



## Tecate Commercial Vehicle Enforcement Facility Project: Increasing Efficiency of Geophysical Survey

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### Introduction

A geophysical survey of CA-SDI-16,798 in San Diego County, California was conducted on July 22-24, 2004 by Caltrans Headquarters staff as a preliminary step to Extended Phase I investigations. CA-SDI-16,798 is located east of Tecate Peak (Figures 11.1 and 11.2) and has one partially standing adobe and the footprints of several additional buildings (Figure 11.3). A magnetic gradient instrument, the G858 Cesium Vapor Gradiometer, and a GEM conductivity meter were used to survey 1,390 square meters in order to locate evidence of sub-surface cultural

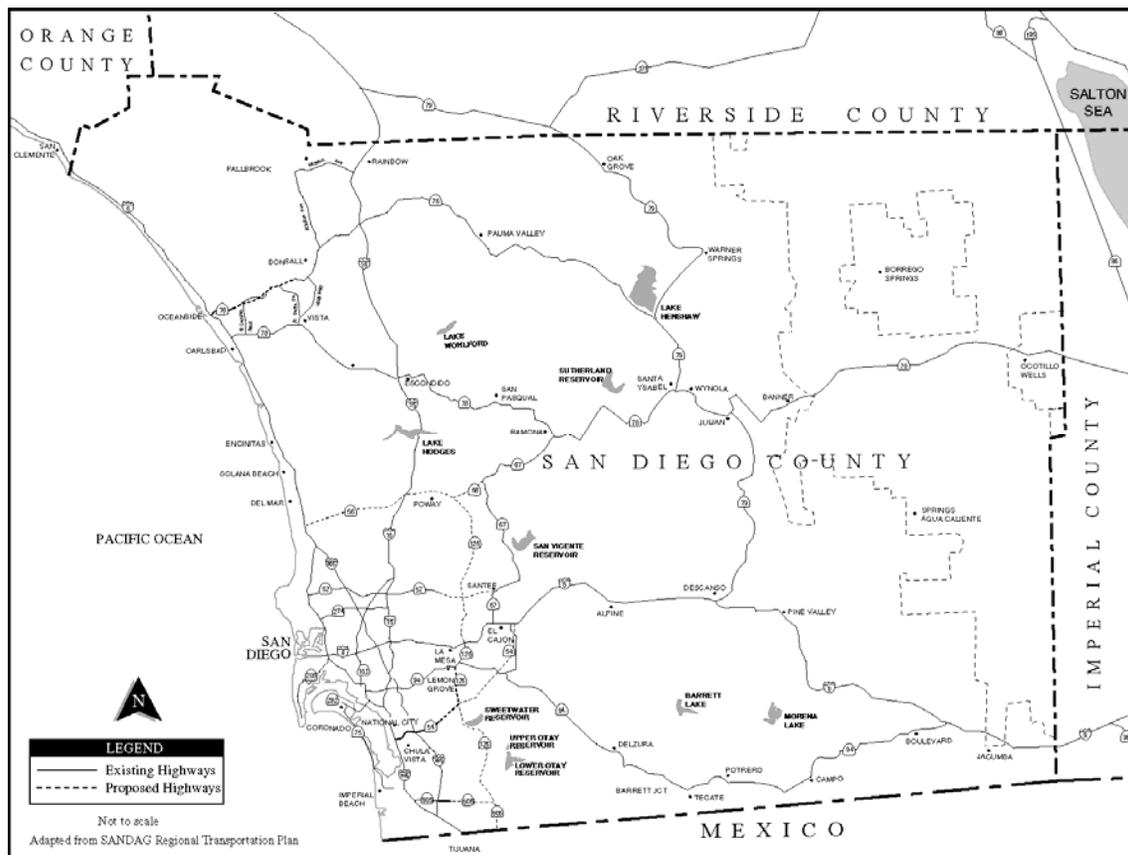


Figure 11.1. Project location. Courtesy Billy A. Silva.

