GEOPHYSICAL INVESTIGATION PLAN
AREA IV RADIOLOGICAL STUDY
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

U.S. EPA Contract Number: EP-S7-05-05
Task Order Number: 0038

Prepared for:

U.S. Environmental Protection Agency Region 9
75 Hawthorne Street
San Francisco, California 94105

August 5, 2010

HGL
HydroGeoLogic, Inc

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TABLE OF CONTENTS

Page

APPENDIX LIST

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

EM	electromagnetic
FDEM	Frequency-domain electromagnetic method
GHz	gigahertz
GIS	geographic information system
GPR	ground penetrating radar
GPS	global positioning system
HGL	HydroGeoLogic, Inc.
MHz	megahertz
mS/m	milliSiemens/per meter
NBZ	Northern Buffer Zone
QA	quality assurance
QC	quality control
USEPA	U.S. Environmental Protection Agency

GEOPHYSICAL INVESTIGATION PLAN
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1.0 INTRODUCTION

HydroGeoLogic, Inc. (HGL) has been tasked by the U. S. Environmental Protection Agency (USEPA) to conduct a radiological characterization study of the Santa Susana Field Laboratory (SSFL) at Area IV and the Northern Buffer Zone (NBZ) located in Ventura County, California. This work is being executed under USEPA Region 7 Architect and Engineering Services Contract EP-S7-05-05, Task Order 0038. The technical lead on the project is USEPA Region 9. This Geophysical Investigation Plan describes the approach, methods, and equipment to perform a geophysical investigation in support of USEPA's overall radiological characterization study.

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2.0 PURPOSE AND GOALS

The overall purpose of this geophysical investigation is to survey, identify, and locate areas of potential buried materials that may contain radiological contamination using non-invasive surface geophysical methods. For purposes of this plan, potential buried materials include the following:

- Buried debris, drums, and other "landfilled" material.
- Subsurface utility pipelines, such as water pipelines, sewer pipelines, liquid waste transfer pipelines, underground storage tanks.
- Buried waste management and disposal units including sumps, septic tanks, leach fields, and dry wells.
- Boundaries of former excavation areas.

Potential buried materials may be metallic or non-metallic. Metallic objects can be ferrous and non-ferrous. Ferrous metals contain iron, for example carbon steel and stainless steel. Non-ferrous metals do not contain iron, and aluminum, brass, and copper are examples of these. The survey approach used by this investigation plan will be able to indentify both metallic (ferrous and non-ferrous) and non-metallic potential buried materials.

The goal of this geophysical survey is to provide geographic information system (GIS) maps that geo-reference the locations of areas surveyed and locations of each potential buried material area. For each area of potential buried material, based on the limitations of the investigation equipment, the following information will be determined: the approximate location, perimeter footprint, approximate depth, and material distinction (e.g. metallic and non-metallic). Footprint location and depth accuracy will be within 2 feet and 3 feet, respectively.

These GIS maps along with all associated technical survey information will be provided to USEPA's soil sampling team and USEPA's SSFL Stakeholders for integration and prioritization into the USEPA's soil sampling approach for identifying Potential Source Areas for targeted sampling.

Survey target areas of interest include: 1) potential buried materials identified in USEPA's Historical Site Assessment Technical Memorandums (including areas identified in USEPA aerial photographic analysis), 2) areas identified as gamma radiation anomalies of concern, and 3) the drainage area immediately north of the Radioactive Material Handling Facility where past burial activities have been alleged.

In order to reduce the potential of missing and not identifying potential buried material and to streamline the logistics of the survey work, USEPA will be surveying all of the reasonably accessible areas within the former Energy Technology Engineering Center except for paved roadways, standing buildings, and rock outcrops. Unless field conditions allow otherwise, a setback distance of 25 to 50 feet from standing buildings will be observed during the survey to reduce interference to the operation of the survey equipment caused by the metal in the building structures and avoid permanent objects such as ground-mounted transformers or other objects that cannot be reasonably removed to survey underneath. Figures 1 - 8 present the preliminary target areas to be surveyed within each of the eight subareas inside USEPA's Study Area. It should be noted that preliminary target areas have been identified on these figures without accounting for terrain features, this adjustment will be made in the field by the survey team.

Should USEPA become aware of new information about locations that warrant survey work (i.e. a gamma radiation anomaly of concern, new information about the location(s) of potential buried material, etc), these areas will be surveyed in accordance with this plan.

This survey will involve using the three methods described below. Frequency-domain electromagnetic method (FDEM) (see Section 3.1) and a magnetometer (see Section 3.2) will first be applied in all areas shown in Figures 1 - 8. Ground penetrating radar (see Section 3.3.) will be applied in limited locations and where the survey results using the FDEM and/or magnetometer show an anomaly of concern that requires further resolution.

3.0 METHODOLOGY

Three methods are proposed to meet or exceed the project goals. These are frequency-domain electromagnetic, magnetic, and ground penetrating radar (GPR). The following provides a brief overview of each methodology.

3.1 FREQUENCY-DOMAIN ELECTROMAGNETIC METHOD

The FDEM is used to measure variations in subsurface electrical conductivity, referred to as terrain conductivity. With this methodology, potential buried materials are indicated at locations where subsurface terrain conductivity is significantly different than a normalized terrain conductivity of the area. Therefore, this methodology is commonly used to identify buried metal objects.

An FDEM instrument is composed of two coils, a transmitter and receiver coil, separated by a fixed distance (in this case). The transmitter coil transmits an alternating electromagnetic signal into the subsurface whose magnetic field component induces current flow, called eddy currents, into the ground. The strength of the eddy currents is directly proportional to the electrical properties of subsurface materials. The eddy currents in turn create a secondary magnetic field which is detected by the receiver coil, and transmitted to an instrument box, where readings are displayed and recorded. The FDEM instrument displays the quadrature component in units of milliSiemens/meter (mS/m), and the inphase component in parts per thousand.

Because these systems transmit at specific frequencies, the induced secondary field is also at that same frequency. A reference signal provides the amplitude of the transmitted signal and the difference between measured and reference amplitude is taken as the response due to the secondary, induced field. The readings consist of two components, the inphase and quadrature. The quadrature component is calibrated to measure terrain conductivity. This reading is a measure of the average bulk terrain conductivity sampled over a volume of earth to a maximum depth proportional to the coil spacing and transmission frequency of the instrument. The inphase component provides a measure of the "quality" of the conductive materials within the volume interrogated. It is essentially nulled over areas representing normal ranges of terrain conductivity, but over areas of buried metallic material, particularly ferrous metal, the readings become much more significant, and can either dip in the positive range or negative range. Hence, the inphase component becomes useful in locating buried metal objects, such as 55-gallon drums, metal pipelines, and subsurface metallic debris.

