnetometer
- Not as sensitive to very small surface debris as other methods
- Can locate electrical and telephone cables which often cannot be located by other methods
- Anomalies of buried objects have simple shape facilitating identification and positioning of the source

Limitations of EM Induction Methods include:

- Metallic structures such as buildings, fences, reinforced concrete, and light posts interfere with the measurements
- High voltage powerlines can often strongly interfere with the measurements
- Depth of investigation not as great as that of a magnetometer for detection of buried ferrous metallic objects
- Highly variable soil conductivity can complicate quadrature component interpretation

## 2.3 Ground Penetrating Radar Method

GPR equipment used during this investigation consisted of a Geophysical Survey Systems, Inc. (GSSI) SIR-2 GPR system with a 500- or 300-MHz antenna (SIR2). Short duration EM pulses of high-frequency (80-1,000 MHz) generated by a transmitting antenna propagate into the ground and are reflected from electrical discontinuities in the subsurface back to a receiving antenna. In GPR the velocity of propagation in the subsurface is determined by the dielectric constant and the attenuation mainly by ground conductivity and scattering. The dielectric constant is largely determined by water content, because the relative dielectric constant of water is 80 and that of rock and soil minerals typically is between 3 and 6. Attenuation is related to soil conductivity, which is primarily a function of clay content, moisture content, and dissolved solids in the pore water. Small percentages of clay in subsurface soils can rapidly increase the attenuation of GPR signals. Depth penetration is also a function of antenna frequency and low frequency antennas can image to greater depths at the sacrifice of resolution. At typical sites in

Southern California, depth penetration of a 300-MHz antenna is limited to about 3 to 6 feet. High-amplitude, hyperbolic reflections are generally observed on GPR records over buried metallic objects.

Typical applications of GPR surveys include:

- Locating metallic and nonmetallic USTs
- Locating metallic and nonmetallic pipes and utility cables
- Mapping rebar in concrete structures
- Mapping landfill boundaries
- Delineating pits and trenches containing metallic and nonmetallic debris
- Mapping leach fields and industrial cribs
- Delineating previously excavated and backfilled areas
- Mapping very shallow water tables
- Characterizing very shallow stratigraphy
- Mapping very shallow bedrock
- Mapping shallow voids and cavities
- Mapping archaeological sites

Some strengths of the GPR methods include:

- Resolution – probably the best resolution of any geophysical method
- Potential to locate nonmetallic targets
- Ability to image approximate depth as well as lateral location of features
- Data can be acquired very close to surface structures and occasionally over reinforced concrete pads

Some limitations of the GPR method include:

- Depth penetration can be extremely limited (less that 3 feet)
- Data is more costly to acquire, process, and interpret than other methods
- Interpretation is not always straightforward (i.e. tree roots may look like pipes on GPR records)

# 3 FIELD PROCEDURES

This section describes the field procedures used during the investigation, including site preparation, magnetic and EM-31 survey procedures, and field verification and GPR survey procedures.

## *3.1 Site Preparation*

Before conducting the geophysical investigation, 4-foot long survey lathe were placed at 20-foot intervals along the southeast (SE) and northwest (NW) edges and in the middle of the approximate 620- by 700- foot original survey area to provide control for the geophysical survey. The survey area was later expanded in an approximate 330- by 280-foot area southwest of the original survey area to map the southwestern end of the Site 5-Perimeter Road Landfill.

A Sokkia GIR1000 single-frequency global positioning system (GPS) was coupled to the geophysical instruments to provide horizontal control for the geophysical data. Differential corrections were applied to the GPS data using GPS base station data recorded at the Sokkia office in Orange, California. GPS data were collected in geodetic coordinates based on the WGS84 system and transformed to approximate California State Plane Coordinates, Zone 6, North American Datum of 1983 (NAD83) after applying differential corrections. Ellipsoid heights measured using the GPS system were converted to NAVD 88 elevations using the Geoid Model of 1996. Maximum horizontal errors in the corrected GPS data are estimated to be about 3 feet, with average errors being about 1 to 2 feet.

The GPS system was also used to map pertinent surficial features at the site, including dirt roads, monitoring wells, fences, and surface debris; GPR profiles; and subsurface utilities located by the geophysical survey. Site mapping activities were conducted on April 24-25 and May 5-10, 2000.

A site map showing the location of the geophysical survey area, State Plane Coordinate System, and surficial features is presented as Figure 2.

## *3.2 Magnetic Survey*

Original magnetic data were acquired on April 20 and 24, 2000. Prior to data acquisition, the base station magnetometer was set up north of the survey area in a location free of surface debris. The internal clock of the base station and G858 were synchronized to GPS time and the base station was programmed to record the magnetic field intensity of the earth at 5-second intervals throughout the day. The G858 and GPS unit were then programmed with the appropriate settings. The magnetometer was operated with the sensor about 3 feet above ground surface. Measurements of the earth's total magnetic field intensity were made at 0.2-second intervals as the operator walked along SE-NW survey lines nominally spaced 10 feet apart. The 0.2-second sampling interval resulted in an average station spacing of about 1 feet. The stakes placed at the ends and middle of the survey area allowed the instrument operator to walk a relatively straight line, thereby ensuring uniform site coverage. The magnetic data were stored in the internal memory of the magnetometer, along with line number, and time of measurement. If an error was made on a survey line the line was deleted from the magnetometer's internal memory and reacquired. GPS, base station and field magnetic data were downloaded to a laptop computer at the end of the magnetic survey. On May 3, 2000, additional magnetic data were acquired along 5-foot profiles in a small area in the northwestern portion of the survey area to better characterize an anomalous area. On May 5, 2000 the survey was expanded to the southwest to delineate the southwest end of the Site 5-Perimeter Road Landfill.

## 3.3 Geonics EM-31 Survey

EM-31 data were acquired on April 20 and 24, 2000. Prior to data acquisition, the EM-31 was assembled and battery levels were checked and found to be within acceptable levels. The in-phase component was then set to zero in a portion of the site with no buried metallic objects. The EM-31 digital data logger was synchronized to GPS time and programmed with the appropriate file name, line number, measurement increment, and direction. Changes in these parameters were made as necessary throughout the survey. The EM-31 was operated in vertical dipole mode with an approximate 3-foot instrument height and the instrument boom parallel to the survey lines. EM-31 measurements of conductivity and in-phase component were made at 0.5-second intervals as the operator walked along SE-NW survey lines nominally spaced 10 feet apart. The 0.5-second sampling interval resulted in an average station spacing of about 2 feet. The EM-31 data were stored in a digital data logger along with line and station number. If an error was made acquiring a line, a note was made in the field log and the line repeated. EM-31 and GPS data were downloaded to a laptop computer at the end of each field day. On May 5, 2000 the survey was expanded to delineate the southwest end of the Site 5-Perimeter Road Landfill.

## 3.4 Field Verification and GPR Survey

The verification phase of the investigation was conducted after processing of the magnetic and EM-31 data. A discussion of data processing procedures is provided in the following section. Significant magnetic and EM-31 anomalies were field checked to verify that they had subsurface sources. Attempts were made to trace any pipes located by the geophysical survey using an EM utility locator or Fisher metal detector. These pipes were marked on the ground with surveyor paint and later surveyed using GPS.

GPR data were collected with the SIR2 on May 10, 2000 over a small area of anomalous magnetic data in the northwestern portion of the survey area and over the Site 5-Perimeter Road Landfill located in the southeast portion of the survey area. The limited GPR survey was conducted in an attempt to better characterize the source, dimensions, and depth of the magnetic and EM-31 anomalies. GPR data were acquired semi-continuously (32 scans per second), as the 300-MHz antenna was hand-towed along the survey lines. Control points were placed on the GPR records at 10-foot intervals using a marker switch on the antenna. GPR data were viewed in real time on the SIR-2's color monitor, plotted in the field on a gray-scale printer, and saved to the SIR-2's hard disk for later processing. GPR file names along with line number, station range and acquisition parameters were recorded in field notes. The endpoints of each GPR line were surveyed using GPS. The locations of all GPR profiles are shown in Figure 2. All field copies of GPR data are retained in the project files.