features and a pair of underground tanks (Figure 11.4). Before Extended Phase I work, aerial photographs from Caltrans' DHIPP library, along with a series of historical photographs, were examined to help locate buildings that are no longer standing. The footprints of a burned-down residence and a border crossing building were discernible in these images. Enhanced historical photographs showed the presence of two gas pumps where only a single pump was expected. Information gained from historical photographs and DHIPP images helped to determine the placement of geophysical survey grids. Overall, the results presented here demonstrate that the combined use of a gradiometer and a conductivity meter for locating subsurface artifacts and features can be advantageous. For example, a possible canon ball, metal water pipes, ceramic sewage pipes, and cement elements associated with both metal and ceramic pipes were discovered via both geophysical instruments. Two underground tanks were also located while using the gradiometer; though official verification was conducted by Caltrans geophysicist Momoh Mallah using the GEM. As with other subsurface features at the site, combining data showed a direct correlation between targets present in both datasets and their subsurface locations.

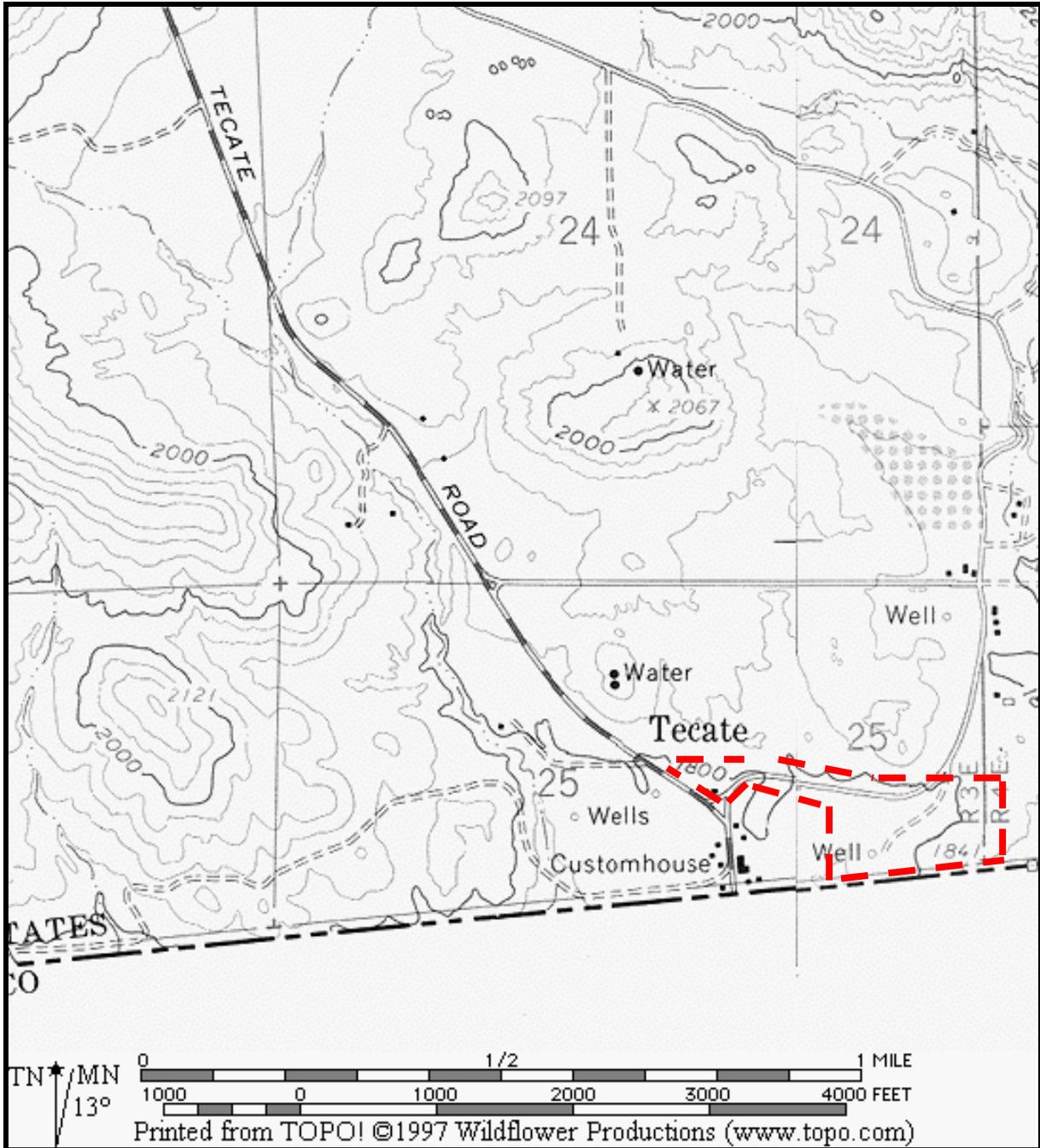


Figure 11.2. Project vicinity. Courtesy Billy A. Silva.



Figure 11.3. Aerial photograph of CA-SDI-16,798 shows adobe ruin in center of image. Courtesy Billy A. Silva.



Figure 11.4. Cesium Vapor Gradiometer. Courtesy Billy A. Silva.

## Geophysical background

Geophysical surveying is useful in carrying out a variety of archaeological investigations, including identifying soil stratigraphy, recognizing feature patterns, and overall site characterization. The ultimate goal of conducting geophysical surveys is to move from inductive methods and interpretations to a deductive model (Kvamme 2006). Inductive models are based upon pattern recognition alone. A deductive model, built from years of context within a given region, allows the researcher to identify archaeological features with little or no testing. Recent advances in instrumentation, software, and the development of geophysical programs at

academic institutions have greatly enhanced the spread of geophysical technology (Conyers and Goodman 1997; Goodman 2007).

