GeoPotential

ENVIRONMENTAL & EXPLORATION GEOPHYSICS

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REPORT

TERRAMAGNETIC SURVEY ACQUISITION AND PROCESSING

LOWER KLAMATH LAKE VALLEY KLAMATH COUNTY, OREGON

CLIENT

Klamath Drainage District
280 Main Street
Klamath Falls, OR 97601

January 25, 2002

GeoPotential Project Number 3862

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INTRODUCTION

GeoPotential performed a TERRAMAGNETIC SURVEY of the LOWER KLAMATH LAKE VALLEY (LKL Valley) for the Klamath Drainage District (KDD). This report discusses the ACQUISITION and PROCESSING of the data collected during the TERRAMAGNETIC SURVEY. The INTERPRETATION of the TERRAMAGNETIC SURVEY is presented in a separate report entitled "TERRAMAGNETIC SURVEY, INTERPRETATION, LOWER KLAMATH LAKE VALLEY, KLAMATH COUNTY, OREGON".

The TERRAMAGNETIC SURVEY was conducted as the first stage of a geophysical program designed to help identify drilling locations for a water well drilling program, which will be conducted by KDD in the LKL Valley. The results from the TERRAMAGNETIC SURVEY will be used to help locate seismic and gravity profiles which will in turn be used to specify drilling locations. COOKSLEY GEOPHYSICS and NORTHWEST GEOPHYSICAL ASSOCIATES will conduct the subsequent seismic and gravity programs under separate contract, respectively.

Ralph Soule and Nikos Tzetos of GeoPotential performed the TERRAMAGNETIC SURVEY, and PROCESSING. The SURVEY was conducted in coordination with Margaret Jenks of MJENKS CONSULTING, Klamath Falls, Oregon who was the consulting geologist for the State of Oregon.

The ACQUISITION and PROCESSING steps described in this report are summarized in a flowchart shown in FIGURE 1. Each step in the flowchart is discussed in detail in the report.

ACQUISITION

The TERRAMAGNETIC SURVEY was conducted in the Lower Klamath Lake Valley (LKL Valley), south of Klamath Falls, in southern Oregon (FIGURE 2.) from December 14 to December 28, 2001. GeoPotential spent approximately 120 hours in the field, and acquired approximately 241line kilometers (150 line miles) of MAGNETIC DATA, covering an area of 111 km^2.

Three instruments were used to acquire data for this project: The Geometrics G823A Airborne Magnetometer was used for the acquisition of the Magnetic data and a Trimble GPS system with the parallel swathing option was used to acquire the GPS data. A Geometrics 858G MagMapper was used for the collection of Base Station Magnetic data.

The vehicle used for this survey was a Chevrolet S-10 Blazer, equipped with a boom that allowed the magnetometer sensor to hang securely 3.7 meters (12 feet) behind the vehicle (FIGURES 3a. and 3b.). The GPS antenna was mounted on the vehicle. The vehicle, carrying two operators, the driver and the magnetometer/GPS operator, traveled along parallel profiles, oriented E-W at an approximate speed of 7 miles per hour (FIGURE 4.). Where possible an approximate 250 meter spacing between profiles was adhered to. However due to terrain, field conditions and flooded fields it was necessary to acquire data along irregular profile intervals. Eight magnetic profiles were acquired twice in order to study the repeatability of the profile data. In addition discrete magnetic stations were acquired to infill areas of sparse profile coverage. Discrete magnetic stations were also acquired along the roads bounding the SURVEY SITE to provide edge effects for processing and geologic constraints for the subsequent magnetic interpretation.

Data from the vehicle-mounted magnetometer and GPS were recorded using Geometric Inc.'s logging software, MagLog NT, running on a laptop computer. Magnetic data and the location of the sensor were recorded every 0.1 second, at approximate intervals of 0.3 meters. A database consisting of the raw magnetic field values, geographic coordinates of longitude and latitude, station number, time and date, was created for later processing. FIGURE 4 is a map of the station locations, showing every 100th data point. Interference from the vehicle was measured in the form of a heading error that was corrected in the filtering process. Together with the measurements taken along E-W-oriented profiles there were 26 discrete measurements within the SURVEY area. They were taken to accommodate for the lower density of profiles in areas where terrain (flooded fields and soft ground) prevented the vehicle to proceed with a profile. Such discrete stations were acquired for one minute, with the vehicle stationary and facing E. Measurements were also taken along the roads that surrounded the SURVEY area in order to provide real values at the boundaries of the SURVEY area for the gridding and contouring in the processing stage. This set of readings consisted of 49 discrete stations where the roads were not oriented E-W, with continuous profiles along E-W-oriented roads.

At the beginning of the SURVEY a TERRAMAGNETIC test profile was compared with a profile taken in a walking survey along the same profile. FIGURE 5 shows the two profiles. A level shift between the TERRAMAGNETIC SURVEY and the WALKING SURVEY is approximately 100-140 nT in a N-S-oriented profile. This difference is attributed to the magnetic field of the survey vehicle. The sharp peaks along this profile are caused by cultural "noise" due to culverts and irrigation piping. However the correspondence of the shape and amplitude of this magnetic profile demonstrates the viability of the TERRAMAGNETIC method for magnetic data acquisition. An error analysis of the TERRAMAGNETIC survey is provided later in this report.

Terrain and Weather

The SURVEY area comprised of the flat farm fields of the LKL Valley (average elevation of 1220 meters). These fields were divided by elevated levies (ranging from 1 to 3 meters above the fields) and irrigation canals that are used to mark property lines and as controls for intentional seasonal flooding. Township Road, an E-W-oriented road, divided the SURVEY area into North and South areas. FIGURE 6 is a representative photograph of the area.

Weather ranged from sunny to cloudy with very light snow at times. Temperatures ranged from 25 to 45° F. There was snow on the ground, ranging from 1-3 feet in the fields to 3-4 feet in the snowdrifts. N-S-oriented drainage ditches and fences, as well as low levies delayed progress at times. The survey was stopped at these features and continued on the other side. Some of the fields were flooded during the time of the survey and were inaccessible for data acquisition (shown as "NO DATA" zones on the MAPS). Soft ground and snow caused the vehicle to get stuck four times.

Surface features included power poles and lines, gates, fences, farming equipment and irrigation lines and equipment. Man-made subsurface features included culverts and bridges that were used to connect fields and levies.

Heading Error and GPS

The heading error caused by the magnetic field of the survey vehicle was measured with the following procedure and corrected in the filtering process. The vehicle was driven in a circle (FIGURE 7.) and data were acquired along this profile (FIGURE 8.). It can be seen that the difference in the field between the locations where the car faced east and west was 25 nT. The difference between the locations where the car faced north and south was 95 nT. Therefore, the heading error induced in the data is minimized along E-W-oriented profiles. Also, the general orientation of the geological features in the SURVEY area is generally NNW-SSE and the levies dividing the fields are oriented E-W and N-S. For the aforementioned reasons the SURVEY was acquired along E-W-oriented profiles.

The GPS system used in this SURVEY was capable of submeter accuracy with the use of Omnistar Differential positioning. Position data were corrected in real time with the use of satellite broadcast techniques. The GPS system's Parallel Swathing option allowed the vehicle to stay on each profile with the use of a dash-mounted lightbar. This system used a series of Light Emitting Diodes (LEDs) to keep the driver on track. The center three LEDs represented the profile, and when they were lit, the vehicle was on track. The LEDs to the right and left represented a distance of 1.7 meters (user-defined) between them. As the vehicle steered 1.7 meters off track to the left (or right), the first LED to the left (or right) of center was lit. The driver then steered to the right (or left) to bring the lit LEDs back to the center. FIGURE 9 shows every 50th station on a profile taken in both directions, and the accuracy of the GPS system.

The distance between the GPS antenna and the magnetic sensor (4.5 meters) was compensated in the GPS acquisition software.

Base Station

Two base stations were used in the survey, one located in the area north of Township road, while data were acquired in that area, and one south of Township road while data were acquired there. A base station was used to measure the daily normal variations of the earth's magnetic field. This data was used to make diurnal corrections to the magnetic data. The base station was operational during each acquisition period.