The FDEM method is useful for delineating subsurface waste burial areas and trenches since the buried materials (especially metallic), disturbed soil, and fill are likely to have electrical conductivity properties differing from the surrounding natural soil.

3.2 MAGNETIC METHOD

The magnetic method is used to locate buried ferrous material and objects at field investigation sites. Ferrous materials may include steel drums and containers, underground storage tanks, unexploded ordnance and pipe utilities, among others. The magnetic method involves the use of an instrument called a magnetometer. The magnetometer measures at one point in space a combination of the earth's magnetic field and a magnetic field caused by the presence of a ferrous object, such as a buried drum. The combination of the fields produces a definable and mappable signature, or footprint, called a magnetic anomaly. Certain features of the anomaly signature can be used to give a rough estimate of the depth below ground surface of the ferrous object and its relative size. It should be noted that because the magnetic signature is a combination of the earth's (ambient) field and the objects field, the effect of the earth's field, which varies in time, has to be removed from the measured response. This correction is monitored by occupying a base station with a stationary magnetometer in an area away from ferrous materials, and later subtracting these data from the data collected by the rover (field) magnetometer.

3.3 GROUND PENETRATING RADAR METHOD

The GPR methodology is a specialized electromagnetic (EM) technique. The GPR employs a pulsed, high frequency signal that is transmitted into the ground by an antenna that usually acts as both as transmitter and receiver (transceiver). The pulsed signal is reflected back to the transceiver antenna at an interface of subsurface materials with differing dielectric properties. As the antenna is moved along the surface, a profile record of the subsurface is produced. The profile record is very descriptive and understandable in that it will show soil and rock interfaces resembling a seismic record. The record has the dimensions of length in meters or feet versus time in nanoseconds. The recorded time is the duration of the pulsed signal from transmission to reception, so it is representative of a two–way path. The two-way travel time can be converted mathematically into depth below ground surface.

The GPR record over solitary objects (such as drums, tanks, and pipes) will give a characteristic hyperbolic or umbrella shaped reflection in the record superimposed on the horizontal or lithologic reflectors. A variety of antennas can be employed with frequencies ranging from less than 50 megahertz (MHz) to greater than 1 gigahertz (GHz). The trade-off between using higher and lower frequency antennas is resolution versus exploration depth. Typically, a range from 200 to 500 MHz is useful for field site investigations. GPR is useful to provide high resolution images of burial trenches, utilities, drums, and underground storage tanks, as well as soil stratigraphy and hydrogeologic features. The usefulness of GPR is limited by the dielectric properties of the subsurface materials and logistical considerations. In general, higher terrain conductivity materials such as silts and clays will preclude the use GPR because of high signal attenuation. Logistically, since the antenna needs to be nearly in contact with the ground surface, it is impractical to use this technology in rough or uneven terrain.

3.4 INSTRUMENTATION

The FDEM survey will employ the Geonics EM31-Short broadband terrain conductivity meter. The response characteristics of the standard EM31 are well-known in the geophysical survey industry, and yields stable and repeatable data. However, weight and dimensions make it difficult and impractical to use in rough, steep terrain. The EM31-Short has the same data advantages, but its shorter transmitter-to-receiver length makes it a better choice in difficult terrain, at the expense of some exploration depth. Vendor information for the FDEM equipment to be used for this project is provided in Appendix A.

The magnetic survey will employ the use of a Geonics G858 cesium vapor magnetometer as the rover, and the economical Geonics G856 proton precession magnetometer as the stationary or base magnetometer. These instruments are widely used in the industry and the G858 is readily integrated with global positioning system (GPS) navigation. Vendor information for this equipment is provided in Appendix A.

The Noggin 250 MHz smart cart self contained radar system will be deployed for the GPR survey. The 250 MHz antenna provides a good trade-off between exploration depth and resolution for field site investigations. The unit can be integrated with GPS. Vendor information for this equipment is provided in Appendix A.

All of the instruments will be integrated with a GPS for sub-meter positioning. HGL has an AG132 with Omnistar for this purpose. Vendor information for this equipment is provided in Appendix A.

3.5 INSTRUMENT FIELD TESTING

An evaluation test strip will be constructed in an undisturbed area, as shown in Figure 9, where a minimum of three targets (e.g. segments of 2-inch Sch 40 pipe) will be buried along straight 100-200 foot north-south line at depths of 2, 4, and 6 feet below ground surface. This test strip will be constructed near the magnetometer base station and be used during the course of the geophysical investigation to perform daily quality control instrument tests and calibrations.

The instrument field tests will be used to:

- Ensure data fidelity and utility of selected technologies.
- Demonstrate the effectiveness and limitations of using geophysical methods to identify and locate potential buried material.
- Test the limitations and capabilities of the instruments such as instrument target response versus background, effective line spacing, etc, and verify that the instruments are working properly.

3.6 SURVEY PROCEDURES AND DATA ACQUISITION

Selected areas of interest will be divided into manageable grids of approximately 100 feet by 100 feet. The four corners of the grid will be staked, and the north and south ends as well as a center tie-line will be marked at 5- or 10-foot intervals to define north-south trending traverse lines. Highway cones will be used to track lines as they are surveyed, and moved along by the operator and field assistant. Where possible, each survey will begin in the southwest corner, and proceed in alternating south-north and north-south directions. If north south lines are not practical, then the grid will be laid out in an alternative fashion, as judged appropriate. All gaps in the data due to obstructions and other reasons will be documented.

The approach of this survey will involve using the FDEM and magnetometer in all areas shown in Figures 1 – 8 by the cross-hatch pattern. The GPR will be applied in limited locations and where the survey results using Electromagnetic and Magnetic methods show an anomaly of concern that requires further resolution.

The data will be monitored on the instrument liquid crystal display screens as it is collected to identify noise issues. If noisy or incoherent data is observed, the operator will halt the collection and troubleshoot the problem. Data collection will resume when the problem is resolved and lines repeated as necessary. All instrument data and GPS data will be recorded concurrently in either an external or internal data logger, depending on the instrument configuration. At the end of the day, the data will be downloaded unto a laptop computer and checked for quality and GPS positioning. Areas of spurious or unaccounted data and data gaps will be flagged for re-survey.