# 4 DATA PROCESSING AND INTERPRETATION

This section presents the data processing procedures and interpretation of the geophysical data.

## *4.1 Data Processing*

### 4.1.1 Magnetic and Geonics EM-31 Data Processing

Color-enhanced contour maps of magnetic and EM-31 data were generated using the GEOSOFT® geophysical mapping system. Prior to contour map generation, a number of preprocessing steps were completed. These preprocessing steps consisted of the following:

- Backup of all original field data files to floppy disk.
- Downloading GPS base station data from Sokkia bulletin board.
- Applying differential corrections to GPS data and outputting an ASCII file containing approximate State Plane Coordinates, elevation, and time.
- Correcting of all data acquisition errors (typically only deleting the first portion of a reacquired line, renaming lines incorrectly labeled, deleting additional readings outside the grid, etc.)
- Reformatting field data files to free format XYZ files containing at a minimum GPS time and field measurements.
- Merging GPS position data and geophysical data using in-house software.
- Removing diurnal variation from total magnetic field measurements using the base station data file and in-house software, if necessary.
- Merging of multiple data files into a single file and sorting, if necessary.

These data adjustments were made using a combination of commercial and in-house software. All adjustments made to data files and resulting file names were documented and are retained in project files.

The outputs of the data preprocessing were data files containing California State Plane, Zone 6, NAD83 Easting and Northing, and the various data measurements. The magnetic data file contained total magnetic field intensity. The EM-31 data file contained conductivity and in-phase response.

These data files were imported into the GEOSOFT® mapping system and the following data processing steps applied:

- Reformatting of data files to GEOSOFT® format.
- Generating final map scale.
- Gridding data using minimum curvature and a 5-foot cell size.
- Masking grid in areas where data not acquired (i.e. around obstructions).
- Applying a single pass Hanning filter to smooth the data.
- Generating color zone file describing color for different data ranges.
- Contouring the data.
- Generating map surrounds (title block, legend, scale, color bar, north arrow, etc.)

- Annotating anomalies.
- Merging various plot files and plotting final map.

The names of the files generated and the processing parameters used were recorded on data processing forms. All completed data processing forms are retained in project files. All files generated during the processing sequence were archived on CD-ROM.

### 4.1.2 Ground Penetrating Radar Data Processing

This section describes the steps used to process the digital GPR data. GPR data presented in the report were processed using the RADAN™ for Windows software package developed by GSSI.

Data preparation and processing steps included the following:

- Downloading data from the SIR2 hard disk to an office computer.
- Trimming the ends of the line (data scans before the beginning and after the end of the survey line).
- File reversal as necessary to present profiles as west-east or south-north.
- Horizontal stacking, as necessary
- Vertical and horizontal high- and low-pass filtering
- Gain adjustment
- Horizontal distance normalization
- Importing of data into Corel Draw™ 8
- Annotation of GPR records and plotting

All GPR data file names resulting from the various stages of processing were documented and data were archived on digital tape or CD-ROM.

## *4.2 Interpretation*

Color-enhanced contour maps of total magnetic field intensity, EM-31 conductivity and EM-31 in-phase response are presented as Figures 3 to 5, respectively. The coordinates shown in these figures reference the California State Plane Coordinate System, Zone 6, NAD83. The color bar indicates the amplitude of the measured quantity with the magenta and cyan colors indicating high- and low-amplitudes, respectively. The light orange, yellow and light green colors in the contour maps of total magnetic field intensity and EM-31 in-phase response indicate average "background" values of the measured quantity.

Significant anomalies in the magnetic and EM-31 data were field checked to determine if a metallic object at the surface caused the anomaly. A number of surface metallic features, such as fences, monitoring wells, and metallic surface debris caused anomalies in the geophysical data. These anomalies are labeled as "SM" on the contour maps.

There are several anomalies on the contour maps of magnetic and EM-31 data (Figures 3 to 5) interpreted as being caused by possible buried pipes or utility lines. These anomalies are labeled as "P" on the contour maps and approximate locations of the pipes are shown on Figure 2. The pipes are shown as solid lines where traced with an EM utility locator or Fisher metal detector, dashed lines where interpreted directly from geophysical data, and are queried where interpretation is uncertain. The pipes that are evident in magnetic data are composed of metal or reinforced concrete, whereas, pipes that are evident only in EM-31 data probably consist of utility cables. All of the interpreted pipes are located near the Perimeter Road Landfill (Site 5) and some may be caused by abandoned infrastructure associated with landfill operations. It is possible that some of the anomalies, interpreted as buried pipes, are caused by features of similar composition, such as steel poles/beams that were used for ingress and egress control during landfilling operations. All of the pipes appear to be abandoned, as they are not continuous for great distances.

There are numerous small magnetic anomalies and several small EM-31 anomalies interpreted as being caused by small, buried metallic objects. These anomalies are labeled as "B" on the respective contour maps and are depicted on Figure 2. The anomalies are probably caused by small pieces of metallic debris at shallow depth. It is possible that some of the anomalies are caused by surface debris that was not mapped.

There are two large anomalous areas in the geophysical data indicative of buried metallic or construction debris. These anomalies are labeled as A-1 and A-2 on the contour maps of magnetic and EM-31 data and are discussed below.

Anomaly A-1 consists of a small area in the northwestern portion of the survey area with scattered, low-amplitude magnetic anomalies and sparse EM-31 anomalies. There is scattered metallic debris, construction debris, and pieces of asphalt and glass on the surface in this area indicating that the area was once used as a staging area for construction or landfilling operations or that construction debris was placed on the surface. Magnetic data were acquired along 5-foot profiles in this area to better define the anomalies. The absence of numerous EM-31 anomalies in this area indicates that the sources of the magnetic anomalies are very small or deeper than about 5 feet. The small lateral dimensions of the individual magnetic anomalies indicate that the source is shallow, rather than deep. Four GPR profiles were collected in this area; two of the GPR profiles (Files 5095 and 5098) are presented as Figure 6. The GPR data revealed the presence of scattered debris in the near surface; however, GPR depth of investigation at this site was limited to about 3 feet and it was not possible to image deeper features. In summary, the presence of surface debris and the nature of the magnetic, EM-31 and GPR anomalies indicate that Anomaly A-1 is caused by scattered construction debris at and near the surface, rather than larger objects at depth.

Anomaly A-2 is a high-amplitude, southwest to northeast trending, linear magnetic and EM-31 in-phase response anomaly caused by the Site 5-Perimeter Road Landfill. The geophysical data indicates that this landfill consists of a long trench with a maximum width of about 60 feet. The geophysical survey area was expanded to delineate the southwest end of the trench but was not expanded to map the northeast end. There is a continuous EM-31 in-phase response anomaly and only scattered conductivity response anomalies associated with the trench. This indicates that the top of the debris may be on the order of 5 to 6 feet deep in those areas without conductivity response and shallower in areas with conductivity response. Several GPR profiles were conducted over this trench as shown in Figure 2. The GPR profiles were not able to delineate the trench or provide other useful information due to limited depth of penetration. The

GPR files are retained in project files. The interpreted location of the Site 5 trench, based on magnetic and EM-31 in-phase response data, is shown on Figure 2 and is expected to be accurate to about 5 feet.

The EM-31 conductivity data (Figure 4) provided no conclusive evidence of fill soils not containing metallic debris at the site. Near-surface soil conductivities at the site are quite variable, ranging from about 24 to 54 mS/m. The near-surface soils in the lower conductivity zones probably consist of coarser grained soils with only minor amounts of clay, such as silty sand; whereas the higher conductivity zones probably have clayey sands or silt in the near surface. The higher conductivity soils associated with the SE-NW trending dirt road bisecting the site (Anomaly A-3 on Figure 4) may be fill associated with construction of the road.

# 5 CONCLUSIONS

A magnetic and Geonics EM-31 (EM-31) survey was conducted in the approximate 12-acre Aerial Photographic Anomaly Area 46 at MCAS EL Toro, California to screen the site for buried metallic and/or construction debris and fill soils. Interpretation of the geophysical data is presented in Figure 2. Contour maps of total magnetic field intensity and EM-31 conductivity and in-phase response are presented as Figures 3 to 5, respectively.