A cesium vapor magnetometer (CVM) was used for this project. The CVM allows rapid data collection and high sensitivity to magnetic anomalies. E. Ambos and D.O. Larson explain that:

Although both methods rely on atomic particle measurements, the CVM relies on the behavior of electron-shell energy levels of certain elements (e.g., cesium) in the presence of a magnetic field; the electron properties can be measured, more precisely than the proton properties. The CVM is a particularly useful tool for archaeologists seeking for nonmetallic artifacts and subsurface structures. Magnetic signatures in an archaeological context tend to be relatively low amplitude in nature, on the order of 2-10 nT and thus difficult to define unless the magnetic measurement tool is able to resolve anomalies on the order of 0.1 nT (Ambos and Larson 2002:35).

Data was collected using a transect interval of 0.5 m and 1-meter mark intervals, resulting in ten readings every meter along each transect and thirty data points every square meter.

A Geophysical Survey Systems, Inc., GEM 300 Multi-frequency Electromagnetic Profiler was used for the EM survey. The device is an active EM induction sensor that transmits and receives electromagnetic signals at up to six different programmable frequencies simultaneously. The unit includes a bucking coil to counteract the primary signal; in free space, no primary or quadrature fields should thus be detected at the receiver coil. The practical effect of this design is that any primary or quadrature signal detected will be contributed by anomalous zones below the surface. According to Maxwell's Laws, lower frequency signals penetrate deeply, higher frequency signals penetrate less deeply, and penetration of EM signals in general is limited by conductivity; the more conductive the subsurface, the shallower the effective penetration. Thus, a six-frequency survey spread can be expected to sample six different depths below the receiver. The GEM-300 system measures both the primary field and the quadrature field for each frequency. The quadrature is the EM field-strength measured 90° out of phase from the oscillating primary signal. Any conductor in the earth will have eddy currents induced in it by the primary signal. These eddy currents, when detected by the receiver coil, will be delayed or phase-lagged with respect to the primary signal. The quadrature signal is a measure of the phase-lag.