3.7 INSTRUMENT QUALITY CONTROL

The following procedures will be performed to ensure repeatable and quality of the collected data:

- Instrument quality assurance (QA)/quality control (QC) and functional checks, and nulling of the EM-31 inphase component will be performed at a base station in a calibration area free of buried metal near the test strip. This will be done four times a day (morning before operations, noon before lunch break, and after lunch break, and after operations at the end of the day). To ensure that the exact same spot is being used, the base station will be marked with a 4-foot by 4-foot sheet of plywood with the center and four cardinal directions marked.
- Data from the instruments will be collected along the evaluation test strip (Section 3.5) twice a day (before operations and after operations) in both forward and reverse directions. This will ensure repeatability and reliability of the data.
- The impact of changing moisture conditions to terrain conductivity measurements due to rainfall is expected to be negligible. Nevertheless, it will be considered when performing daily quality control checks. Over the length of the investigation, calibration readings should not differ by more than 10 percent to be considered inconsequential in interpretation. The impact of changing soil moisture conditions will be corrected for if determined to be significant.
- Data from the QA/QC checks will be saved in dated files and archived.

3.8 DATA PROCESSING AND PRESENTATION

The data will be pre-processed using software specific to each instrument. The EM and magnetometer data will be exported into Geosoft XYZ files using the software tools, and the GPR data will be pre-processed and processed for presentation using software provided by

Sensors and Software, the Noggin manufacture. Geosoft Oasis Montaj will be used to convert the positioning of the EM and Magnetometer data into site utilized state plane coordinates. Montaj will be used to grid the data into geo-referenced color fill isopleth overlays using kriging or minimum curvature interpolation. The color fill overlays will be draped over site maps developed by the HGL GIS team for final presentation. GPR data will be presented as profile sections and time slice plan views.

3.9 REPORTS

A Technical Memorandum will be prepared and issued for each Historical Site Assessment subarea (e.g. HSA 5C) where geophysical survey work occurs. The Technical Memorandum will summarize survey results including a map of all locations surveyed and locations of potential buried materials.

3.10 SCHEDULE

The schedule below presents proposed start and completion dates of major tasks for the initial stages of the geophysical survey. USEPA will prepare a schedule for each phase of the survey work and provide periodic updates to its SSFL Stakeholders regarding the status of the survey work.

Task	Start Date	Completion Date
Stakeholder Notification	August 5	
Start Geophysical Survey in HSA 5C Area	August 9	August 20
Present Draft Geophysical Survey Results To Stakeholders	September 1	
Issue Draft Technical Memorandum for HSA 5C Area	September 17	

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FIGURES

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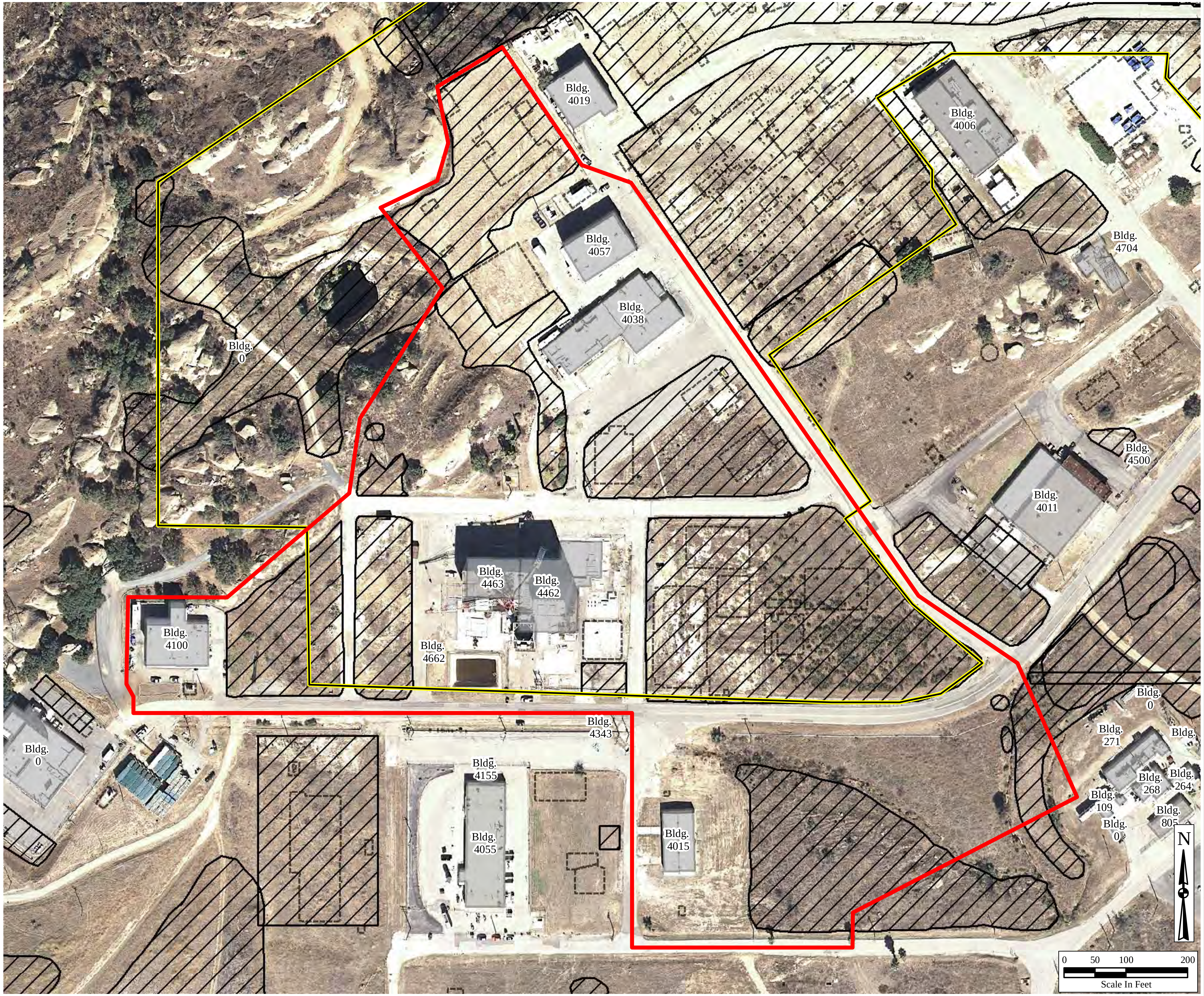

