

# Exhibit 5.10: Geophysical Guidance for Archaeological Resources

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## Introduction

Non-invasive geophysical investigations map anomalous readings that represent changes in subsurface soil conditions. This exhibit presents Caltrans' guidance for determining when such investigations are warranted. Through proper analyses, testing anomalous readings may help identify classes of data related to cultural deposits, such as middens, storage pits, foundations, etc. When used in conjunction with other tools available to Caltrans staff archaeologists and/or consultants, non-invasive geophysical applications have shown potential in meeting environmental compliance obligations to avoid, minimize or mitigate the effects of transportation projects on archaeological resources.

This guidance focuses on the three components necessary for implementing a successful geophysical study:

1. Obtaining an understanding of the literature, types of equipment, and methods for survey and data processing/interpretation
2. Gathering the information needed to assess the appropriateness of a given geophysical approach
3. Identifying the fundamental components of a geophysical survey in order to develop a scope of work that will help meet project goals

The guidance is divided into two main sections:

- The [General Guidance](#) discusses the justification for using geophysical technology, pre-field specifications, and report requirements.
- The [Practitioners Guide](#) introduces the online tutorial that guides the reader (beginner or advanced) through the proper steps to determine whether a geophysical survey will help, and the information that is needed for specialists to conduct a geophysical survey. California State University, Long Beach designed the tutorial for Caltrans "as an online self-study resource for the collection, processing and analysis of archaeogeophysical data,"<sup>1</sup> and is based on a

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<sup>1</sup> [Archaeogeophysics website](#)

compilation of Caltrans geophysical research. The tutorial covers the fundamentals of geophysical survey and sampling methods, as well as advanced statistical analyses using multiple types of data within a Geographic Information System (GIS) environment.

Each of the technologies listed in the following pages have been identified as a means of mapping potential subsurface cultural components. Examples of projects using these technologies from around the United States can be found at [NADAG<sup>2</sup>](#).

Geophysical technologies available to Caltrans staff include Ground Penetrating Radar (GPR), Magnetometer/Gradiometer (CVM/CVG), Resistivity, Conductivity, and Light Detection and Ranging (LIDAR) – although not a geophysical technology, LIDAR is showing great promise in sensing and mapping minute detail. Other types of non-invasive equipment that Caltrans does not currently own also may help with subsurface mapping; most notably seismic refraction and portable X-ray Fluorescence (XRF) instruments. Though not discussed within this guidance or the associated Tutorial, Alan J. Witten's *Handbook of Geophysics and Archaeology* from 2006 contains a discussion on how seismic refraction functions.

Geophysical investigation is a growing and advancing field; therefore this guidance cannot cover all possible applications. However, information in the following pages may be applied to most situations, technologies and software.

## General Guidance

When incorporating the use of geophysical or any other technical equipment (LIDAR, thermal imaging, etc.) into a survey, Caltrans archaeologists need to be familiar with available technologies to determine how and when to incorporate their use. Part of this familiarity is in knowing what information is required to make an educated decision, such as having a basic knowledge of the technology, how to interpret the data, and, importantly, how to integrate their use into a typical phased compliance investigation (i.e. survey, testing, and mitigation).

The pre-field geophysical survey requirements must be discussed in detail so that the method(s) appropriate to the geology, soil, land cover and expected archaeology can be justified. Because there is a wide array of site types and geology, non-invasive data gathering may not be suitable in all situations.

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<sup>2</sup> North American Database of Archaeological Geophysics

This guidance will help Caltrans staff archaeologists:

- Determine whether a geophysical survey is warranted.
- Determine which methods and technologies are appropriate.
- Show how to effectively incorporate the use of appropriate geophysical methods and technologies.

### **Choosing the Appropriate Technology**

Choosing which instrument to use has as much to do with the feature type anticipated as with geology and soil. Table 1 below lists the types of equipment that are useful in locating various archaeological deposits/features. Only the most commonly used survey methods are listed. *This is only a rough guide, to which there will be exceptions, depending upon individual site circumstances and future technical developments.* As Table 1 demonstrates, each type of equipment is suitable for a range of feature types. For instance, GPR identifies many of the same features as magnetometers. This is one reason Caltrans has invested in these two technologies. Results are most reliable when verified by more than one technology.