PROCESSING

Initial data processing was performed with Geometric Inc.'s software, MagMap 2000. Three data sets were processed that way, the magnetic field stations, the magnetic base stations and the GPS data. Gridding and contouring was performed with Golden Software's SURFER program.

Magnetic Field Stations

Readings of 0 nT amplitude were linearly interpolated with the previous and next non zero readings using the Linear Interpolation Function of MagMap 2000. Spikes in the data were removed with the Despike Function of the software, which was setup with a peak threshold of 1 nT and maximum readings of 120. FIGURES 10., 11. and 12. show the effect of each processing step on a sample profile.

Magnetic Base Stations

The same type of processing was performed on the base station data. Dropouts were linearly interpolated and spikes removed. The Despike Function for the base stations was setup with a peak threshold of 100 nT and maximum readings of 300. A bias value of 408 nT was added to the diurnal magnetic values of the south base station.

GPS Positions

The first step in GPS location corrections was to transform latitude and longitude data in degrees that are output by the GPS system to Universal Transverse Mercator (UTM) coordinates in meters. This is desirable because the UTM system is a rectangular coordinate system measured in meters or feet, so these coordinates can be used to calculate distances directly. The LKL Valley is in zone 10 of this system with its central meridian at –123 degrees. UTM coordinates are distances from this meridian. The conversion was performed in MagMap, using the WGS-84 ellipsoid as a reference ellipsoid. All stations that were not taken along an E-W profile were removed, to eliminate the introduction of large heading errors.

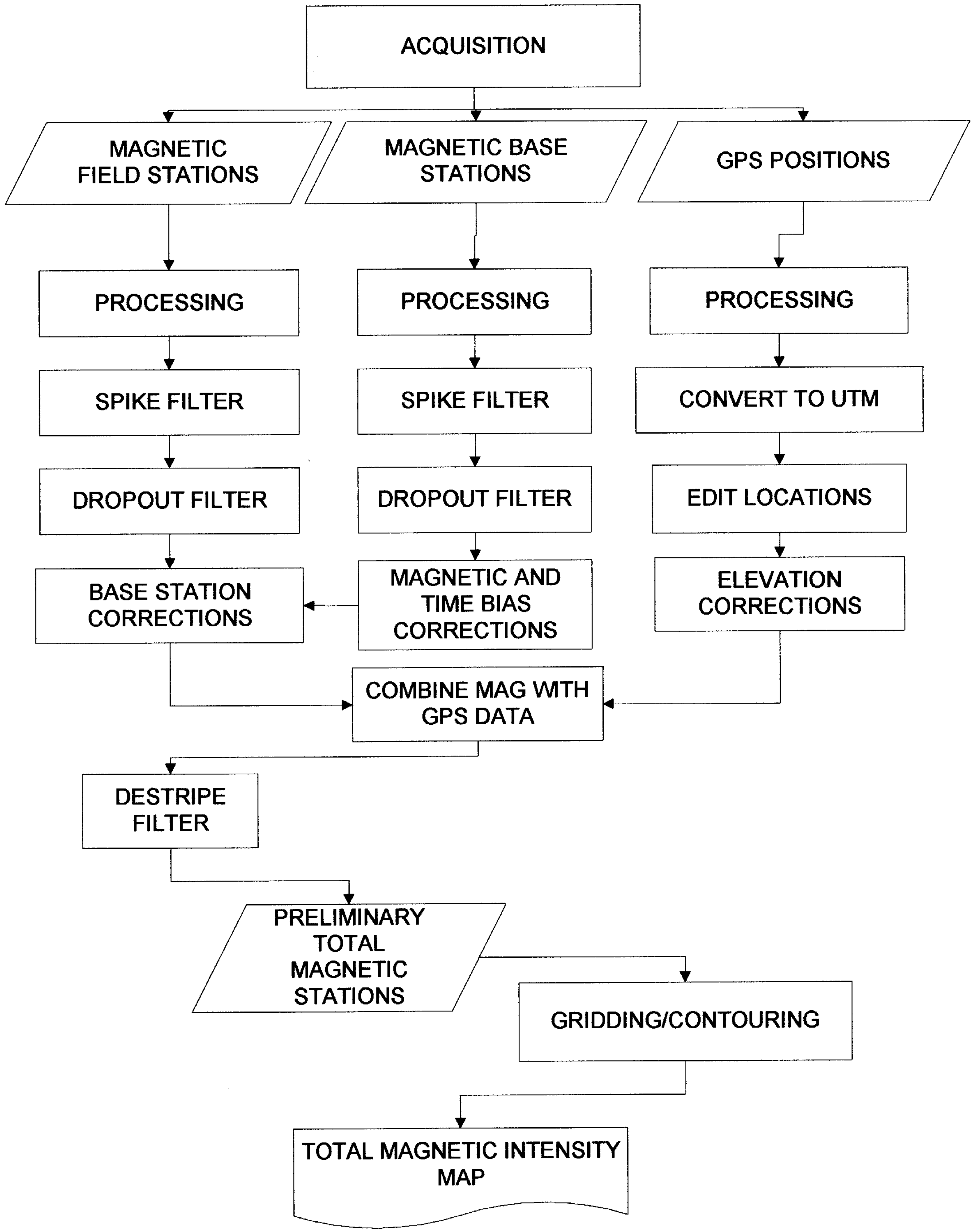
Total Magnetic Stations

After these processing steps were completed, the magnetic and GPS data were combined, and MagMap 2000's Destripe filter was employed to add a heading error correction to the data. This filter calculates a constant difference between east- and west-oriented profiles and subtracts it from the higher values. Then, the data were exported to a Total Magnetic Station spreadsheet file for further processing. MagMap 2000 automatically added a diurnal correction to the magnetic stations during that process.

To derive the Total Magnetic Intensity Map, the dataset was gridded onto a 100 m grid using a minimum curvature method. The resulting Total Magnetic Intensity Map (FIGURE 13.) is contoured at 25 nT. MAGNETIC HIGH ANOMALIES are red while MAGNETIC LOW ANOMALIES are blue on this map.

Repeatability and Survey Quality

There were eight profiles on levies, each taken twice, in opposite directions (FIGURE 13 shows an example of such a profile). Such profiles are good indicators of repeatability of results and of survey data quality, therefore a heading error analysis was performed on these profiles. One set of profiles (consisting of a pair of opposing-direction profiles) was not used because of several metal culverts that affected the quality of the data. For each set, the mean difference in magnetic field values between easterly and westerly directions was calculated. That value was deleted from the higher of the two magnetic field profiles and the difference between the original and the corrected opposite profile was calculated. These differences were grouped and are shown in FIGURE 15, in the form of a distribution histogram. The total number of values is 13731. The mean difference is 0.1397 nT and the standard deviation is 19.2292 nT. This indicates the average data quality for the TERRAMAGNETIC SURVEY is approximately 20 nT.