HGL—Santa Susana Field Laboratory
Site Ventura County, California

Figure 1
Preliminary Survey Target Areas of Interest
Former Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- **Preliminary Survey Target Areas of Interest**
- **Demolished Buildings**
- **Standing Buildings**
- **ETEC (Energy Technology Engineering Center)**
- **HSA-5C**

Filepath: Y/Santa_Susana/EP9038/Geophysical/PotentialGeophysicalTargets_5C.mxd
Project: EP9038
Edited By: TJansen 2010-08-04
Source: CIRGIS 2007, Boeing 2009, HGL 2010

HGL—Report Name Here, Santa Susana Field Laboratory Site Ventura County, California

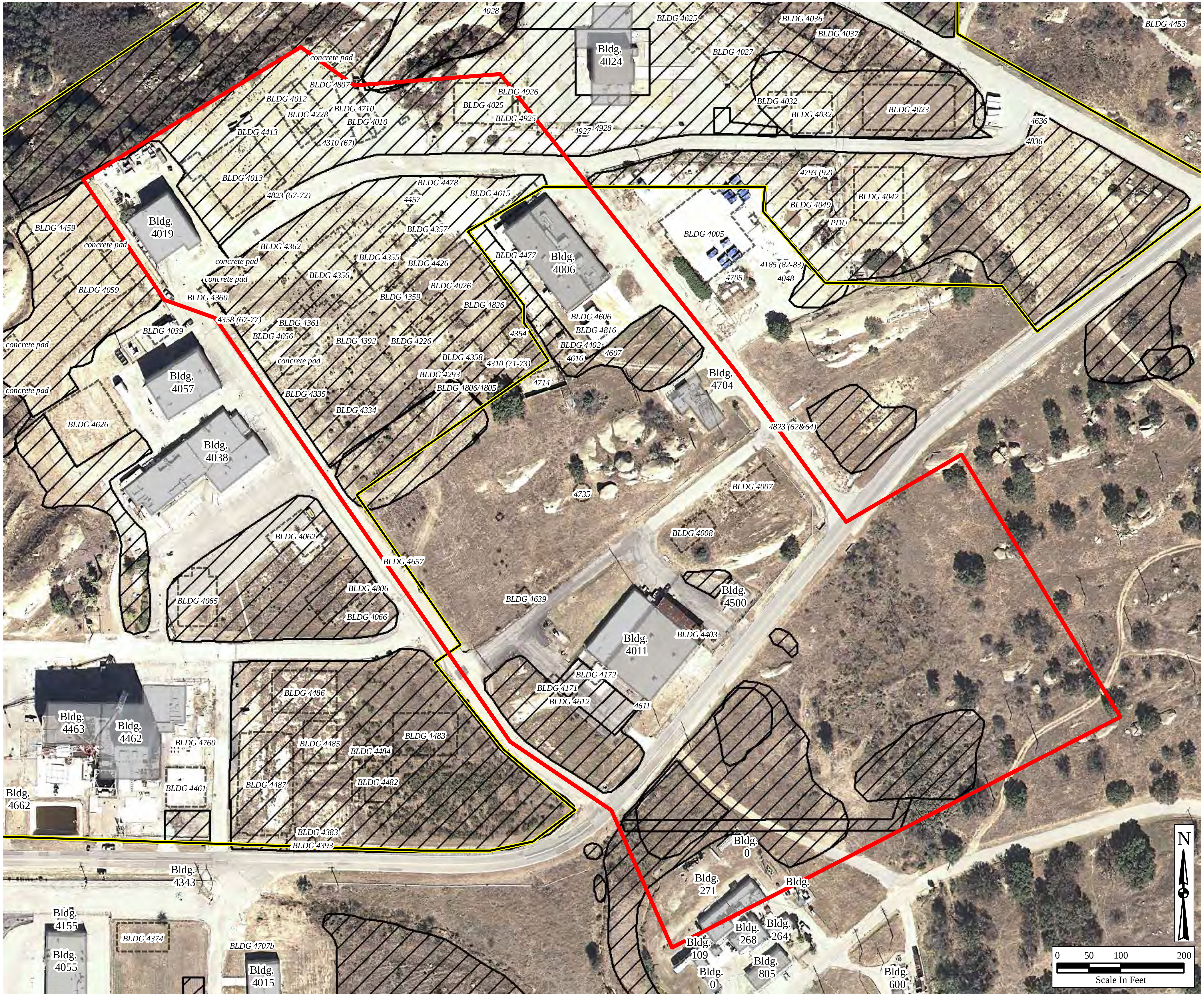

Figure 2
Preliminary Survey Target Areas of Interest
Former Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- **Preliminary Survey Target Areas of Interest**
- **Demolished Buildings**
- **Standing Buildings**
- **ETEC (Energy Technology Engineering Center)**
- **HSA-5B**