Table 1 is adapted from the English Heritage [Geophysical Survey in Archaeological Field Evaluation](#).

TABLE 1 MATCHING SURVEY METHOD TO FEATURE TYPE*:				
Feature Type	<a href="#">Magnetometry Equipment</a>	<a href="#">Resistivity Equipment</a>	<a href="#">GPR Equipment</a>	<a href="#">Conductivity Equipment</a>
middens	Y	N	N	?
activity areas	y	Y	n	?
large pits (>2m diameter)	Y	y	Y	?
small pits (<2m diameter)	Y	?	Y	?
post holes	y	n	y	N
hearths	Y	N	y	n
kilns/furnaces	Y	N	y	?
building footings	y	y	Y	?
paleochannels	y	y	Y	y
roads/tracks	y	y	y	?
masonry foundations/piers	?	Y	Y	Y
brick foundation/piers	y	Y	Y	?
house floors	y	Y	Y	?
graves	?	y	y	N
cremations	n	N	N	N
Key: <b>Y</b> The technique responds well in many conditions and is usually to be recommended. <b>y</b> The technique can respond effectively in many conditions but is best used in conjunction with other techniques. <b>?</b> The technique may work well in some conditions, and its use may therefore be questionable; another technique might be preferable. <b>n</b> The technique may work in some conditions, but is not usually recommended; another technique is usually preferable. <b>N</b> The technique is probably not effective, or its effectiveness is uncertain.				
*adapted from English Heritage 2008 Guidelines.				

## Survey Guidelines

The following summarize the main components necessary to complete a successful geophysical survey as outlined in the online [Tutorial](#).

### Scoping/Fieldwork

For a geophysical survey to be successful, an understanding of the physical setting is necessary. *This analysis should be conducted prior to any fieldwork* and should include at a minimum:

- Geology of the area, both hard rock and soil formation.
- Identification of above and below ground utilities.
- Some basic information about the regional archaeology.

Knowledge of these three areas will help to identify geophysical expectations for site boundary, feature types, and intra-site patterning. Any planning for geophysical survey needs to be accomplished in close coordination with the principal project archaeologist to ensure integration with the project's goals and research design.

Geophysical fieldwork should be undertaken under the concept of repeatability so that independent verification of findings reasonably could be reached by any geophysical specialist. The online Tutorial explains how to accomplish this goal by discussing standard sampling techniques.

It is highly recommended that data collection be conducted using multiple technologies because different equipment measures different physical properties of the same types of features.

### **Data Treatment**

In-field processing of raw data should be conducted to ensure data fidelity. If corrupt data are found, the area should be re-surveyed. All phases of exploratory data analysis (EDA) should be documented and included in the final report. Data outliers should be removed during EDA; any outliers that cannot be removed should be identified, explained in the notes, and clearly depicted in any images included in the report. EDA varies from instrument to instrument and should follow standard guidelines for the equipment and the software used. Complete records of the EDA process should be kept and included in the Geophysical Survey Report appendix.

### **Data Interpretation**

Whenever possible, include in the data interpretation input from all specialists working on-site. At minimum, archaeological, geophysical and geomorphological specialists will add insights that otherwise might be overlooked. In the report, clearly state the distinctions between scientifically based interpretations versus anecdotal observations. Explain negative data (the absence of anomalous readings) and include a clear statement about what negative data do and do not mean (e.g., negative data may not imply an absence of archaeological components/features at the site). In the event of negative data, appropriate alternative methods should be used to determine whether subsurface archaeological deposits are present. This could include the use of some other form of geophysical technology, hand or mechanical excavation, or combination thereof.

## Data Archiving

Data archiving is an integral part of geophysical data collection. The results from a typical geophysical survey using GPR and magnetometers can produce gigabytes of data. This would include raw data files, converted data files from third party software, raster and vector data, GPS, and tabular/spatial data from GIS sources. All spatial data and images should be linked to the Caltrans Cultural Resource Database (CCRD). This could be accomplished through creating and linking a zipped file to the CCRD.

## Competence of Survey Personnel

All geophysical work must be performed under the responsible charge of a Professional Geophysicist who is registered in the state of California pursuant to the [Geologist and Geophysicist Act](#), California Business and Professions Code, Chapter 12.5 [section 7800 et seq.](#) Qualifications for registration are found in [section 7841.1](#) and are available on-line at (<http://www.bpelsg.ca.gov/applicants/>).