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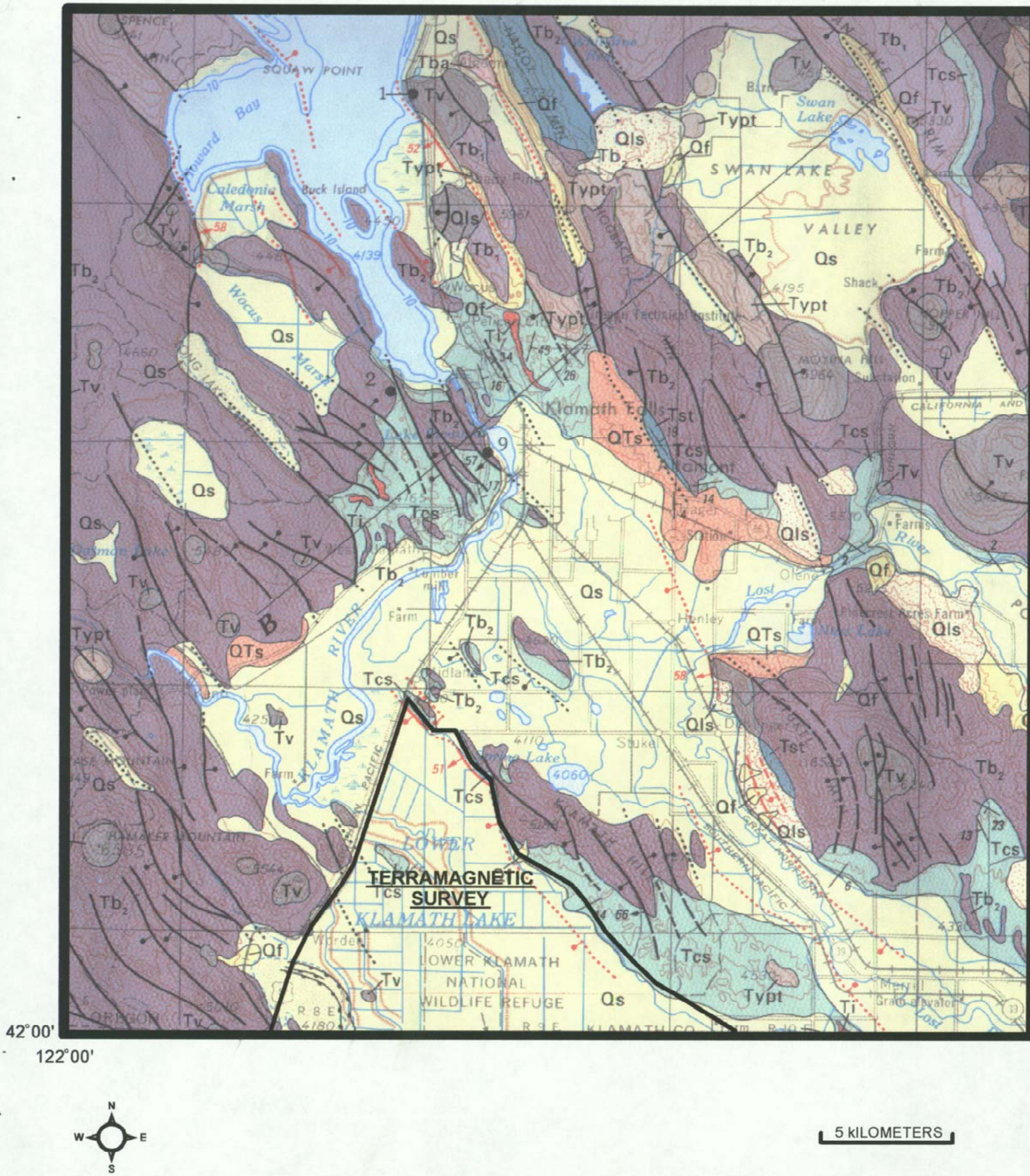
DATE: January 25, 2002 SUBSURFACE MAPPING SURVEY PROJECT No. 3862

LOCATION: LOWER KLAMATH LAKE VALLEY KLAMATH COUNTY, OREGON

CLIENT: Klamath Drainage District

FIGURE 1. FLOWCHART OF PROCEDURES



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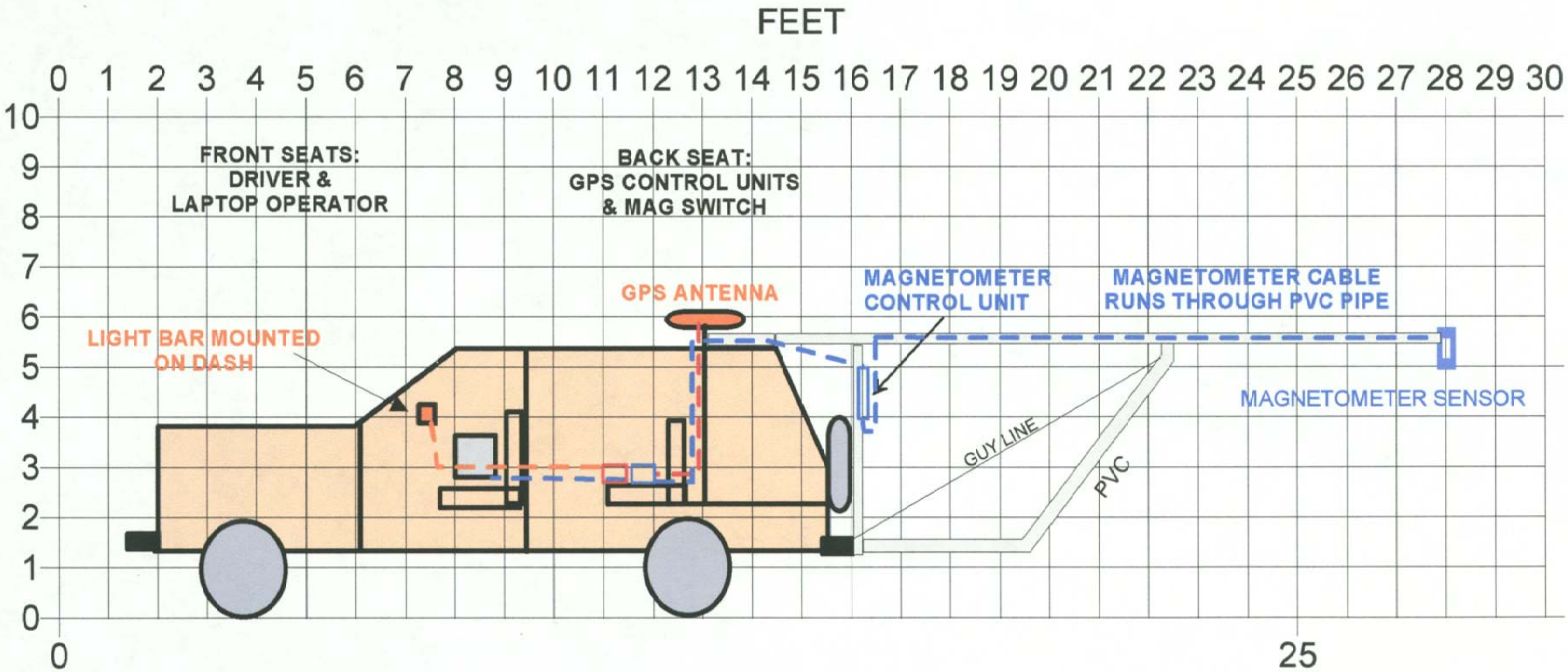
DATE: January 25, 2002 — SUBSURFACE MAPPING SURVEY — PROJECT No.: 3862	CLIENT: Klamath Drainage District		