Filepath: Y/Santa_Susana/EP9038/Geophysical/PotentialGeophysicalTargets_5B.mxd
Project: EP9038
Edited By: TJansen 2010-08-04
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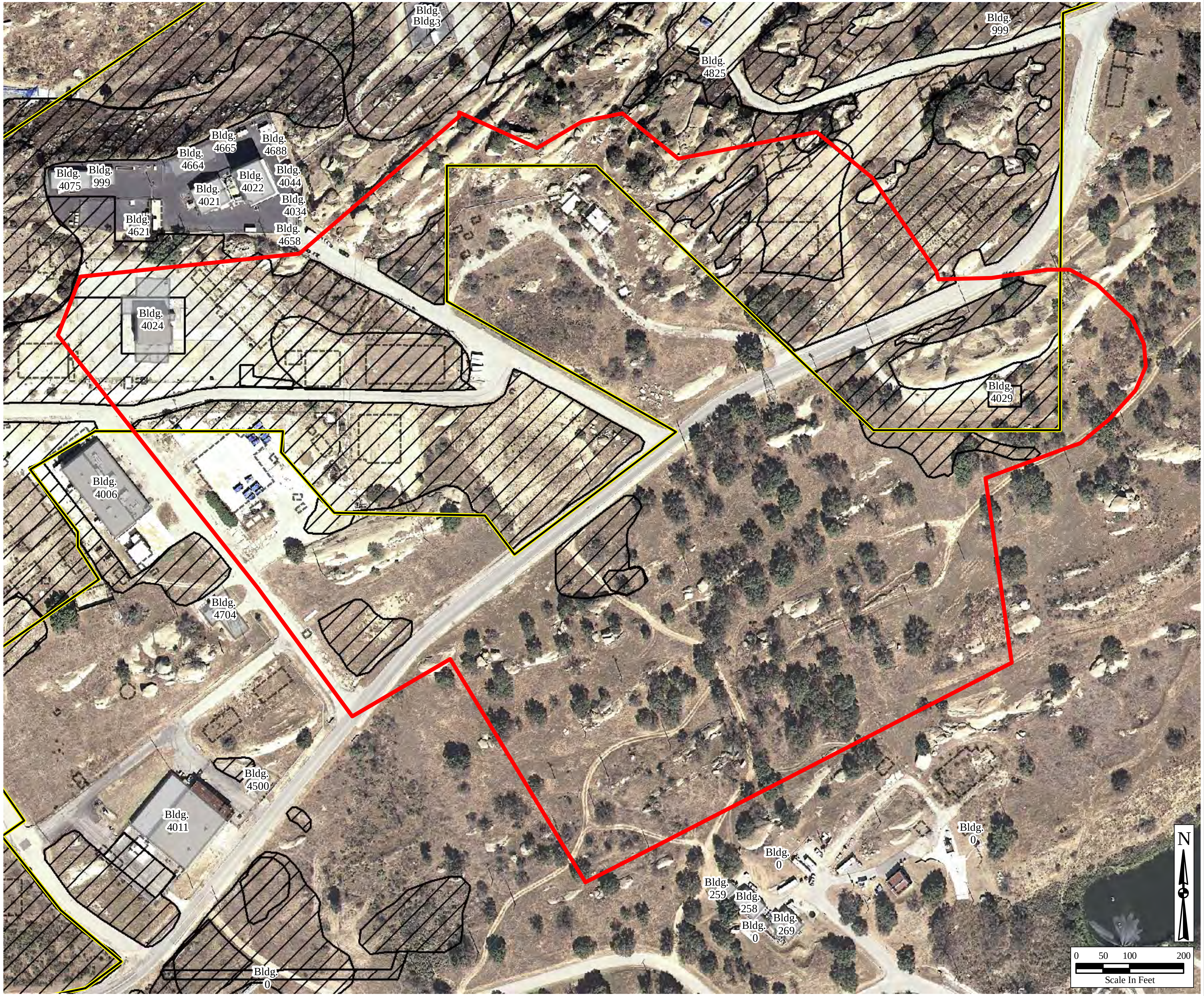
Figure 3
Preliminary Survey Target Areas of Interest
Former Santa Susana Field Laboratory

U.S. EPA Region 9



Legend

- Preliminary Survey Target Areas of Interest
- Demolished Buildings
- Standing Buildings
- ETEC (Energy Technology Engineering Center)
- HSA-5A

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Edited By: TJansen 2010-08-04
Source: CIRGIS 2007, Boeing 2009, HGL 2010

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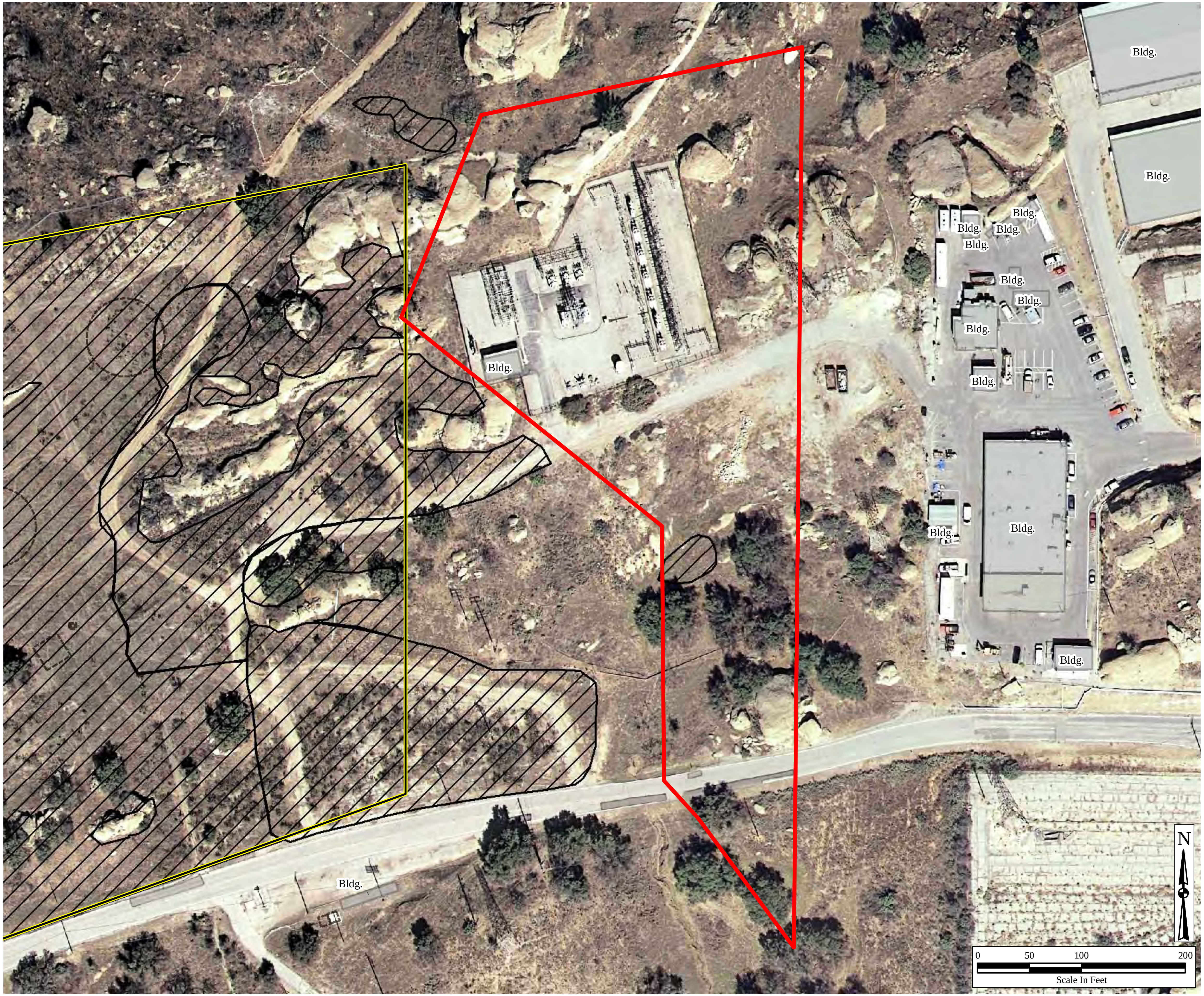