All geophysical work conducted in-house will be performed under the responsible charge of a registered geophysicist from the Chief of the [Geophysics and Geology Branch](#) in the [Division of Engineering Services](#), [Geotechnical Services](#), [Office of Geotechnical Support](#). Once Caltrans has updated the requirements, this exhibit will be revised accordingly.

## Geophysical Survey Report Guidelines

The Geophysical Survey Report (GSR) is a clear and concise discussion of every stage of the geophysical survey, supported by figures and tables that are understandable to the specialist and non-specialist alike. Format is similar to an Archaeological Survey Report (ASR), see [Exhibit 5.1](#), but with the focus on the geophysical data. At minimum, the GSR should contain the following sections:

- Background information on the geology and soils (including moisture, pH, etc).
- Background information on the archaeology (e.g., what types of features are likely in the region).
- Discussion of the methods used during the survey and EDA
- Detailed discussion of the survey results that clearly point to what was found
- Interpretation and detailed discussion of what the results mean in reference to the overall project.

- Clearly stated reference as to how the geophysical results can be used in ensuing phases. This might include mitigation measures requiring additional geophysical survey or potential excavation sampling strategies.
- Appendix that includes detailed technical information with all raw data files, field notes, and images created during processing (burned onto a CD and attached to the final report).

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**GSR FORMAT**

- |   |   |
|---|---|
| • Title page                                      | • Discussion of the survey results                            |
| • Table of Contents                               | • Interpretation of what the results mean for overall project |
| • Summary of Findings                             | • How the results can be used in ensuing phases               |
| • Introduction                                    | • Appendix  |
| • Background information on the geology and soils | • Maps and other Figures                                      |
| • Background on the archaeology                   |   |
| • Methods used during survey and EDA              |   |

***Don't forget the transmittal memo!***

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Caltrans PQS certified at the Principal Investigator level (Prehistoric Archaeology or Historical Archaeology, as appropriate) must peer review the all geophysical documentation, including GSRs, as outlined below in [Peer Review and Approval](#).

## Practitioners' Guide

The California State University, Long Beach developed the online geophysical website with Caltrans providing the funds and staff oversight. It is designed to lead all levels of practitioners from the beginning “How To” steps through advanced statistical analyses in a GIS environment using multiple sources of data. Because it was designed in a *wiki* environment, it is a user-updated program. Experienced users can add their own projects and beginners can upload data, send and ask the experts questions about the data. As new technologies are developed and tested, these can be added to the website, located at:

[http://mendel.cla.csulb.edu/archaeogeophysics/index.php/Main\\_Page](http://mendel.cla.csulb.edu/archaeogeophysics/index.php/Main_Page). Follow the registration and login tools to create a user name and password.

The website is divided into the sections described below.

## Equipment

Though the principles behind the geophysical instrumentation remain the same, the [equipment](#) models and configurations may vary, which can present additional



considerations in survey design. GPR, magnetometry, resistivity, and conductivity are each explained.

## Techniques

Each [technique](#) has strengths and constraints that make it more or less effective in detecting sub-surface features, depending on the conditions of the environment associated with the archaeological investigation. The purpose of this section is to explain exactly what each technique measures, the strengths and weaknesses of each technique, and the conditions which allow the technique to be most useful.

## Datasets

The [dataset](#) portion of the website is where real data will be placed. This section allows users to practice data processing with previously recorded geophysical data.

## Tutorial

The [tutorial](#) page provides step-by-step operating instructions for geophysical instruments as well as how to process data generated in the field. Each page generally focuses on individual tasks.

## Analysis and Integration

Among of the most powerful and dynamic [analysis and integration](#) tools for interpreting processed geophysical data are GIS programs such as ArcGIS. Geophysical data may be integrated into GIS by directly importing processed data as layered image files or interpolating raw data within ArcGIS itself. These layers then may be compared using statistical processes by using Spatial Analysts for ArcGIS users.

## Software

The [software](#) section is under construction because Caltrans is trying to find a means of adding software capabilities that do not conflict with software user licenses. However, step-by-step instructions are included for each software package used/recommended for each piece of equipment.