To reduce the possibility of ambiguity in interpreting the results, both the in-phase and quadrature components of the received signal were recorded. The in-phase signal is usually high for metal conductors and the quadrature component is typically high for non-metallic objects. As high frequencies enhance the response of near-surface features, and low frequencies enhance the response of deep-seated features, six widely spaced frequencies were recorded to investigate different depths. All in-phase and quadrature values are in parts per million (PPM). For the purpose of this study, three frequencies were selected: 330Hz, 3870Hz, and 19950Hz. Both in-phase and quadrature components were used.

### **Geophysical survey of CA-SDI-16,798**

Caltrans Headquarters and District 11 staff conducted Extended Phase I investigations at the original Tecate border crossing (CA-SDI-16,798), located east of the Tecate turnoff (Route 188) and the current U.S. – Mexico border crossing (see Figures 11.1 and 11.2). The original crossing was recorded within the Area of Potential Effects (APE) for the Tecate Commercial Vehicle Enforcement Facility (CVEF) project. CA-SDI-16,798 is comprised of 14 features. One of the features has been identified as a backcountry store that included gas pumps. Due to the possibility that there were subsurface fuel tanks, the District 11 Hazardous Waste Branch in the Environmental Division requested geophysical testing to locate the tanks. Through subsequent discussion with Headquarters staff, it was decided that combining geophysical survey work (locating the subsurface tanks) with the archaeological geophysical survey (locating subsurface features containing artifacts, like trash pits, privies, etc.) would be the best approach.

## **Methods**

Geophysical testing for archaeological features was conducted on January 20-21, 2004 by Billy A. Silva, Darrell Cardiff, and Debra Dominici. On July 21-22, Momoh Mallah and David Rodriguez conducted the conductivity survey in an effort to locate archaeological features and verify the existence and location of any subsurface tanks. Extended Phase I excavations were to follow data collection and analysis in February of 2004. Portions of the site were heavily vegetated with sage and prickly pear cactus and excluded from the survey area. Other locales had large granitic boulders that produce magnetic signatures; these were also excluded from the survey. Figure 11.5 shows the location of each geophysical grid in relation to the project area. Modern debris, associated with road and foot traffic, was visible on the surface of the site. Where possible, the debris was removed before starting the survey. The geophysical survey was conducted using grids that varied in size from 10 x 10 meters (test grid over Feature 2) to 25 x 35 meters. Nine grids were established that covered a large portion of CA-SDI-16,798, oriented along a north-south axis (Figure 11.6). Measuring tapes were laid along the north-south axis of the grid at one-meter intervals. The tapes helped to guide the operator across each grid during data collection. Grid corners were located with GPS technology using a Trimble XR Pro that georeferenced magnetic survey data.

Once data was collected, it was downloaded and processed both in the field and in the laboratory. Initial field examination involves downloading data from the gradiometer and GEM data logger into a laptop. Exploratory data analysis (EDA) filters data using both high and low pass filters to remove spurious spikes. Geometrics Mag Map and Mag Pic software accomplished much of the data processing. Data for both the gradiometer and GEM were exported to Surfer, where it was interpolated and the final images were created. All final images were georeferenced in ArcGIS 8.3 for creation of field maps.