The magnetic data revealed the presence of a small area in the northwestern portion of the survey area containing scattered surface and near-surface metallic and/or construction debris. This area is labeled A-1 on the contour map of total magnetic field intensity (Figure 3) and interpretation map (Figure 2). This anomalous area may result from a former staging area for construction or landfilling activities or a load of construction debris being placed at the site. The magnetic signature in this area is indicative of scattered, small, metallic objects/debris at shallow depth rather than larger objects at greater depth. This interpretation is supported by GPR traverses that were collected over the anomaly.

The magnetic and EM-31 data also located a large southwest-northeast trending trench containing metallic debris in the southeastern portion of the survey area. This trench corresponds to the Site 5 – Perimeter Road Landfill and is characterized by a high amplitude magnetic and EM-31 in-phase response anomaly and low amplitude, discontinuous EM-31 conductivity response anomalies. The southwestern end of this trench was delineated by this investigation, but the northeastern portion of the trench extends outside the survey area. Poor depth of GPR investigation limited the use of this method to accurately define the edges of the trench or depth of the top of debris. The top of the debris in the trench is probably shallower than 5 feet in areas where the EM-31 conductivity response (Figure 4) detects the trench and deeper than 5 feet in areas with no or very weak conductivity response.

The geophysical data also revealed the presence of several possible pipes and numerous small, buried metallic objects/debris within the survey area as shown on Figure 2. The pipes are all located in the vicinity of the Site 5 landfill trench and appear to be abandoned because they are not continuous. There is a possibility that some of the interpreted pipes are different linear features of similar composition to a pipe (i.e. metal poles, tracks, etc.).

Near-surface soil conductivity is quite variable at the site ranging from about 24 to 54 mS/m. Much of the conductivity variation is probably related to natural soil variation, although a zone of elevated conductivity associated with a southeast to northwest trending dirt road that bisects the site (Anomaly A-3 on Figure 4) may be related to the placement of fill soils to support the road.

The geophysical survey was designed to map small accumulations of metallic debris in the subsurface and strong variations in near-surface soil type that could be indicative of fill soils. It was assumed that any debris buried at the site would contain enough metallic components (i.e. rebar, pipe segments, steel plates, etc.) to be detectable by the magnetic and EM methods.

# 6 CERTIFICATION

All geophysical data, analysis, interpretations, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by a **GEO*Vision*** California Registered Geophysicist.

REGISTERED GEOPHYSICIST
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GP 989
Exp. 3/31/2003
STATE OF CALIFORNIA

6/14/2000

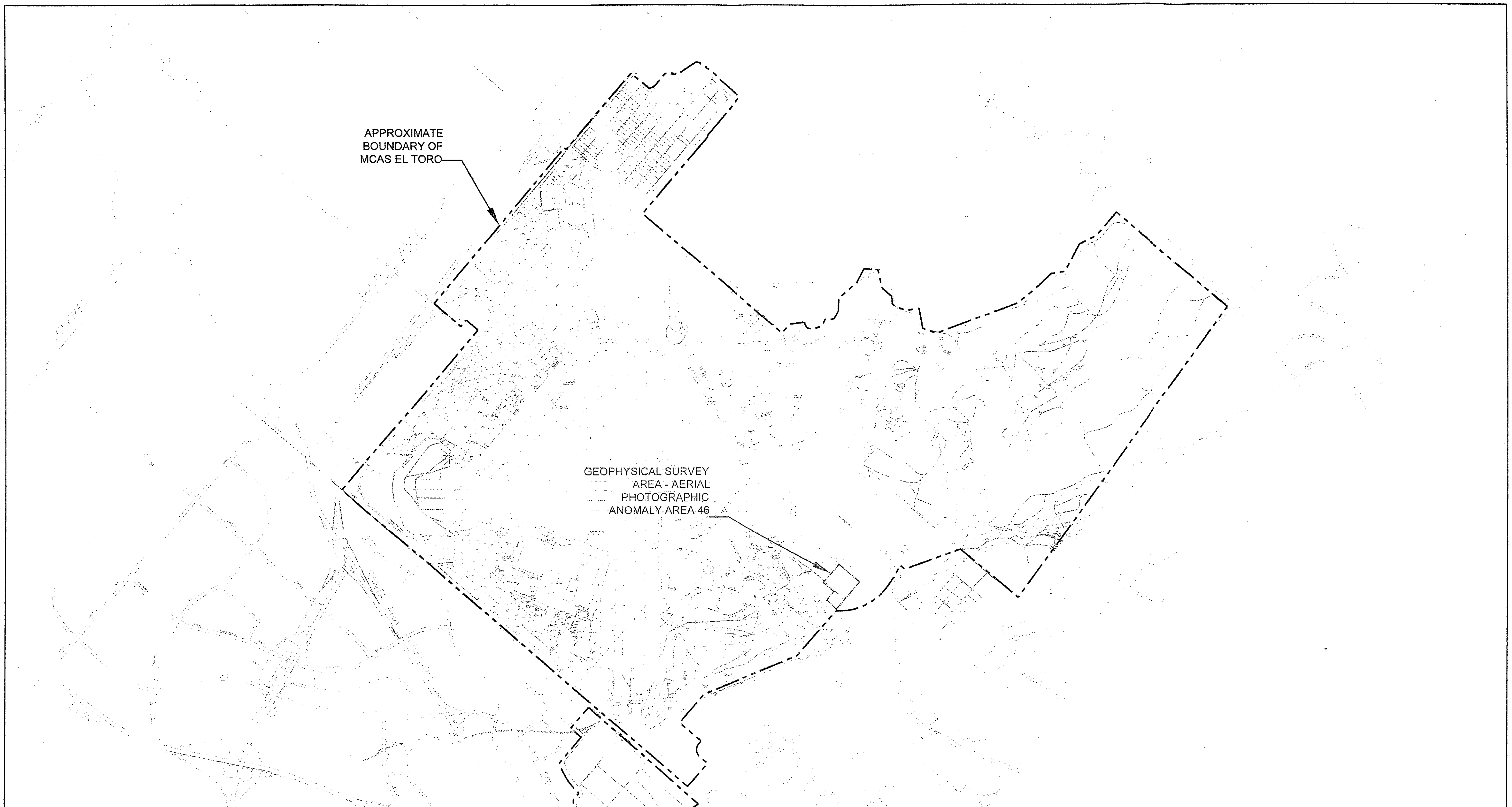
Antony J. Martin
California Registered Geophysicist GP989
**GEO***Vision* Geophysical Services

Date

* This geophysical investigation was conducted under the supervision of a California Registered Geophysicist using industry standard methods and equipment. A high degree of professionalism was maintained during all aspects of the project from the field investigation and data acquisition, through data processing interpretation and reporting. All original field data files, field notes and observations, and other pertinent information are maintained in the project files and are available for the client to review for a period of at least one year.

A registered geophysicist's certification of interpreted geophysical conditions comprises a declaration of his/her professional judgment. It does not constitute a warranty or guarantee, expressed or implied, nor does it relieve any other party of its responsibility to abide by contract documents, applicable codes, standards, regulations or ordinances.