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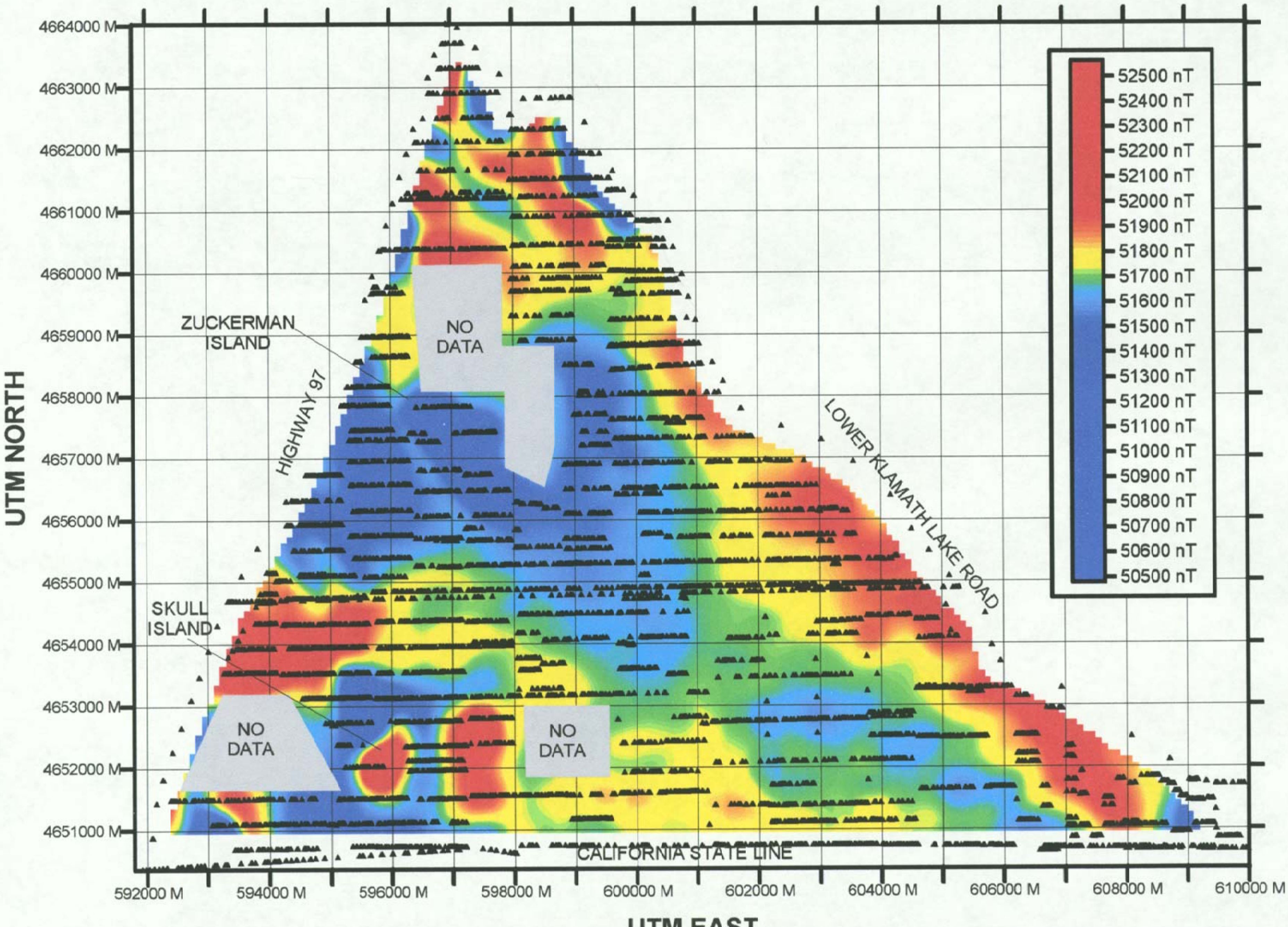
DATE: January 25, 2002	*SUBSURFACE MAPPING SURVEY* PROJECT No. 3862	CLIENT: Klamath Drainage District	



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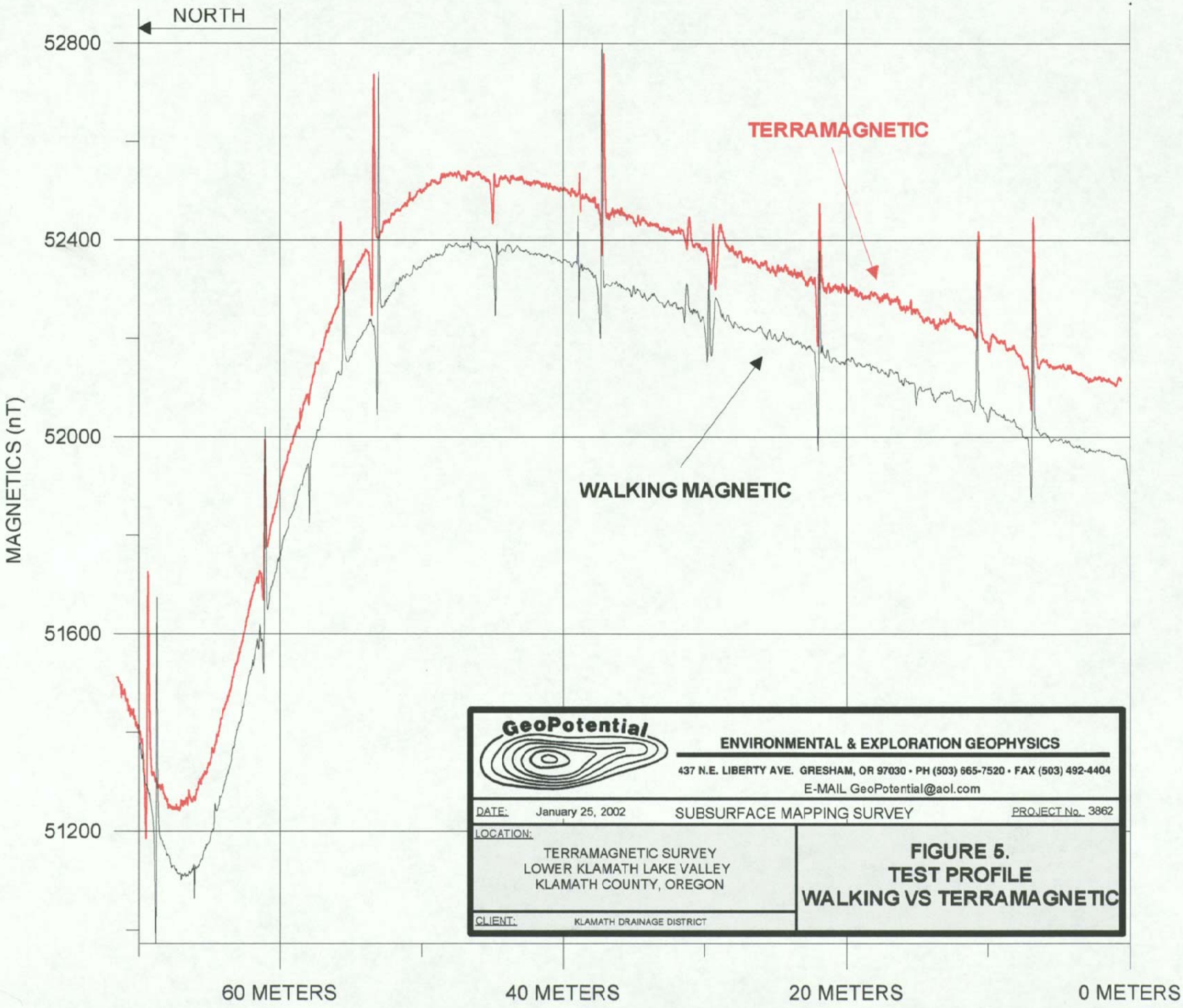