## Tecate Geophysical Test Unit Locations

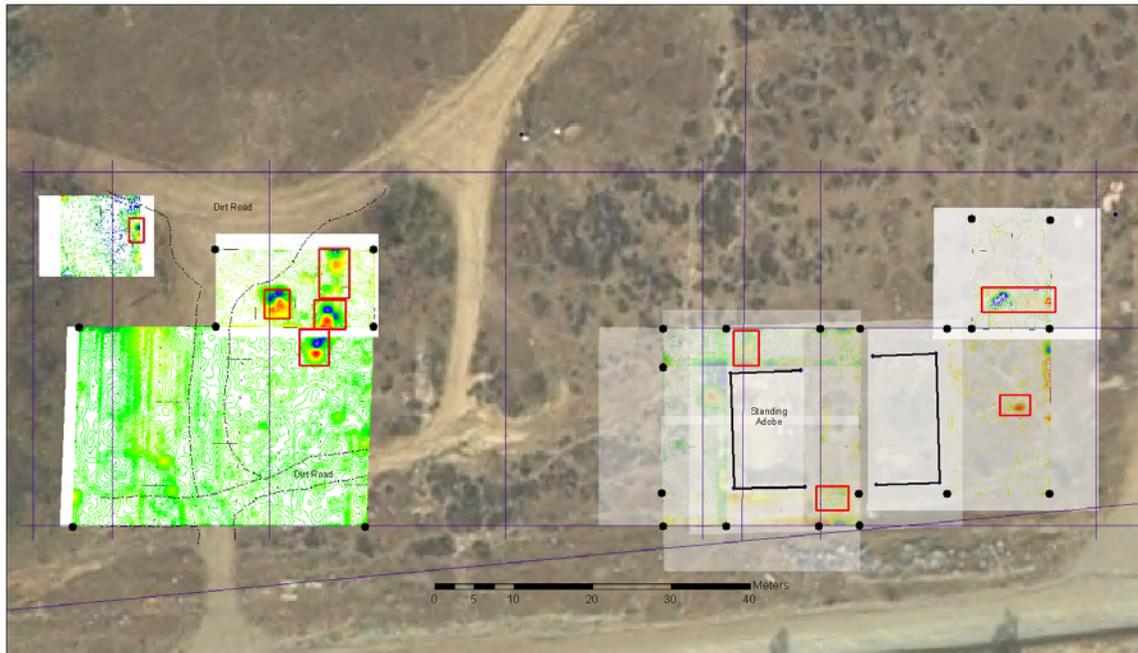


Figure 11.5. Overlay of geophysical data onto aerial photograph. Courtesy Billy A. Silva.

## Tecate CVEF - Geophysical Survey Results

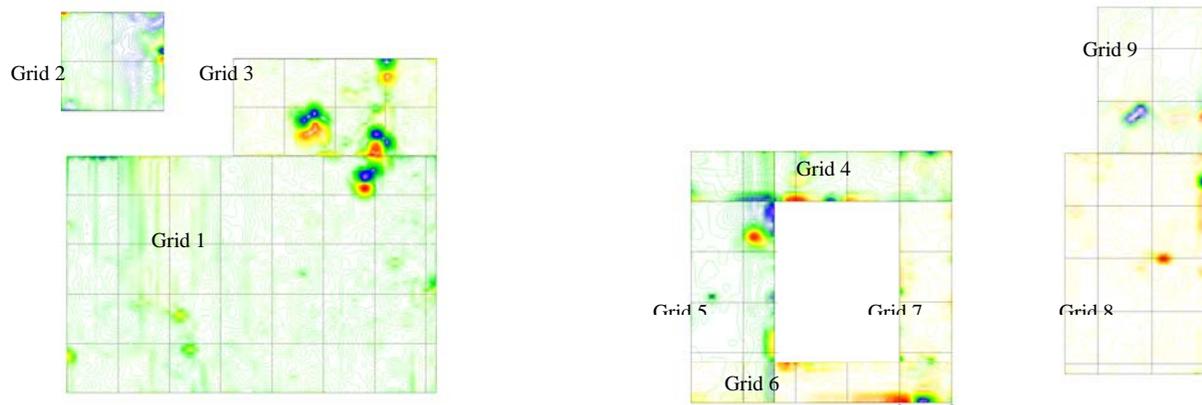


Figure 11.6. Overview of geophysical data, Grids 1-9. Courtesy Billy A. Silva.