## FIGURES




NOTES:
1. BASE MAP PROVIDED BY THE IT GROUP
2. COORDINATES ARE IN THE CALIFORNIA STATE PLANE COORDINATE SYSTEM, ZONE 6, NAD83
3. ESTIMATED MAP ACCURACY = 10-30 FEET

0 1250 2500 5000
(feet)

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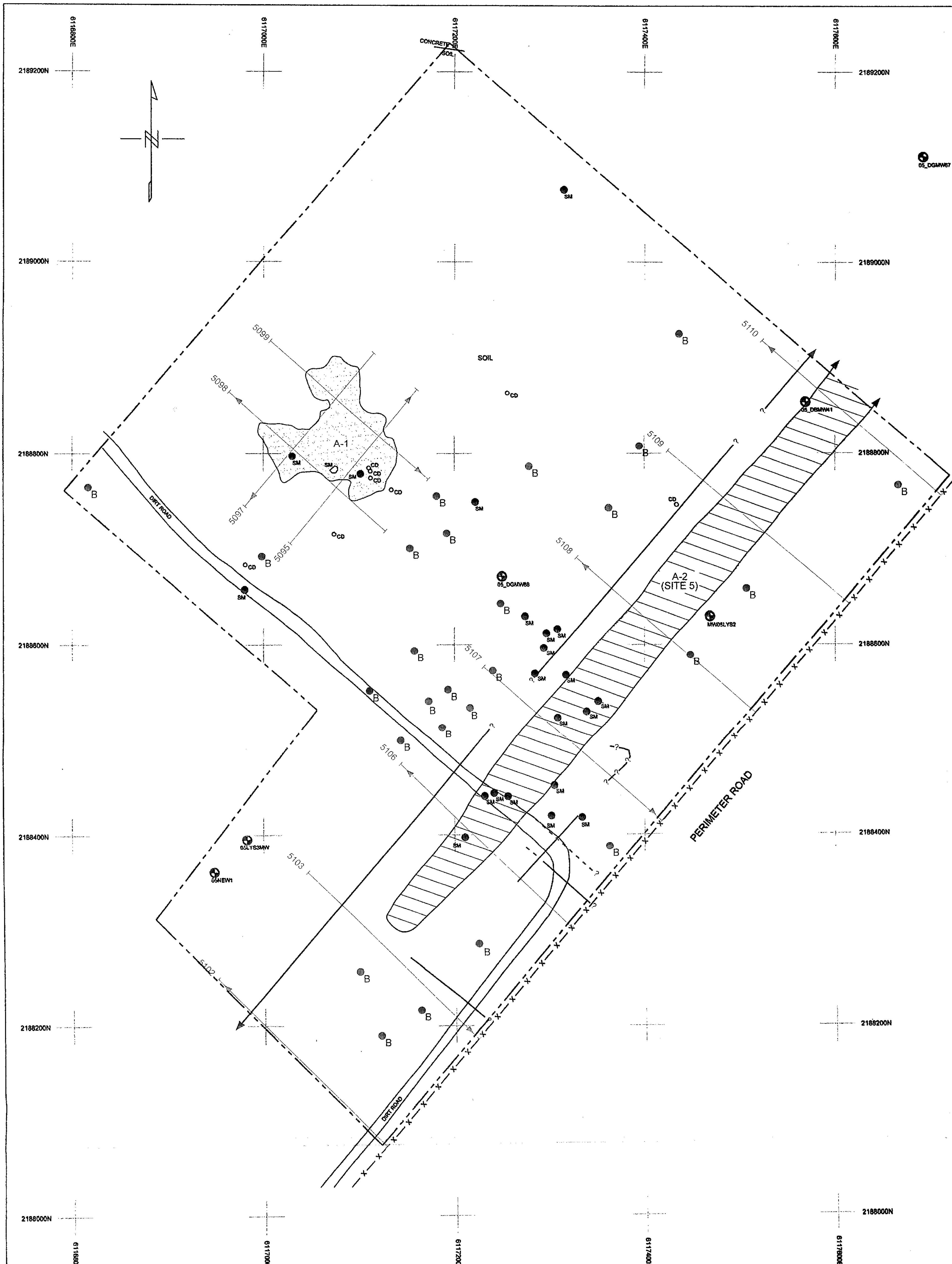
*a division of Blackhawk Geometrics*

| | |
|---|---|
| Project No. 0260-46 | Date Jun 13,2000 |
| Developed by | A MARTIN |
| Drawn by | T RODRIGUEZ |
| Approved by | [signature] |
| File | C:\AcadMap2000 Drawings\0260\a46\0260-46-1.dwg |

# FIGURE - 1
## SITE LOCATION MAP

MARINE CORPS AIR STATION, EL TORO
ORANGE COUNTY, CALIFORNIA

PREPARED FOR
THE IT GROUP




## LEGEND

- 2188000N, 6116800E STATE PLANE COORDINATE SYSTEM
- BOUNDARY OF GEOPHYSICAL SURVEY AREA
- 5102 GPR SURVEY LINE AND FILE NUMBER
- FENCE
- 05LYS3MW MONITORING WELL
- SM SURFACE METALLIC OBJECT / DEBRIS
- CD CONCRETE / ASPHALT DEBRIS
- POSSIBLE BURIED PIPE, DASHED WHERE APPROXIMATE, QUERIED WHERE UNCERTAIN
- B VERY SMALL BURIED METALLIC OBJECT / DEBRIS
- A-1 AREA CONTAINING SCATTERED, SMALL, SHALLOW BURIED METALLIC OBJECTS / DEBRIS
- A-2 APPROXIMATE BOUNDARY OF SITE 5 - PERIMETER ROAD LANDFILL

0 50 100 200
(feet)

NOTES:
1. COORDINATES ARE IN CALIFORNIA STATE PLANE COORDINATE SYSTEM, NAD83, ZONE 6

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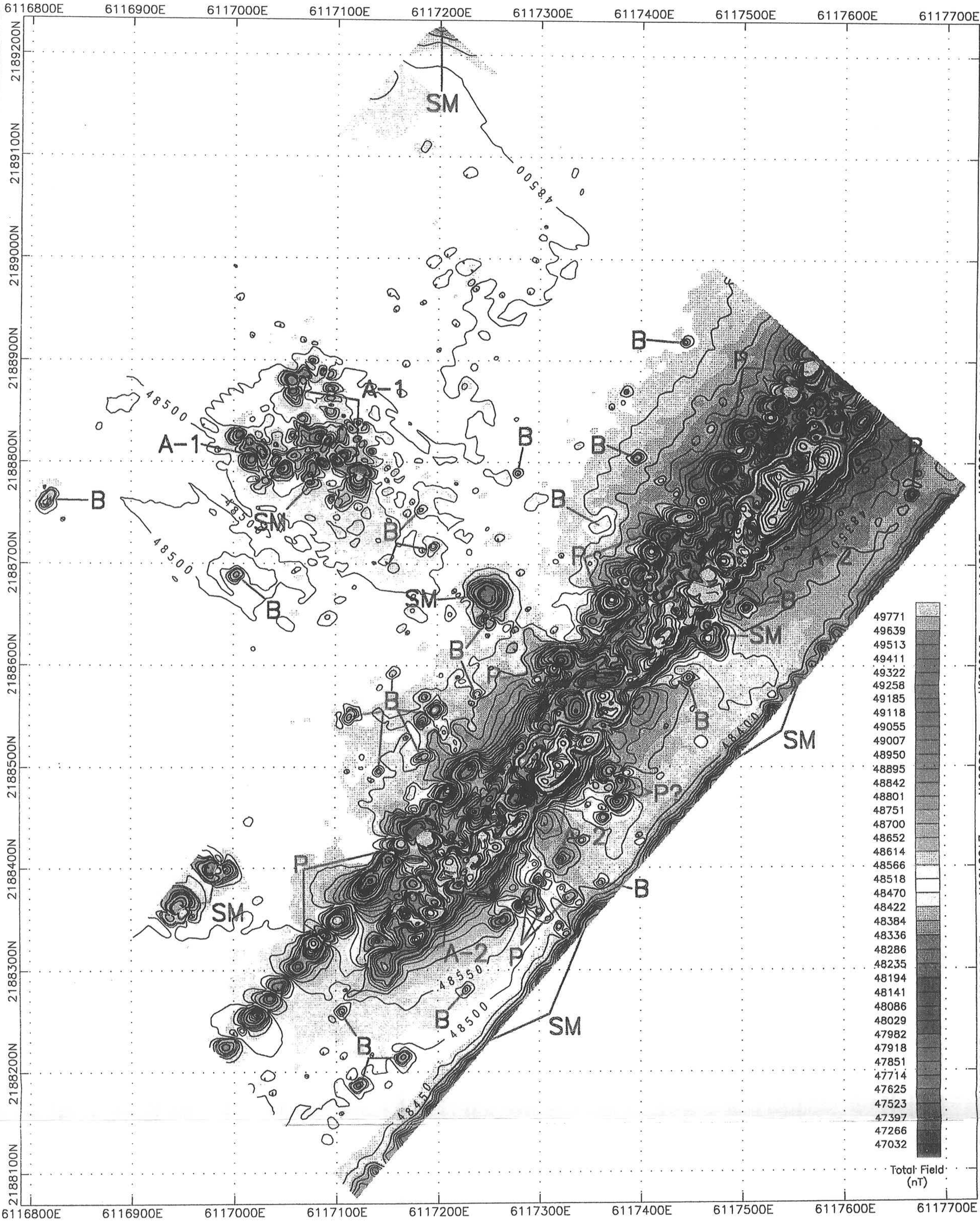
| | |
|---|---|
| Project No. 0260 | Date Jun 14,2000 |
| Developed by | A MARTIN |
| Drawn by | T RODRIGUEZ |
| Approved by | [signature] |