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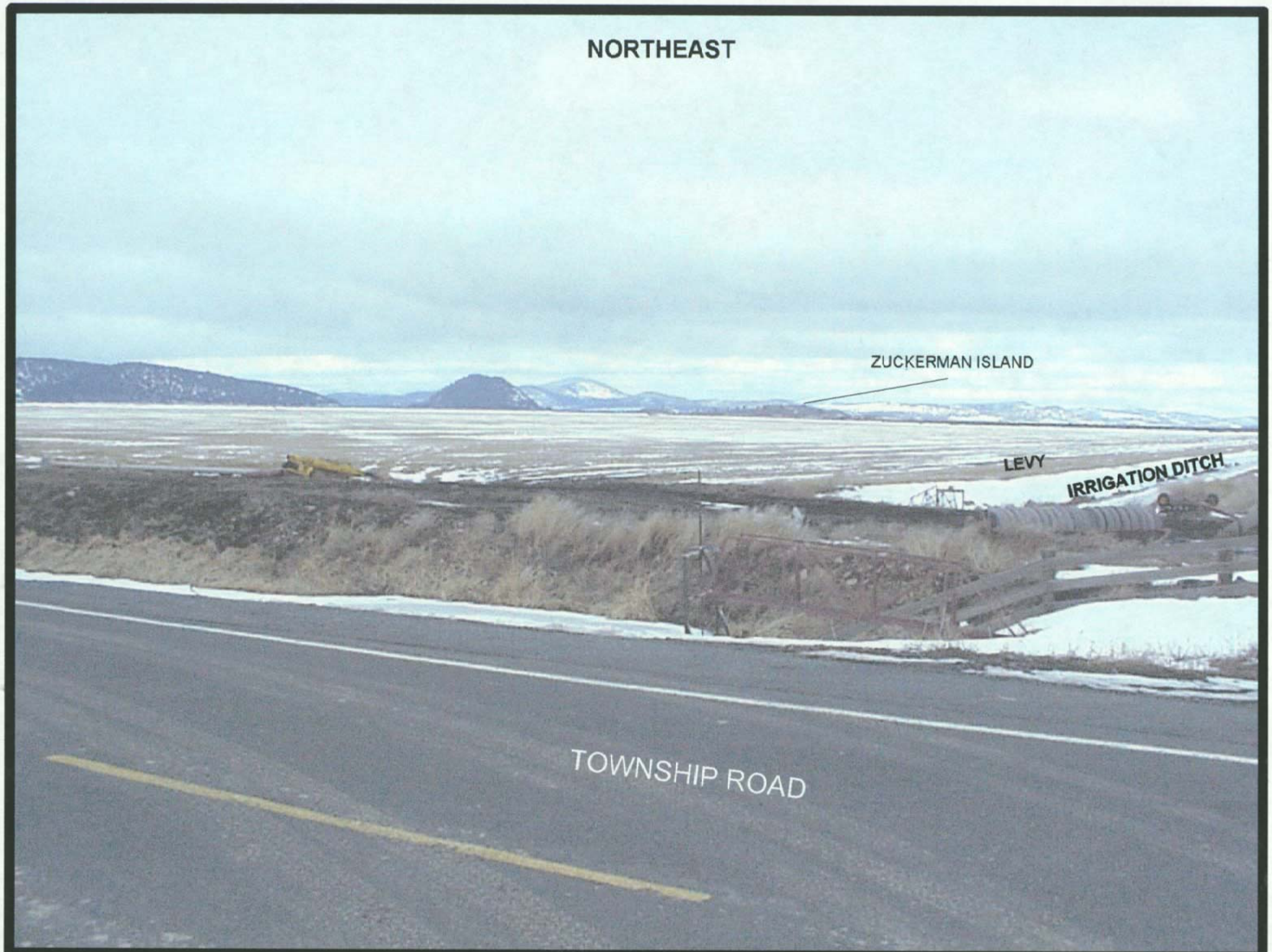
KLAMATH COUNTY, OREGON

CLIENT: KLAMATH DRAINAGE DISTRICT

FIGURE 5.
TEST PROFILE
WALKING VS TERRAMAGNETIC



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DATE: January 25, 2002 SUBSURFACE MAPPING SURVEY PROJECT No. 3862	CLIENT: Klamath Drainage District	

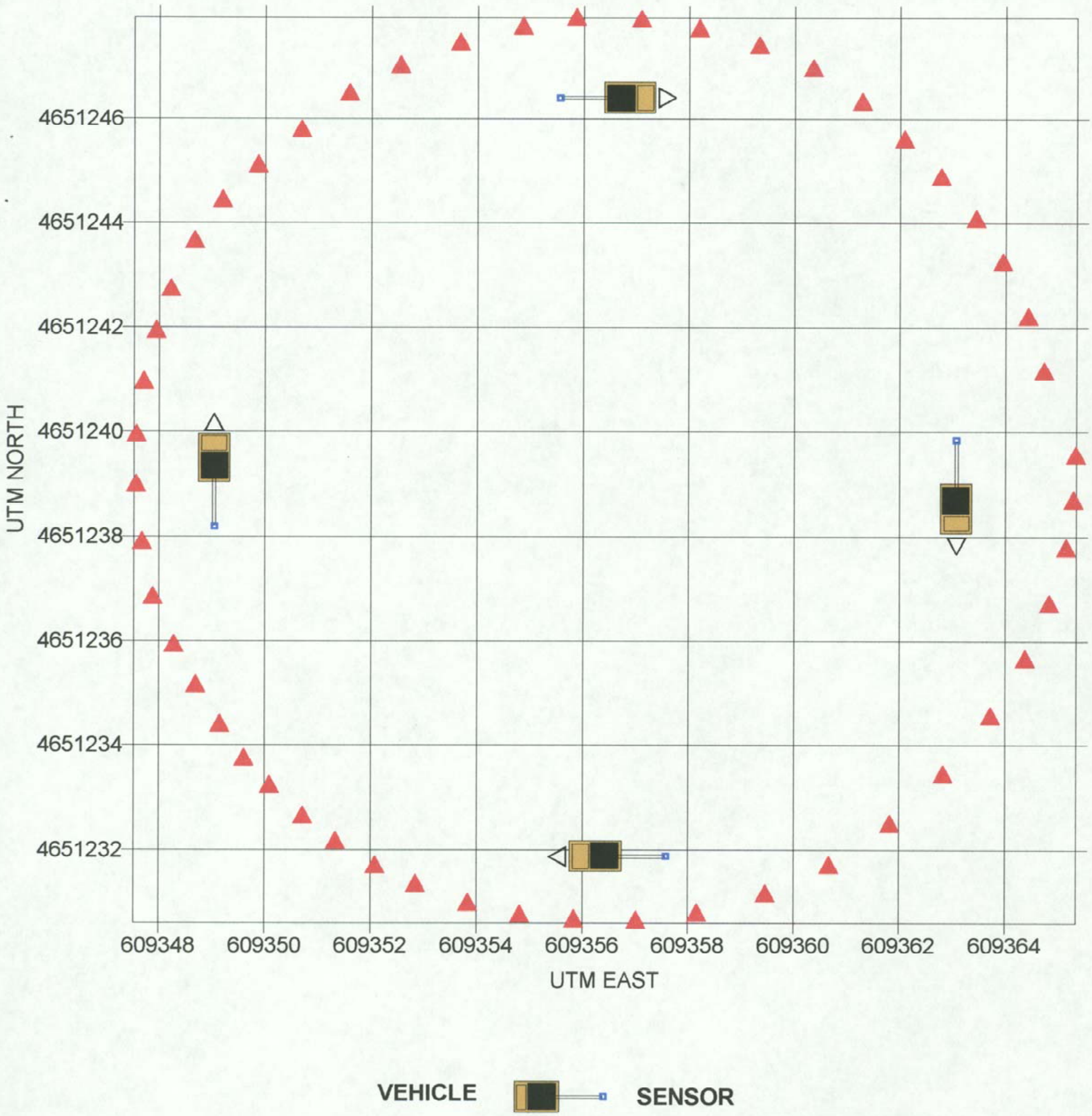

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**FIGURE 7.
CIRCULAR PROFILE
USED TO CHECK
HEADING ERROR**

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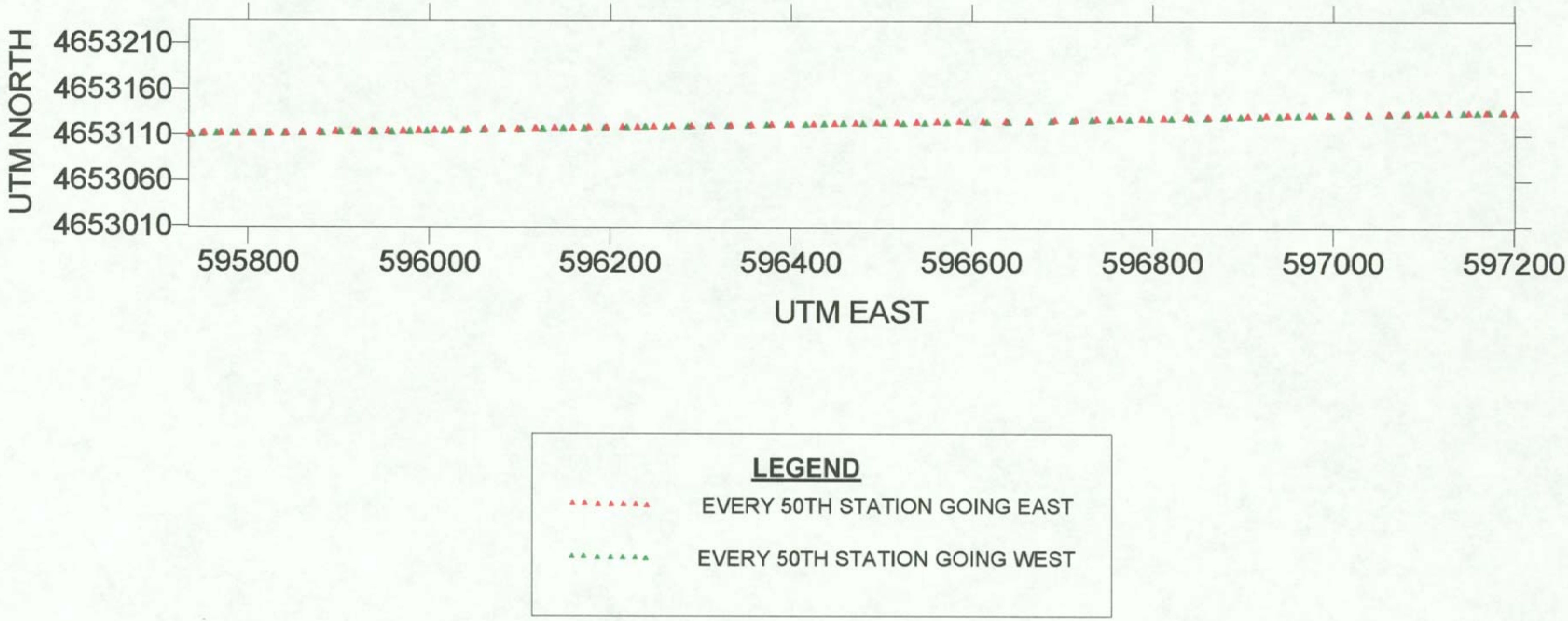