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Figure 4
Preliminary Survey Target Areas of Interest
Former Santa Susana Field Laboratory

U.S. EPA Region 9

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Legend

- **Preliminary Survey Target Areas of Interest**
- **Demolished Buildings**
- **Standing Buildings**
- **ETEC (Energy Technology Engineering Center)**
- **HSA-3**

Filepath: Y/Santa_Susana/EP9038/Geophysical/PotentialGeophysicalTargets_3.mxd
Project: EP9038
Edited By: TJansen 2010-08-04
Source: CIRGIS 2007, Boeing 2009, HGL 2010

HGL HydroGeoLogic, Inc

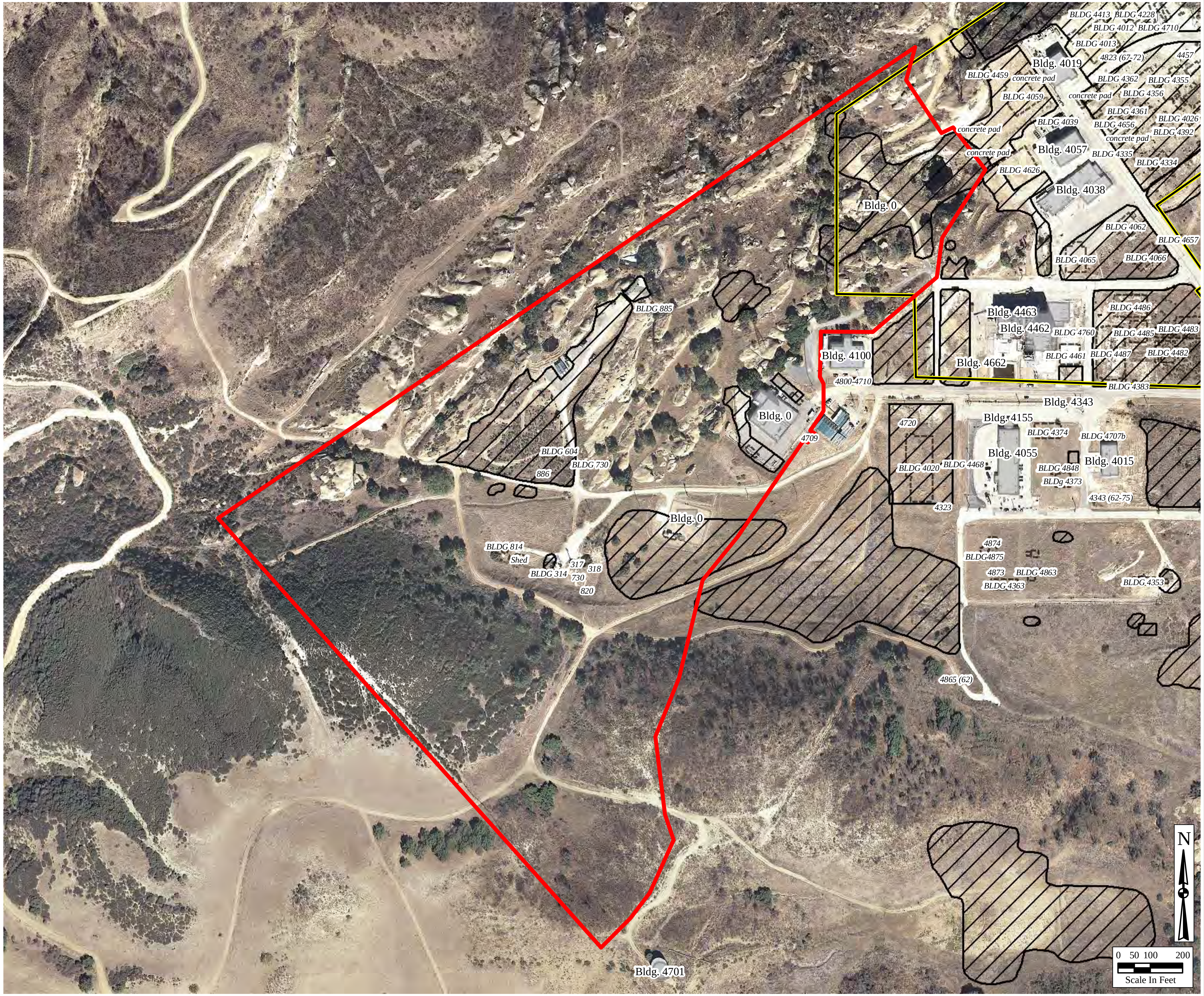

Figure 5
Preliminary Survey Target Areas of Interest
Former Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- Preliminary Survey Target Areas of Interest
- Demolished Buildings
- Standing Buildings
- ETEC (Energy Technology Engineering Center)
- HSA-8

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Project: EP9038
Edited By: TJansen 2010-08-04
Source: CIRGIS 2007, Boeing 2009, HGL 2010

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Figure 6
Preliminary Survey Target Areas of Interest
Former Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- Preliminary Survey Target Areas of Interest
- Demolished Buildings
- Standing Buildings
- ETEC (Energy Technology Engineering Center)
- HSA-7

Filepath: Y/Santa_Susana/EP9038/Geophysical/ PotentialGeophysicalTargets_7.mxd
Project: EP9038
Edited By: TJansen 2010-08-04
Source: CIRGIS 2007, Boeing 2009, HGL 2010

HGL HydroGeoLogic, Inc.