# FIGURE - 2
## SITE MAP WITH GEOPHYSICAL INTERPRETATION

AERIAL PHOTOGRAPHIC ANOMALY AREA 46
MCAS EL TORO
ORANGE COUNTY, CALIFORNIA

PREPARED FOR
THE IT GROUP




CONTOUR INTERVAL = 50 NANOTESLAS

## LEGEND

| | |
|---|---|
| **A–1** | GEOPHYSICAL ANOMALY DISCUSSED IN REPORT |
| **P** | ANOMALY CAUSED BY BURIED PIPE |
| **B** | ANOMALY CAUSED BY SMALL BURIED METALLIC OBJECT OR DEBRIS |
| **SM** | ANOMALY CAUSED BY SURFACE METALLIC OBJECT OR DEBRIS |

N

50 0 50 100 150
(feet)

FIGURE 3
CONTOUR MAP OF TOTAL MAGNETIC FIELD INTENSITY

AERIAL PHOTOGRAPHIC ANOMALY AREA 46
MCAS EL TORO, CALIFORNIA

PREPARED FOR
THE IT GROUP

*GEOVISION GEOPHYSICAL SERVICES*

Note: Coordinates are in the California State Plane Coordinate System, Zone 6, NAD83


CONTOUR INTERVAL = 2 MILLISIEMENS PER METER

## LEGEND

| | |
|---|---|
| A–1 | GEOPHYSICAL ANOMALY DISCUSSED IN REPORT |
| P | ANOMALY CAUSED BY BURIED PIPE |
| B | ANOMALY CAUSED BY SMALL BURIED METALLIC OBJECT OR DEBRIS |
| SM | ANOMALY CAUSED BY SURFACE METALLIC OBJECT OR DEBRIS |

50 0 50 100 150

(feet)

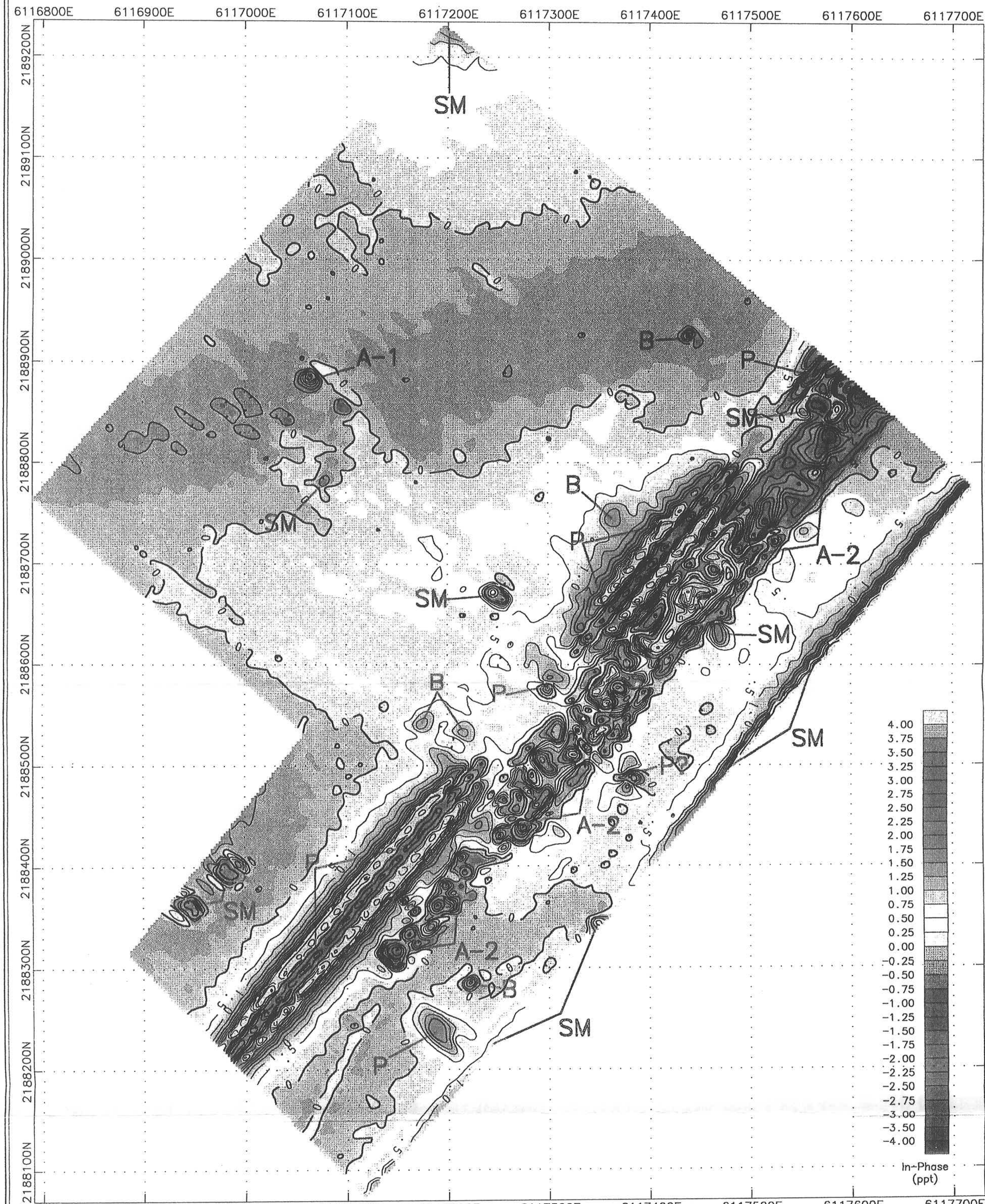
Note: Coordinates are in the California State Plane Coordinate System, Zone 6, NAD83

FIGURE 4
CONTOUR MAP OF GEONICS EM–31 CONDUCTIVITY RESPONSE

AERIAL PHOTOGRAPHIC ANOMALY AREA 46
MCAS EL TORO, CALIFORNIA

PREPARED FOR
THE IT GROUP

*GEOVISION GEOPHYSICAL SERVICES*




CONTOUR INTERVAL = 0.5 PARTS PER THOUSAND

## LEGEND

| | |
|---|---|
| **A-1** | GEOPHYSICAL ANOMALY DISCUSSED IN REPORT |
| **P** | ANOMALY CAUSED BY BURIED PIPE |
| **B** | ANOMALY CAUSED BY SMALL BURIED METALLIC OBJECT OR DEBRIS |
| **SM** | ANOMALY CAUSED BY SURFACE METALLIC OBJECT OR DEBRIS |

50 0 50 100 150
(feet)