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FIGURE 9.
GPS STATION
LOCATION ACCURACY

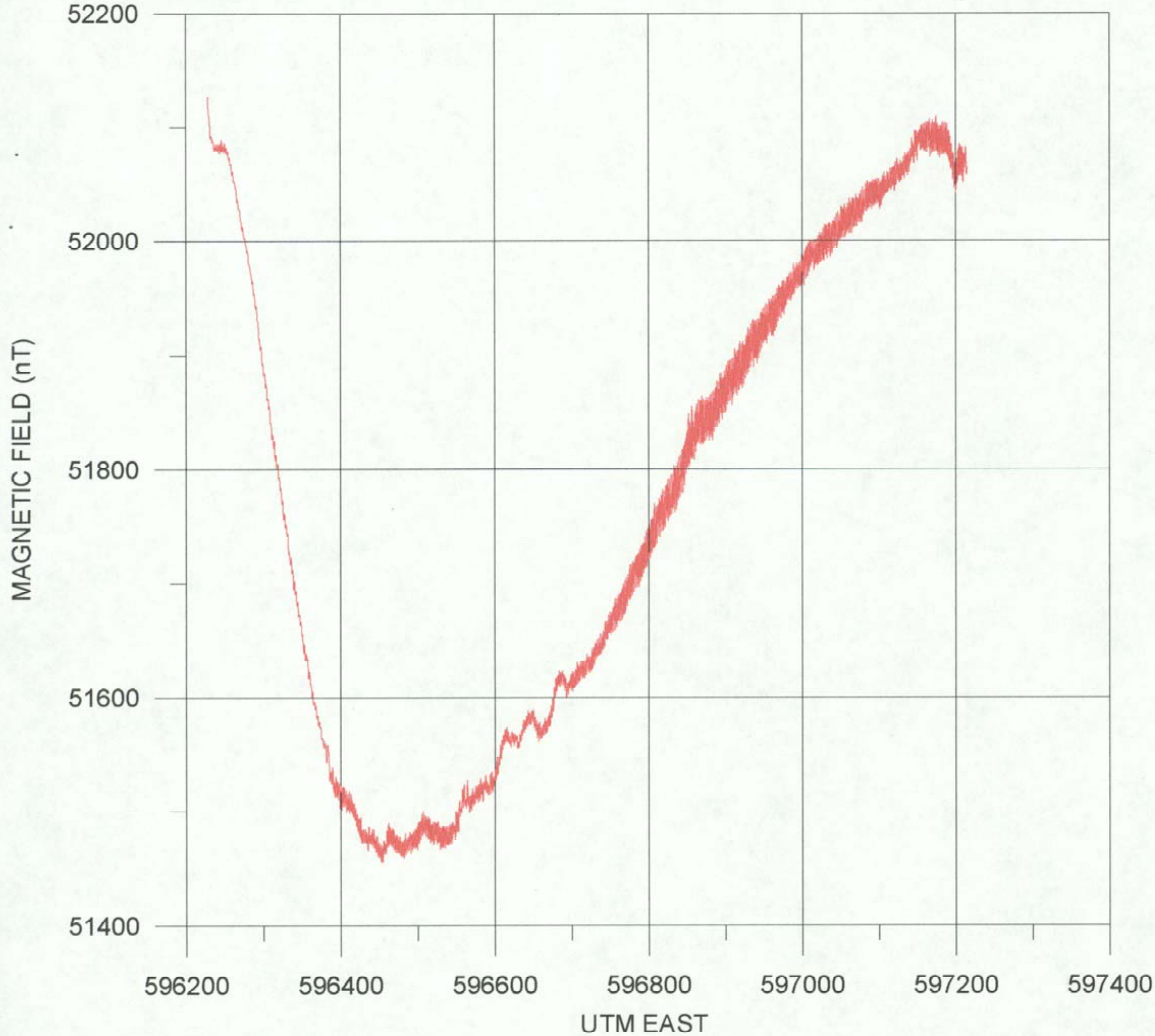

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FIGURE 10. EXAMPLE PROFILE RAW DATA