## Interpretation

The primary goal of the EDA process was to locate and map any anomalies large enough to represent a cultural feature warranting investigation. A secondary objective was to locate any subsurface tanks associated with the gas station. Interpretation of geophysical data, in general, is not an exact science. Although one may speculate on the type of feature an anomaly may represent, nothing can be certain without ground truthing. To reduce the risk of misidentifying

geologic features during a geophysical survey, two types of technology were incorporated into the survey design: gradiometer and GEM. Both detect similar archaeological features and were ideal for the project. By comparing only those anomalies that occur in both sets of data, the chance of mis-identifying geologic features is greatly reduced.

Five anomalies were detected within the geophysical survey area. At least two anomalies in Grids 1 and 3 (Figures 11.6 and 11.7) and one in Grid 9 (Figure 11.8) were of the size and orientation expected to represent cultural features and warranting further investigation. Anomaly 1 was a metal pipe, aligned north-south and passing through a cement block and a metal “T” junction (Figure 11.7). Anomaly 2 was a ceramic pipe, aligned east-west, running from the cement block in Grids 1 and 2 (Figure 11.7). Two large anomalies found in Grid 5, west of the adobe, and Grid 6, south of the adobe, clearly represent two subsurface features (Figure 11.9). Their signatures matched the locations of the gas pumps depicted in historical photographs (Figure 11.10). Based on the geophysical data and historical photographs, it appears that the underground tanks are represented in the geophysical data as depicted in Figure 11.9. However, testing by Hazardous Waste indicated that a single tank was located in Grid 5, west of the adobe. A geophysical specialist was not present during removal of the underground tanks, so it is unclear what caused the signatures in Grid 6, south of the adobe. As for the correspondence between magnetic and conductivity data, four of the five anomalies were represented in both data sets. Anomalies 4 and 5 fit historical evidence for the locations of gas tanks. The fifth anomaly in Grid 9 was detected only in the magnetic data (Figure 11.8). Excavation at this locale produced what appeared to be a diffuse rust scatter.

## **Conclusion**

Geophysical technologies are useful for identifying a range of feature types, including archaeological features. The application of multiple technologies reduces the number of spurious anomalous readings that would have resulted if a single instrument had been used. In the absence of the geophysical survey, traditional excavation methods would have been used, including a random sampling of 2,158 square meters. The consequent method of earth stripping as a means of ground truthing confirmed what the geophysical data indicated. No other features were present within geophysical survey areas. As for the underground tanks, it is clear from the historical photographs and the correlation between the magnetometer and GEM data that a tank existed, though no testing was done at the time of the Extended Phase I excavations. The combined use of the gradiometer and GEM technology, along with the decision to conduct the survey in-house, were two strategies that optimized the efficiency of this geophysical survey.