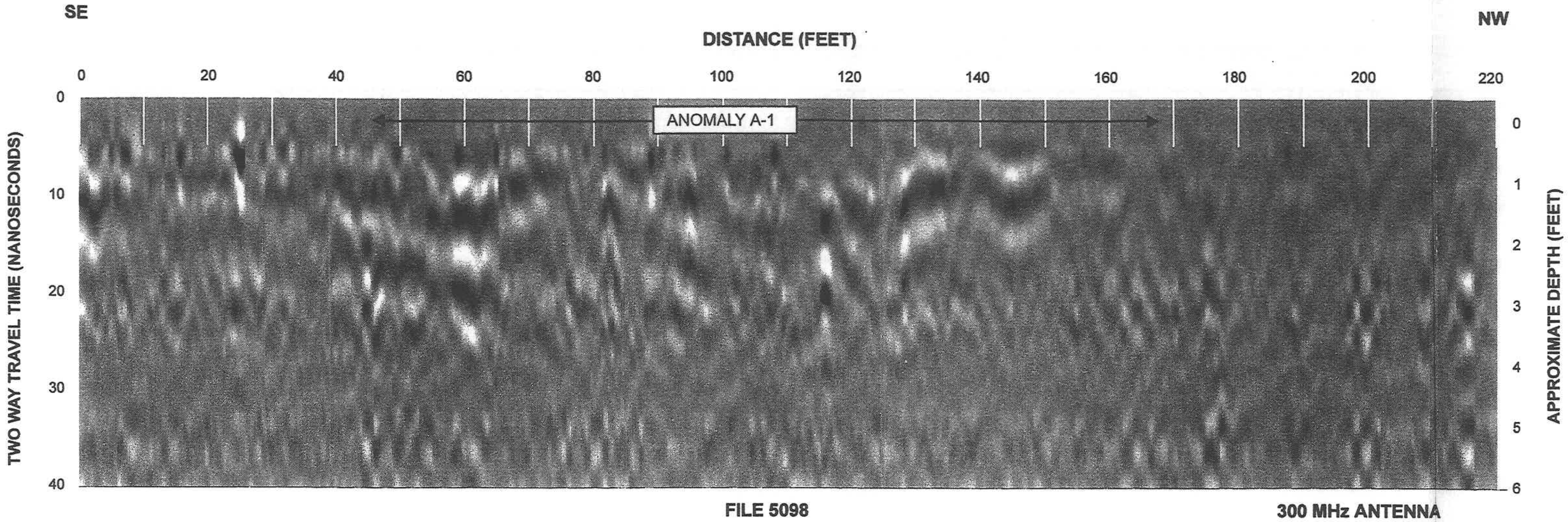
Note: Coordinates are in the California State Plane Coordinate System, Zone 6, NAD83

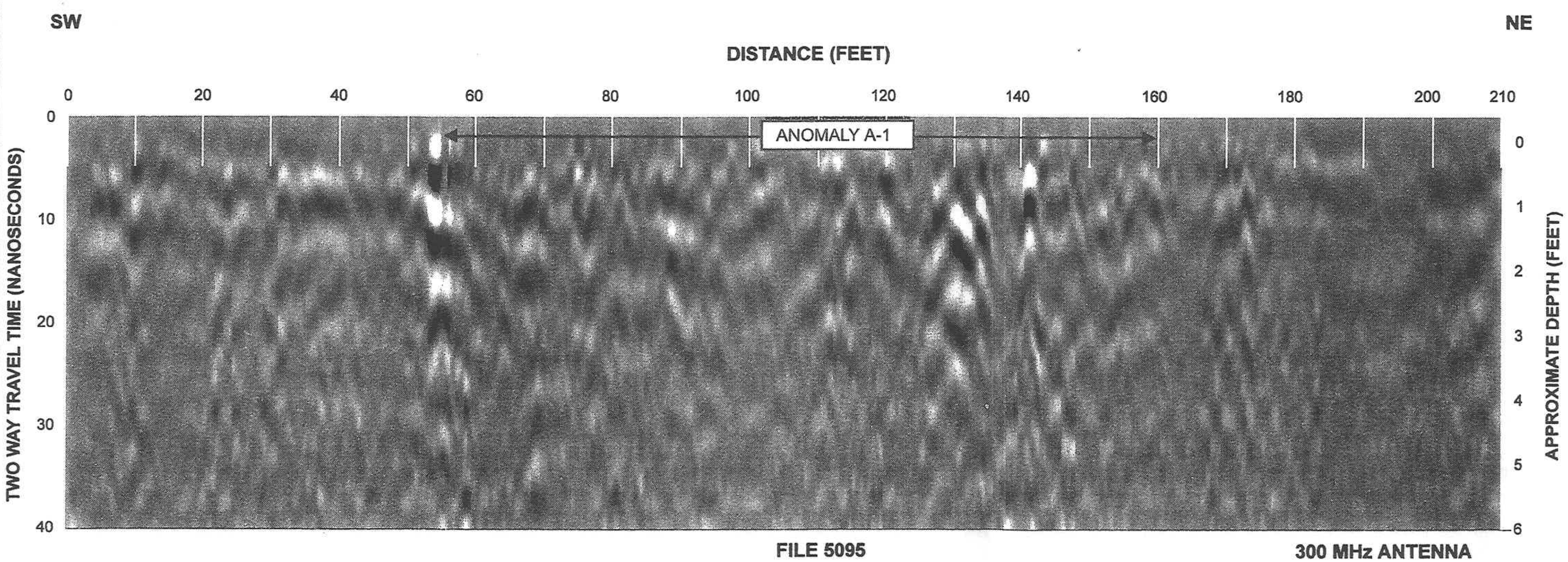
FIGURE 5
CONTOUR MAP OF GEONICS EM-31 IN-PHASE RESPONSE

AERIAL PHOTOGRAPHIC ANOMALY AREA 46
MCAS EL TORO, CALIFORNIA

PREPARED FOR
THE IT GROUP

*GEOVISION GEOPHYSICAL SERVICES*

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| |
|---|
| FIGURE 6 |
| GROUND PENETRATING RADAR PROFILES 5095 AND 5098 |
| AERIAL PHOTOGRAPHIC ANOMALY AREA 46<br>MCAS EL TORO, CALIFORNIA |
| PREPARED FOR<br>THE IT GROUP |
| *GEOVISION GEOPHYSICAL SERVICES* |

# APPENDIX A
# GEOPHYSICAL TECHNIQUES FOR
# SHALLOW ENVIRONMENTAL INVESTIGATIONS

# GEOPHYSICAL TECHNIQUES FOR SHALLOW ENVIRONMENTAL INVESTIGATIONS

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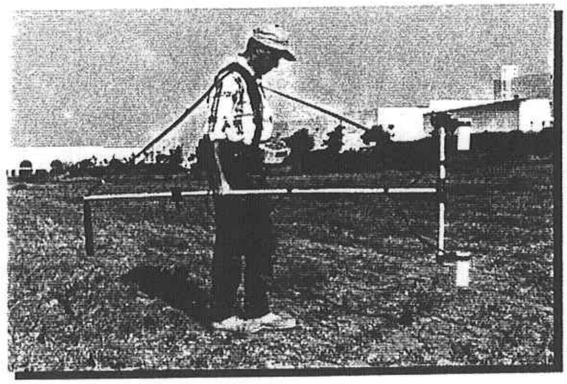
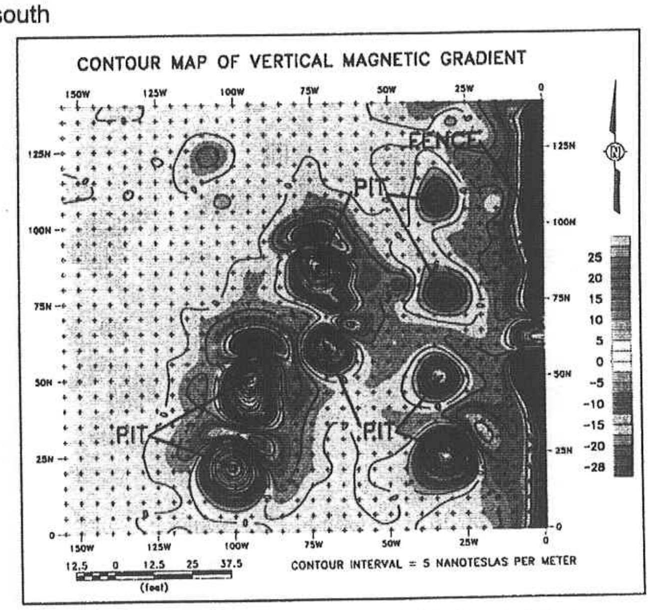
## MAGNETIC METHOD

The magnetic method generally involves the measurement of the earth's magnetic field intensity or vertical gradient of the earth's magnetic field. Anomalies in the earth's magnetic field are caused by induced or remanent magnetism. Induced magnetic anomalies are the result of secondary magnetization induced in a ferrous body by the earth's magnetic field. The shape and amplitude of an induced magnetic anomaly is a function of the orientation, geometry, size, depth, and magnetic susceptibility of the body as well as the intensity and inclination of the earth's magnetic field in the survey area. The magnetic method is an effective way to search for small metallic objects, such as buried ordnance and drums, because magnetic anomalies have spatial dimensions much larger than those of the objects themselves. Typically, a single buried drum can be detected to a depth of about 10 feet. Larger metallic objects can often be located to greater depths. Induced magnetic anomalies over buried objects such as drums, pipes, tanks, and buried metallic debris generally exhibit an asymmetrical, south up/north down signature (positive response south of the object and negative response to the north).