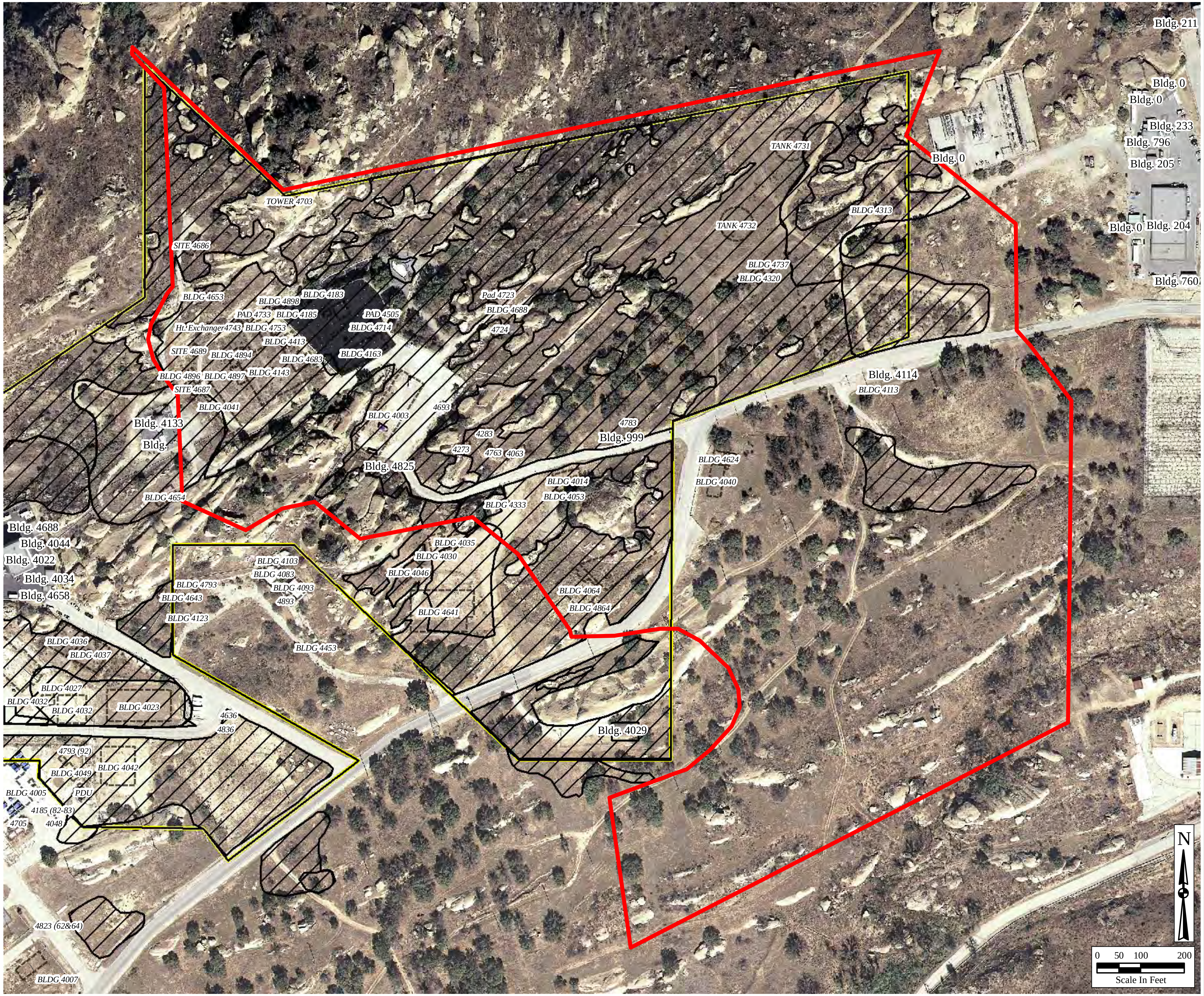

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Figure 7
Preliminary Survey Target Areas of Interest
Former Santa Susana Field Laboratory

U.S. EPA Region 9

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Legend

- Preliminary Survey Target Areas of Interest
- Demolished Buildings
- Standing Buildings
- ETEC (Energy Technology Engineering Center)
- HSA-6

Filepath: Y/Santa_Susana/EP9038/Geophysical/PotentialGeophysicalTargets_6.mxd
Project: EP9038
Edited By: TJansen 2010-08-04
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Figure 8
Preliminary Survey Target Areas of Interest
Former Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- **Preliminary Survey Target Areas of Interest**
- **Demolished Buildings**
- **Standing Buildings**
- **ETEC (Energy Technology Engineering Center)**
- **HSA-5D**

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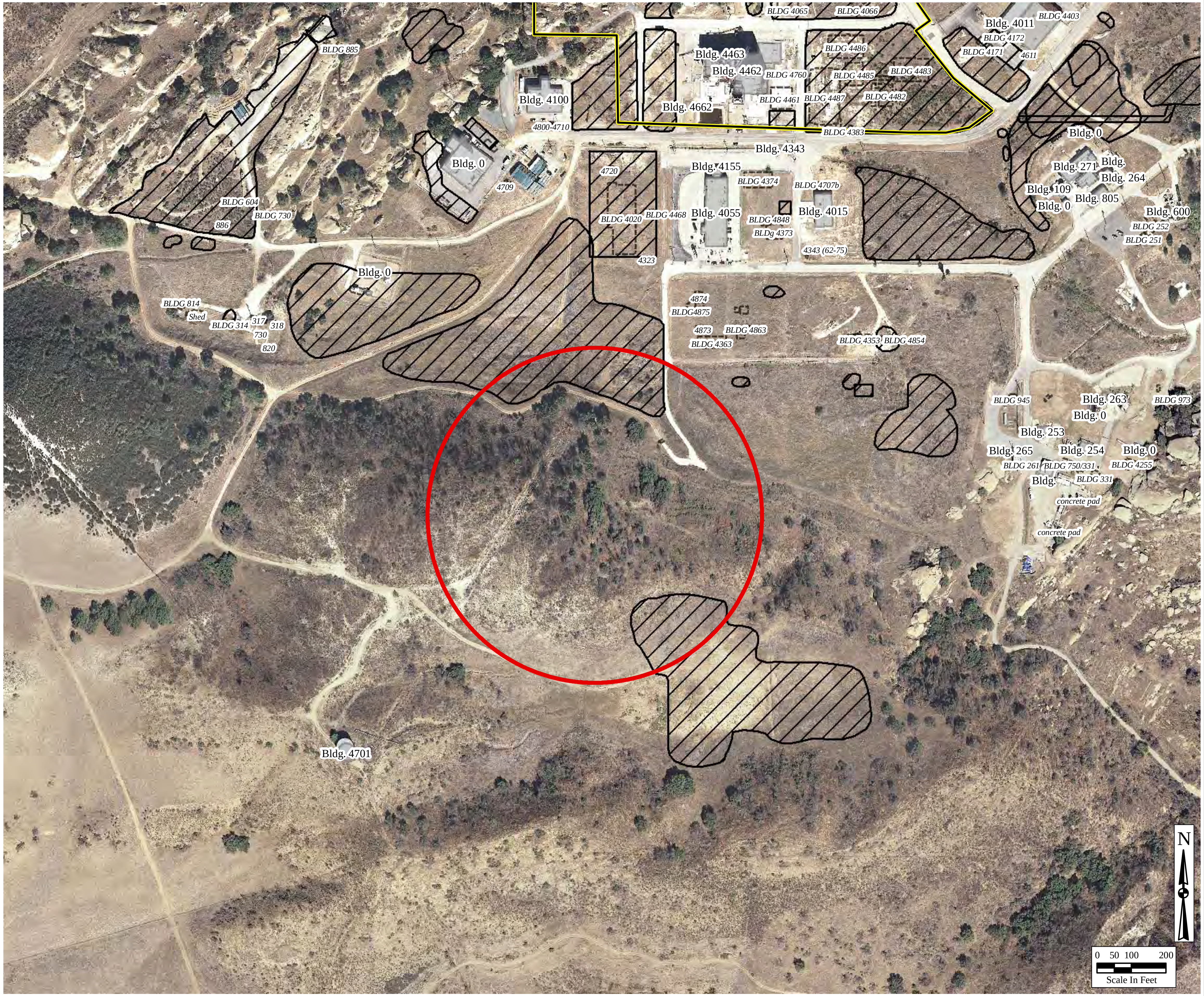
Source: CIRGIS 2007, Boeing 2009, HGL 2010