## References

The [reference](#) section is divided into four subsections. The general geophysics bibliography contains references for different types of geophysical equipment. The [magnetometry bibliography](#) contains references specifically for magnetometry surveys, while the [GIS bibliography](#) focuses on sources regarding the use of GIS in

archaeology. The [remote sensing](#) bibliography contains references for photogrammetry and satellite imagery in archaeology.

## **Glossary**

A [glossary](#) is provided to help the beginner understand terminology used throughout the tutorial.

## **Peer Review and Approval**

Caltrans PQS certified at the Principal Investigator level must peer review the all geophysical documentation, including the draft GSR, following the guidelines in [Exhibit 2.13](#): Guidelines for Peer Review of Cultural Resources Reports. Peer reviewers' names should be kept on record and comments retained in the project files. [Chapter 2 Section 2.5.5](#) and [Exhibit 2.11 Table C](#) contain additional guidance on peer reviews and reviews for approvals.

Only Caltrans PQS at the Principal Investigator level reviews GSRs for approval, which the EBC approves. The Caltrans PQS or consultant who prepares the GSR signs, dates and includes his/her discipline, PQS level (as applicable) and District/Headquarters or affiliation. The Caltrans PQS reviewing the GSR for approval likewise signs, dates, and includes his/her PQS discipline, level and District or HQ affiliation. Finally, the EBC approves the GSR by signing and dating the document. See [Chapter 5 Section 5.6.9](#) for more detailed information.

GSRs may be provided as a stand-alone document, as a chapter of a larger report such as an ASR, or as an appendix. This should be discussed prior to the field investigation as the required information may vary. All other Caltrans guidance on report dissemination should be followed.

## **Recommended Readings**

The following references are provided to enhance the reader's understanding of the principles on which the geophysical instrumentation works, and directs the reader to guidance from other agencies and sources and databases containing geophysical reports from around North America.

ADS Guidance. Geophysical Data in Archaeology: A Guide to Good Practice:  
<http://guides.archaeologydataservice.ac.uk/>

Application of Geophysical Methods to Highway Related Problems:

<http://www.cflhd.gov/resources/geotechnical/>

Avery, Thomas Eugene and Graydon Lennis Berlin

1992 *Fundamentals of Remote Sensing and Airphoto Interpretation*, 5<sup>th</sup> edition, Prentice Hall, New Jersey.

Bevan, Bruce W.

1998 *Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration*, Midwest Archaeological Center, Special Report No. 1.

Clay, R. Berle, Lawrence B. Conyers, Rinita A. Dalan, Marco Geardino, Thomas J. Green, Brian S. Haley, Michael L. Hargrave, Jay K. Johnson, Kenneth L. Kvamme, J. J. Lockhart and Lewis Somers

2006 *Remote Sensing in Archaeology, an Explicitly North American Perspective*, edited by Jay Johnson (Tuscaloosa: University of Alabama Press).

Conyers, Lawrence B.

2004 *Ground Penetrating Radar for Archaeology*, Alta Mira Press.

English Heritage Geophysical Survey Database: <http://sdb.eng-h.gov.uk>

Federal Lands Highway Program on the FHWA website:

<http://flh.fhwa.dot.gov/programs/flap/>

Geophysical Survey in Archaeological Field Evaluation:

<http://www.english-heritage.org.uk/publications/geophysical-survey-in-archaeological-field-evaluation/>

International Society for Archaeological Prospection: <http://archprospection.org/>

Journal: Archaeological Prospection:

<http://www3.interscience.wiley.com/journal/15126/home>

NERC Geophysical Equipment Facility: <http://gef.nerc.ac.uk/>

North American Database of Archaeological Geophysics (with extensive links):

<http://www.cast.uark.edu/nadag/>

National Park Service

1983 Secretary of Interior Standards and Guidelines: Archeology and Historic Preservation: [http://www.nps.gov/history/local-law/Arch\\_Standards.htm](http://www.nps.gov/history/local-law/Arch_Standards.htm)

Standards for Field Archaeology in the East of England: [www.eaareports.org.uk](http://www.eaareports.org.uk).

Waters, Michael R.

1992 *Principles of Geoarchaeology*. The University of Arizona Press.

Witten, Alan J.

2006 *Handbook of Geophysics and Archaeology*, Equinox Publishing, Ltd., London.