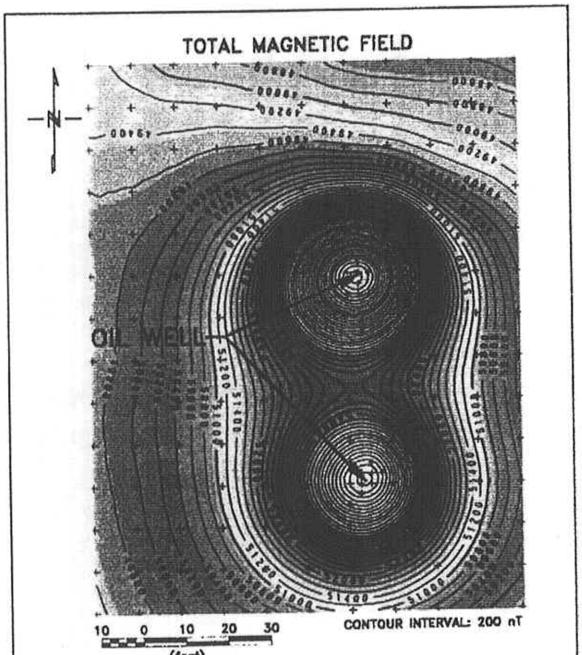


*Geometrics G858 Cesium Magnetic Gradiometer*

Magnetic data is typically acquired along a grid with results being presented as color-enhanced contour maps generated by the Geosoft™ Mapping System or OASIS montaj. The approximate location and depth of magnetic objects can be calculated using the Geosoft™ UXO System.




*Magnetic Survey to Locate Pits Containing Buried Metallic Containers*




*Magnetic Survey to Locate Abandoned Oil Wells*

Magnetic surveys are typically conducted to:

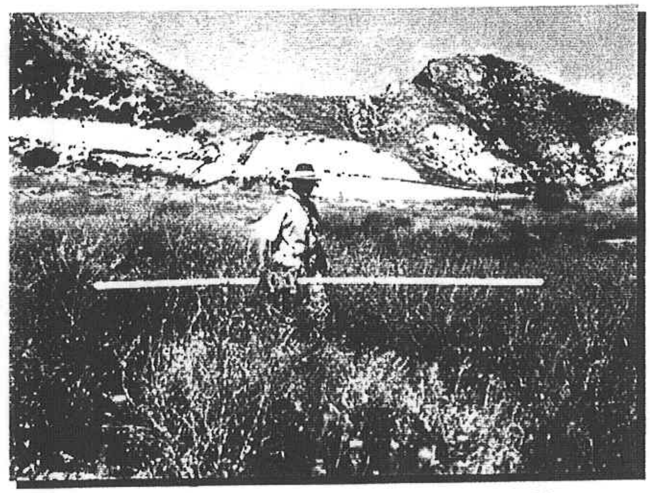
- Locate abandoned steel well casings
- Locate buried tanks and pipes
- Locate pits and trenches containing buried metallic debris
- Detect buried unexploded ordnance (UXO)
- Map old waste sites and landfill boundaries
- Clear drilling locations
- Map basement faults and geology
- Investigate archaeological sites

# ELECTROMAGNETIC METHODS

Electromagnetic (EM) methods typically applied to shallow environmental investigations include frequency domain EM methods, such as EM induction and EM utility location methods, time domain electromagnetic (TDEM) metal detection methods, and ground penetrating radar (GPR) methods.

## EM Induction Method

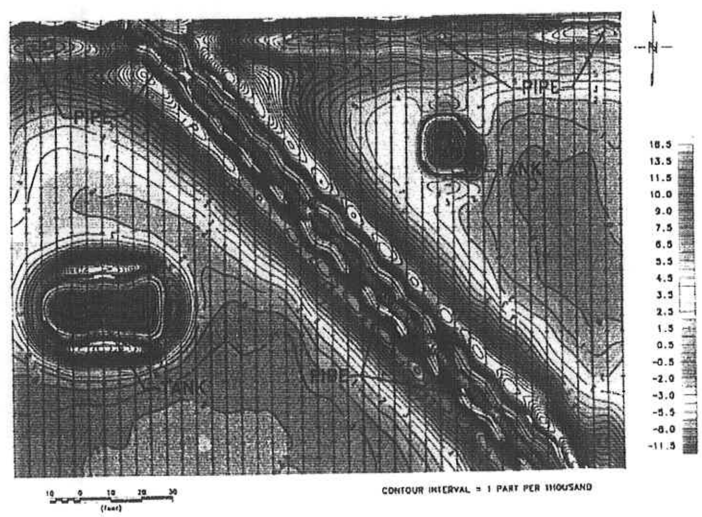
EM induction surveys are often conducted using the Geonics EM-31 terrain conductivity meter (EM-31). The EM-31 consists of a transmitter coil mounted at one end and a receiver coil mounted at the other end of a 3.7-meter long plastic boom. Electrical conductivity and in-phase component field strength are measured and stored along with line and station numbers in a digital data logger. In-phase component measurements generally only respond to buried metallic objects; whereas conductivity measurements also respond to conductivity variations caused by changes in soil type, moisture or salinity and the presence of nonmetallic bulk wastes. The EM-31 must pass over or immediately adjacent to a buried metallic object to detect it. Typical EM-31 anomalies over small, buried metallic objects consist of a negative response centered over the object and a lower amplitude positive response to the sides of the object. When the instrument boom is oriented parallel to long, linear conductors such as pipelines a strong positive response is observed. The EM-31 can explore to depths of about 6 meters, but is most sensitive to materials about 1 meter below ground surface. Single buried drums can typically be detected to depths of about 5 feet.



***Geonics EM-31 Terrain Conductivity Meter***

EM-31 surveys are typically conducted to:

- Locate buried tanks and pipes
- Locate pits and trenches containing metallic and/or nonmetallic debris
- Delineate landfill boundaries
- Delineate oil production sumps and mud pits
- Map conductive soil and groundwater contamination
- Map soil salinity in agricultural areas
- Characterize shallow subsurface hydrogeology
  - Map buried channel deposits
  - Locate sand and gravel deposits
  - Locate conductive fault and fracture zones




***Geonics EM-31 Survey to Locate Underground Storage Tanks***

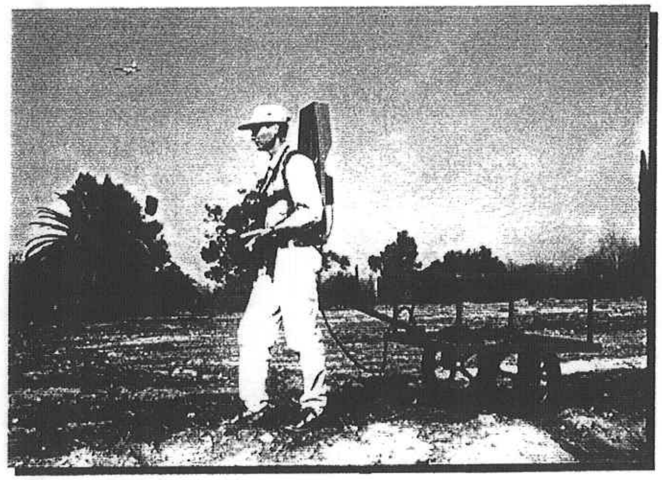
## EM Utility Location Methods

EM utility locators; such as the Metrotech 810, Metrotech 9890 and Radiodetection RD400, are designed to accurately trace metallic pipes and utility cables and clear drilling/excavation locations. These utility locators consist of a separate transmitter and a receiver. The transmitter emits a radio frequency EM field that induces secondary fields in nearby metallic pipes and cables. The receiver detects these fields and is used to accurately locate and trace the pipes, often to distances over 200 feet from the transmitter. Many of the utility locators have a passive 60Hz mode to locate live electrical lines. Modern utility locators are also capable of providing rough depth estimates of the pipes.