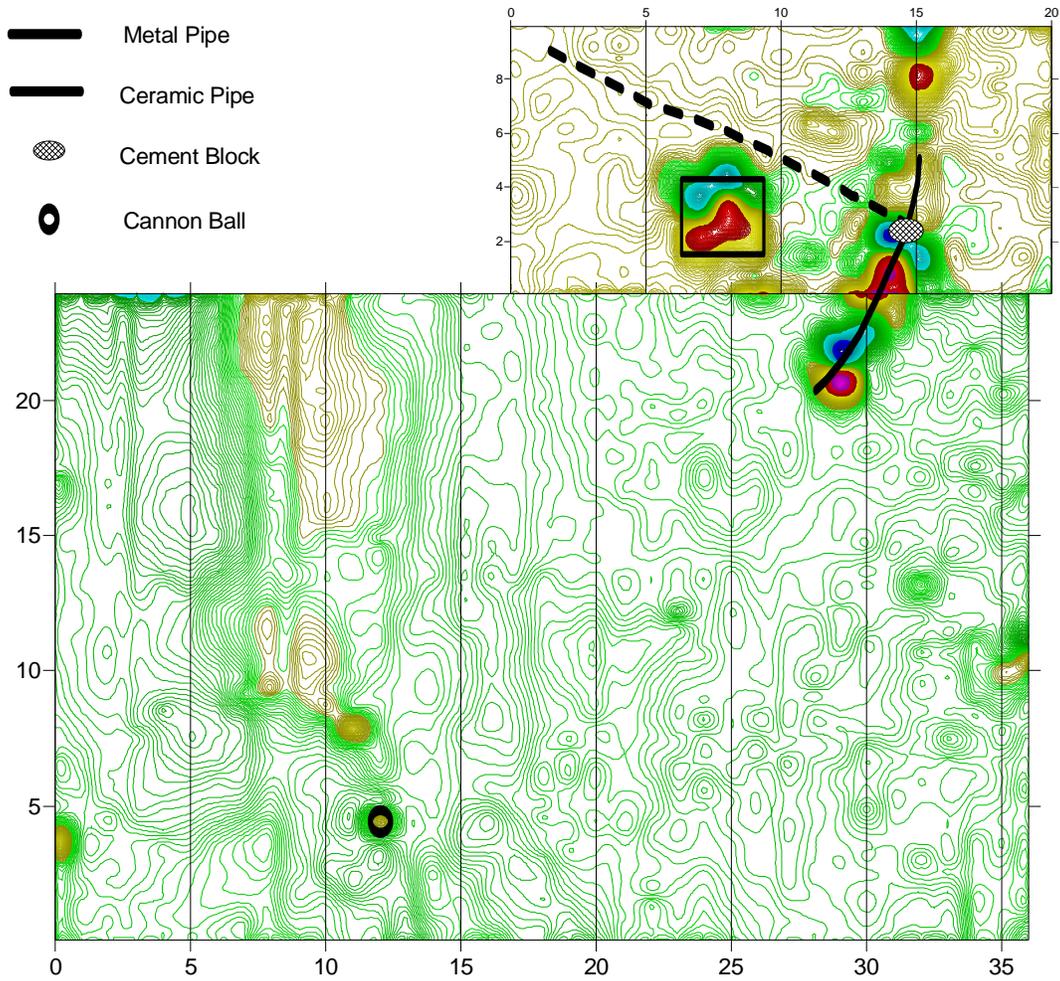


Figure 11.7. Close-up of Grids 2 and 3 with anomalies highlighted. Courtesy Billy A. Silva.

As evidenced by this project, iterative approaches to assessing archaeological resources hold great promise. Caltrans continues to employ the geophysical techniques used at CA-SDI-16,798 in an effort to explore these technologies and develop additional methodologies for obtaining maximal information with the least amount of effects.

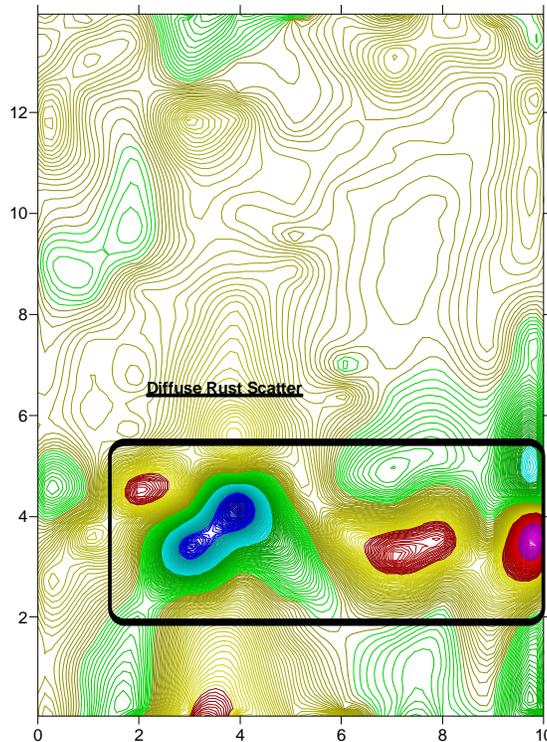


Figure 11.8. Grid 9 highlighted with the location of a diffuse rust scatter. Courtesy Billy A. Silva.