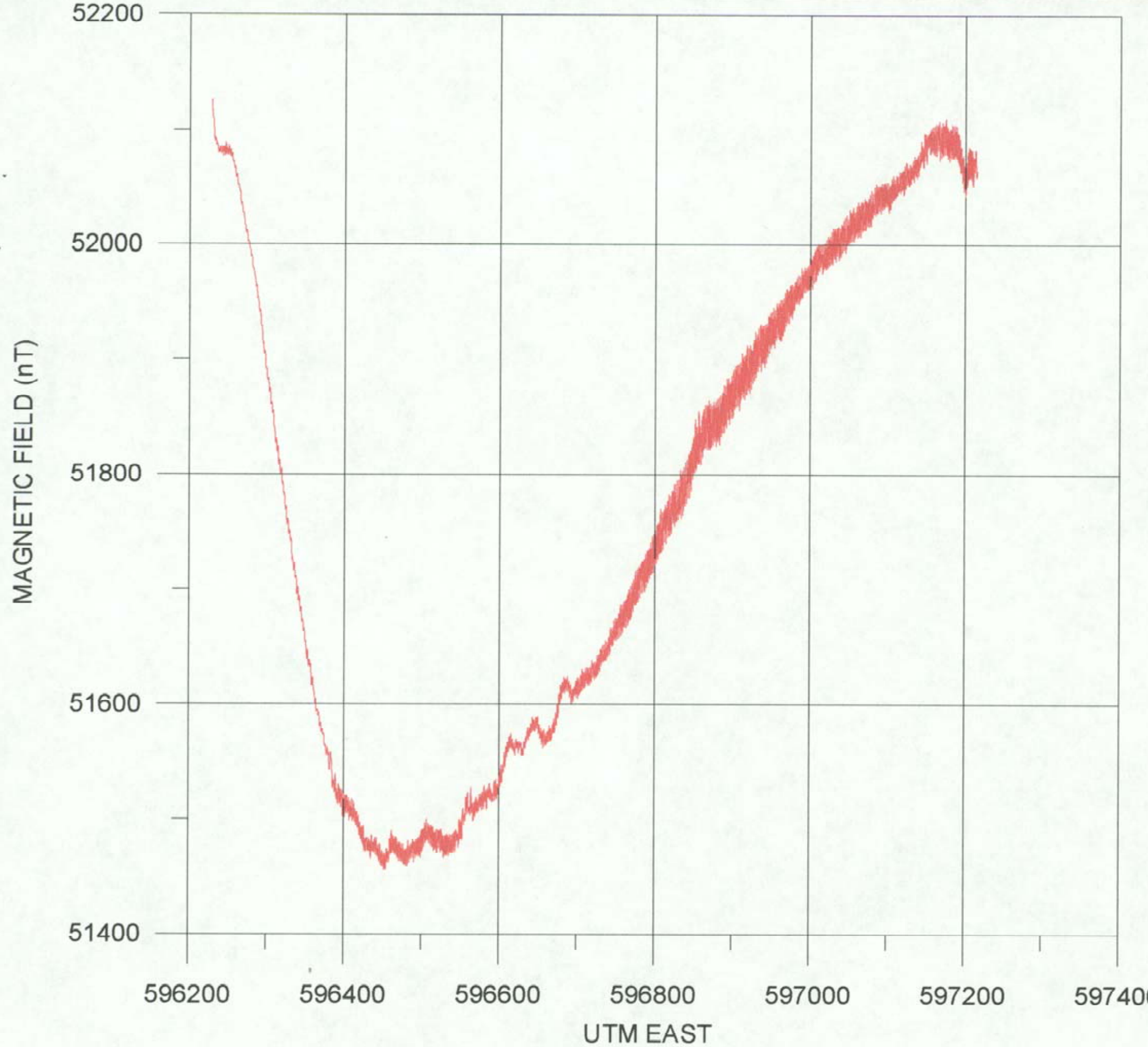

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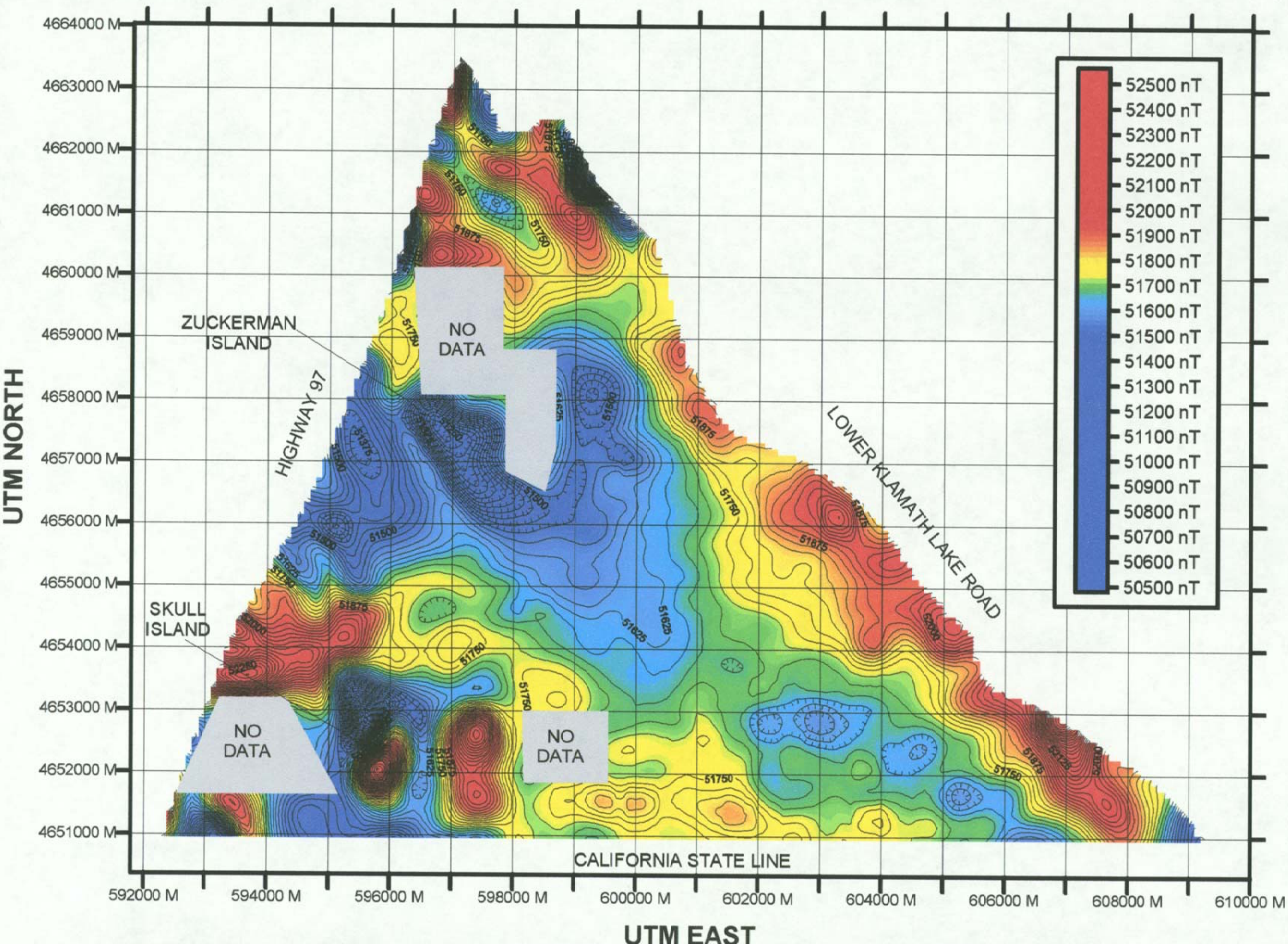
FIGURE 12.
EFFECT OF
THE DESPIKE FILTER



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DATE: January 25, 2002 — *SUBSURFACE MAPPING SURVEY* — PROJECT No. 3862	CLIENT: Klamath Drainage District	