⟸ ***Metrotech EM Utility Locator***

## *TDEM Metal Detection Methods*

A Geonics EM-61 (EM-61) is a high sensitivity, time-domain, digital metal detector which is often used to detect both ferrous and non-ferrous metallic objects. It is designed specifically to locate buried metallic objects such as drums, tanks, pipes, UXO, and metallic debris and to be relatively insensitive to above ground structures such as fences, buildings, and vehicles.

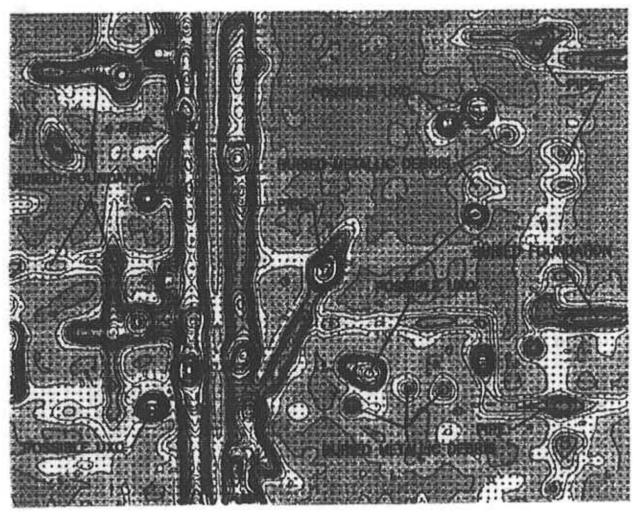


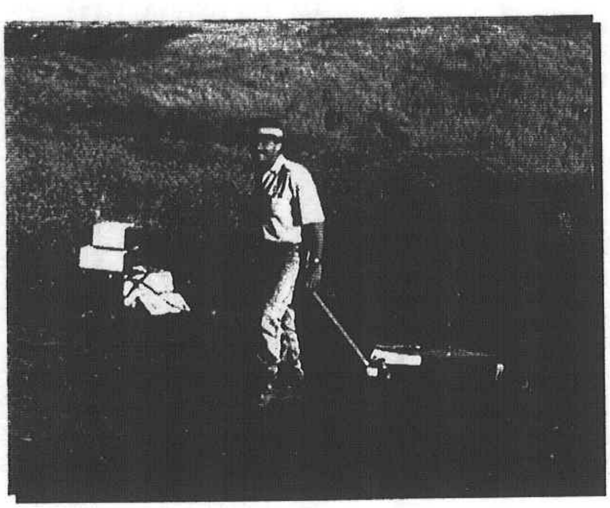
***Geonics EM-61 Digital Metal Detector***

The EM-61 consists of two square, 1-meter coils, one mounted over the other and arranged on a hand-towed cart. The bottom coil acts as both a transmitter and receiver while the top coil is a receiver only. While transmitting the bottom coil generates a pulsed primary magnetic field, which induces eddy currents into nearby metallic objects. When the transmitter is in its off cycle both coils measure the decay of these eddy currents in millivolts (mV) with the results being stored in a digital data logger along with position information. The decay of the eddy currents is proportional to the size and depth of the metallic target. A symmetrical positive anomaly is recorded over metallic objects with the peak centered over the object. The signal from the top coil is amplified in such a way that both coils record effectively the same response for a metallic object on the surface and the top coil records a larger response for buried metallic objects. The response of near surface objects can, therefore, be suppressed by subtracting the lower coil response from the upper coil response (differential response).

In practice, the usable depth of investigation of the EM-61 depends on the size and shape of the object and the amount of above ground interference encountered at the site. A single buried drum can often be detected at a depth of about 10 feet.

***Geonics EM-61 Survey to Map Subsurface Infrastructure and Potential UXO***





***GSSI SIR-10A GPR Unit***

## *GPR Methods*

Ground-penetrating radar (GPR) is a high-frequency electro-magnetic method commonly applied to a number of engineering and environmental problems.

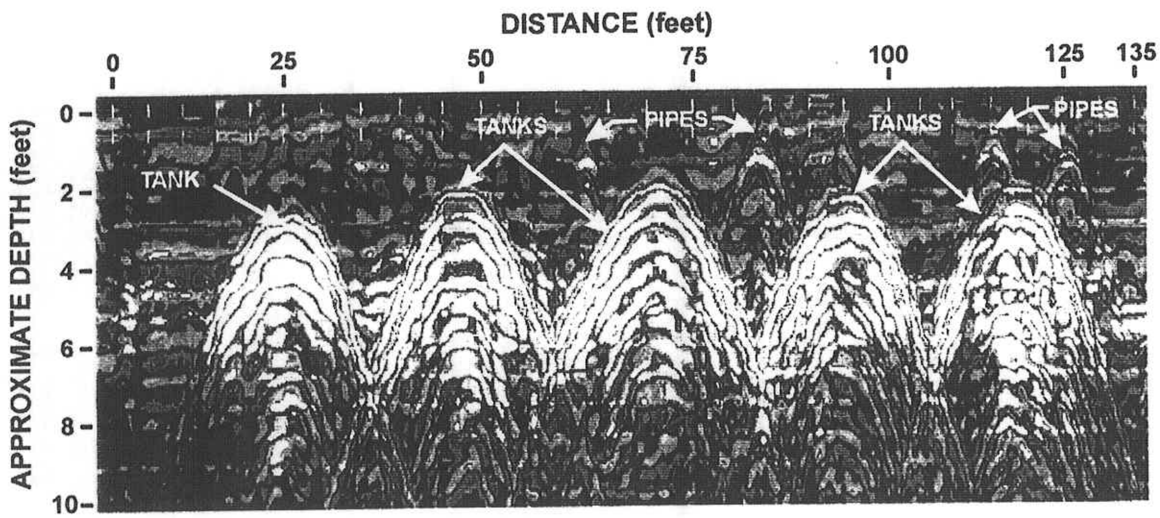
A GPR system radiates short pulses of high-frequency EM energy into the ground from a transmitting antenna. This EM wave propagates into the ground at a velocity that is primarily a function of the relative dielectric permittivity of subsurface materials. When this wave encounters the interface of two materials having different dielectric properties, a portion of the energy is reflected back to the surface, where it is detected by a receiver antenna and transmitted to a control unit for processing and display.

Depth penetration is a function of antenna frequency and the electrical conductivity of the soils in the survey area. Lower frequency antennas achieve greater depth penetration than higher frequency antennas, but have poorer spatial resolution. Conductive soils, such as clays, attenuate the radar waves much more rapidly than resistive dry sand and rock. In many environments in California, depth penetration of 500 and 300 MHz antennas is limited to 3 to 5 feet. Depth penetration may be greater if shallow soils consist of clean sands and less if shallow soils consist of clay.

GPR surveys are typically conducted to:

- Locate and delineate underground storage tanks (metallic and non-metallic)
- Locate metallic and nonmetallic pipes and utility cables
- Map rebar in concrete structures
- Map landfill boundaries
- Delineate pits and trenches containing metallic and nonmetallic debris
- Delineate leach fields and industrial cribs
- Delineate previously excavated and backfilled areas
- Map shallow groundwater tables
- Map shallow soil stratigraphy
- Map shallow bedrock topography
- Map shallow subsurface voids and cavities
- Characterize archaeological sites

Geophysical Survey Systems Inc. (GSSI) SIR-2 or SIR-10 GPR systems with antennas in the frequency range of 50 to 1,000 MHz are often used during GPR investigations. Mala Geoscience and Sensors and Software, Ltd also manufacture GPR systems. GPR data is processed using a variety of software including the RADAN™ or GRADIX software packages by GSSI and Interpex Ltd., respectively.




***GPR Survey to Locate Underground Storage Tanks***