## References

Ambos, E. and D. O. Larson

2002 Verification of Virtual Excavation Using Multiple Geophysical Methods: Case Studies from Navan Fort, County Armagh, Northern Ireland. *SAA Archaeological Record* 2(1):32-38.

Conyers, L. B. and D. Goodman

1997 *Ground-Penetrating Radar: An Introduction for Archaeologists*. AltaMira Press, Walnut Creek, California.

Goodman, Dean

2007 *Methods for Archaeology*. Unpublished Paper presented at University of California, Santa Barbara Field School.

Accessed July 2007; available at: [www.GPR-Survey.com](http://www.GPR-Survey.com)

Kvamme, K. L.

2006 *Remote Sensing Approaches to Archaeological Reasoning: Physical Principles and Pattern Recognition*. In *Archaeological Concepts for the Study of the Cultural Past*, edited by Alan P. Sullivan, III, University of Utah Press, Salt Lake City, Utah.

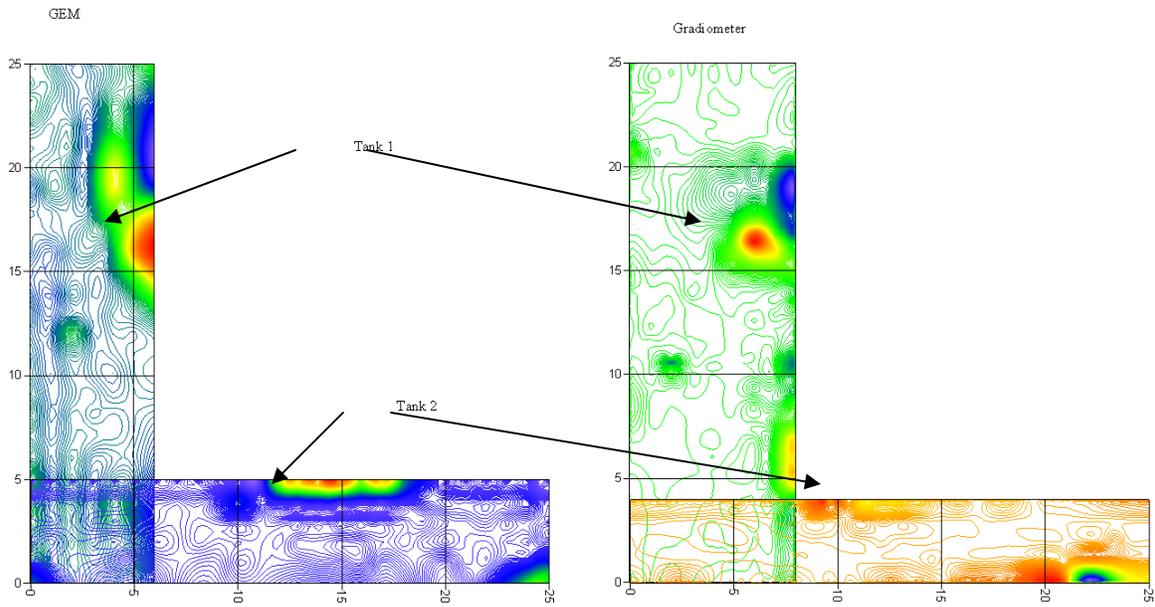


Figure 11.9. Grid 5 and 6 comparison of GEM (left) and Gradiometer (right) showing the location of Tanks 1 and 2 as marked. Courtesy Billy A. Silva.



Figure 11.10. Location of Tanks 1 and 2 west and south of the Johnson store. Courtesy Billy A. Silva.