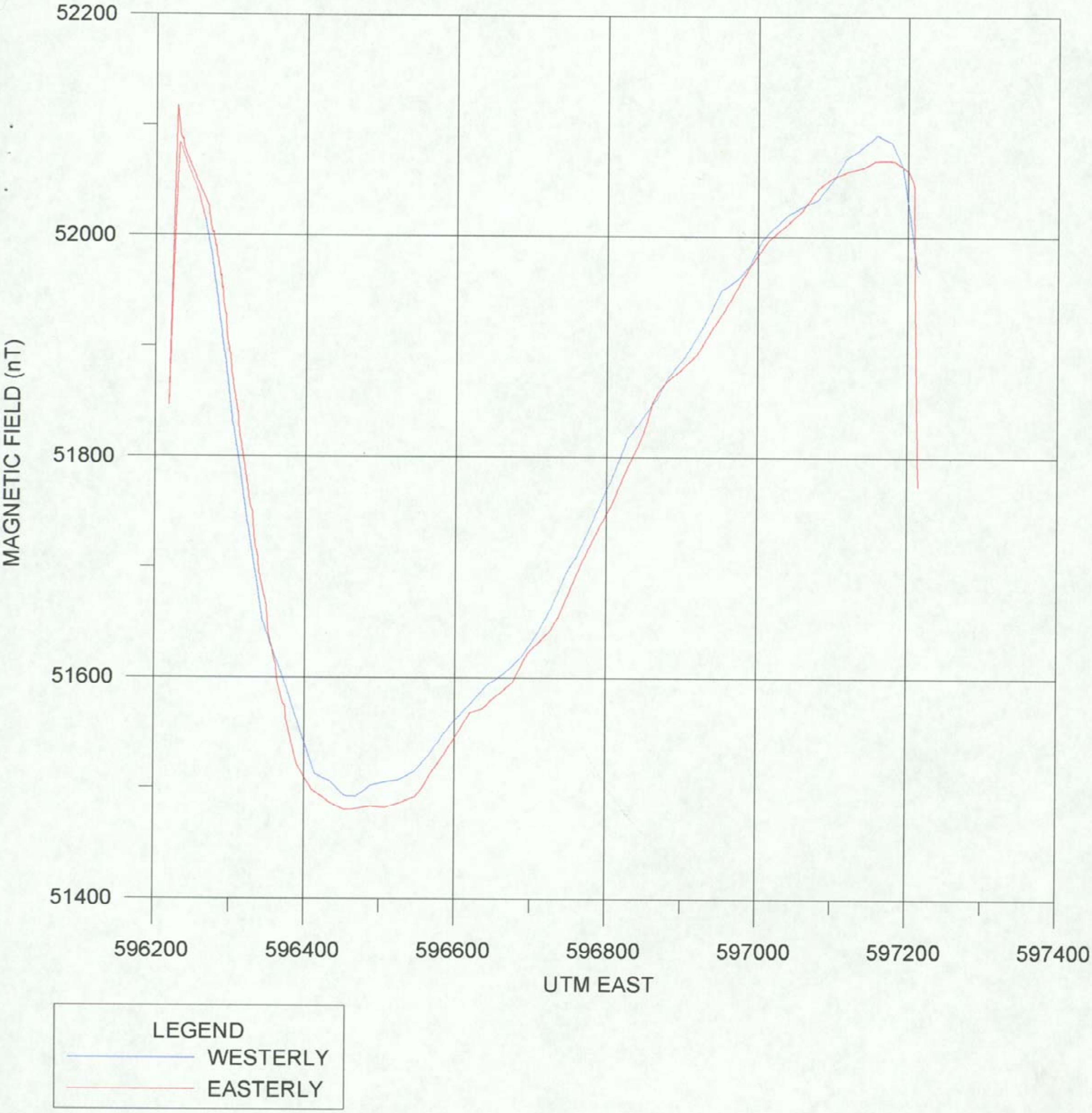

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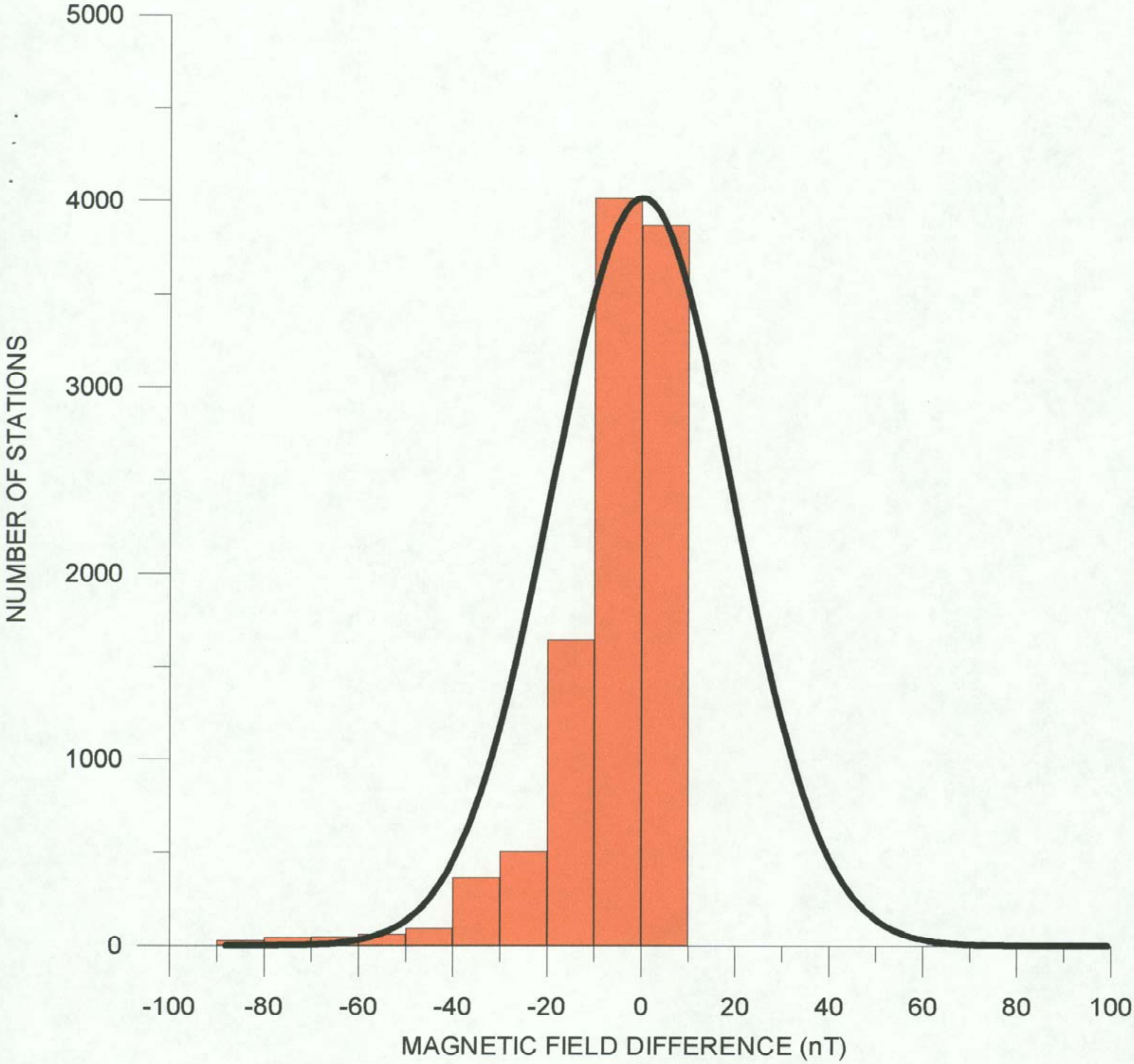
FIGURE 14.
EXAMPLE OF A
REPEATED PROFILE
(LATITUDE: 4652333)



TOTAL STATIONS: 13731
MEAN: 0.1397 nT
STANDARD DEVIATION: 19.2292 nT

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FIGURE 15.
ERROR DISTRIBUTION

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Ralph Soule
GeoPotential

1/25/02
DATE

Nikos Tzetos
GeoPotential

1/25/02
DATE

STATEMENTS OF QUALIFICATIONS

RALPH P. SOULE III

I have been a consulting geophysicist for 27 years. After completing my education I worked for 4 years as a consulting geophysicist at EXPLORATION DATA CONSULTANTS in Denver, Colorado. During this period the majority of my experience consisted of consulting to oil and mineral exploration companies. In 1979 I started GeoPotential in Golden, Colorado continuing to consult in exploration geophysics. In 1987 I moved GeoPotential to Gresham, Oregon and started consulting in environmental geophysics. Since 1987 I have consulted on over 900 projects. My clients included private individuals, environmental firms, construction companies, engineering firms and governmental organizations.

To perform environmental geophysics I have developed a MOBILE GEOPHYSICAL LABORATORY that allows me to acquire, process and interpret geophysical data on the project site. This both reduces the cost of geophysical surveys and allows for higher quality surveys. Using the LAB I can perform Ground Penetrating Radar, Magnetic and Electromagnetic surveys. In addition I perform Downhole Video Logging surveys.

With this data I perform SUBSURFACE MAPPING SURVEYS that consist of identifying and mapping the location of shallow subsurface objects, which are of environmental or engineering interest. These include underground storage tanks, buried waste drums, utilities, trenches and pits, building foundations, rebar reinforcements, shallow geology, groundwater, contaminant plumes and a variety of other features.

EDUCATION

POSTGRADUATE COURSE WORK IN GEOPHYSICS AND ASTROPHYSICS
Colorado School of Mines, Golden, Colorado.
University of New Mexico, Albuquerque, New Mexico

MS GEOLOGY/GEOPHYSICS
Western Washington University, Bellingham, Washington, 1975

BS GEOLOGY
Montana State University, Bozeman, Montana, 1971

PROFESSIONAL AFFILIATIONS
Society of Exploration Geophysicists
Environmental and Engineering Geophysical Society
Association of Engineering Geologists, Northwest Energy Association
Northwest Environmental Business Council

NIKOS TZETOS

After three years of working as a freelance geologist, I have worked the last year and continue to work as a geophysicist. As a freelance geologist I assisted with environmental assessments and geotechnical engineering projects. My geophysical experience includes working with ground penetrating radar, magnetic and electromagnetic surveys.

EDUCATION

MS GEOSCIENCES
The Pennsylvania State University, University Park, PA, 1997

BS GEOLOGY
Aristotle University of Thessaloniki, Thessaloniki, Greece, 1989

PROFESSIONAL AFFILIATIONS
Geological Society of America
American Geophysical Union
Oregon Association of Environmental Professionals