HGL HydroGeoLogic, Inc



HGL—Report Name Here, Santa Susana Field Laboratory Site Ventura County, California

Figure 9
Proposed Equipment Calibration Area
Former Santa Susana Field Laboratory

U.S. EPA Region 9

Legend

- **Preliminary Survey Target Areas of Interest**
- **Demolished Buildings**
- **Standing Buildings**
- **ETEC (Energy Technology Engineering Center)**
- **Proposed Equipment Calibration Area**

Filepath: Y/Santa_Susana/EP9038/Geophysical/ PotentialGeophysicalTargets_BackgroundLocation.mxd
Project: EP9038
Edited By: TJansen 2010-08-04
Source: CIRGIS 2007, Boeing 2009, HGL 2010

HGL HydroGeoLogic, Inc

APPENDIX A

VENDOR INFORMATION FOR GEOPHYSICAL INSTRUMENTS

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The FDEM survey will employ the use of a Geonics EM31-Short broadband terrain conductivity meter (Fig. 1). Vendor information for the FDEM equipment to be used for this project is provided below. (www.geonics.com).

Geonics EM31-Short

MEASURED QUANTITIES

1. Apparent conductivity in millisiemens per meter (mS/m).
2. In-phase ratio of the secondary to primary magnetic field in parts per thousand (ppt).

PRIMARY FIELD SOURCE

Self-contained dipole transmitter

SENSOR

Self-contained dipole receiver

INTERCOIL SPACING

2 meters

OPERATING FREQUENCY

9.8 kHz

POWER SUPPLY

8 disposable alkaline “C” cells (approximately 20 hours of continuous power)

MEASURING RANGES

Conductivity: 10, 100, 1000 mS/m; In-phase: ± 10 ppt

MEASUREMENT RESOLUTION

±0.1% of full scale

MEASUREMENT ACCURACY

±5% at 20 mS/m

NOISE LEVELS

Conductivity: 0.1 mS/m; In-phase: 0.008 ppt

DATA STORAGE

10,000 records (2 components); 16,500 records (1 component) [extended memory available]

DIMENSIONS

Boom: 2.3 m extended; Shipping Case: 145 x 38 x 23 cm

WEIGHTS

Instrument: 9 kg; Shipping: 21 kg

Figure 1. Geonics EM31-Short instrument in field carrying position.

The magnetic survey will employ the use of a Geonics G858 cesium vapor magnetometer (CVM) (Figs. 2 and 3) as the rover, and the economical Geonics G856 proton precession magnetometer (PPM) (Figs. 4 and 5) as the stationary or base magnetometer. Vendor information is provided below.

(http://www.kdjonesinstruments.com/LinkClick.aspx?fileticket=ei9F16W8dmU%3d&tabid=5125).

Geonics G858 Cesium Vapor Magnetometer (CVM)

MAGNETOMETER/ELECTRONICS

Operating Principle: Self-oscillating split-beam Cesium Vapor (non-radioactive Cs-133) with automatic hemisphere switching. Operating Range: 17,000 nT to 100,000 nT Operating Zones: For highest signal-to-noise ratio, the sensor long axis should be oriented at 45', ±30' to the earth's field angle, but operation will continue through 45', ±35'. Sensor is automatic hemisphere switching. Sensitivity: 90% of all reading will fall within the following Peak-to Peak envelopes: 0.05 nT at 0.1 sec cycle rate, 0.03 nT at 0.2 sec cycle rate, 0.02 nT at 0.5 sec cycle rate, 0.01 nT at 1.0 sec cycle rate.

Information Bandwidth: < 0.004 nT / √HzRMS)

Heading Error: < ± 1 nT

Gradient Tolerance: > 500 nT / inch >20,000 nT / meter

Temperature Drift: 0.05 nT per 'C

Cycle Rate: Variable from 0.1 sec to 1 hr in 0.1 sec steps or by external trigger.

Data Storage: Nonvolatile RAM with capacity for 8 hrs of Magnetometer time, event marks, field notes, location, or 3 hrs of Gradiometer and GPS at maximum sample rates.

Audio Output:

1. Audio tone of earth's field variation, pitch and volume adjustable. (Search)

2. Audio pulse each 1 second (Pace metronome).

3. Alarm for loss of signal, low battery or Quality Control setting exceeded

Data Output: Three wire RS232 standard serial port, optional continuous real time transmittal of data via RS232 to PC. Total memory output transfer time less than 5 minutes at 115,200 KBaud.

Visual Output: 320x200 graphic liquid crystal display, daylight visible with selectable outputs for:

1. Data display: Up to 5 stacked profiles, real time or review mode. Survey grid shows boundaries and position.

2. All system setup functions, e.g., memory status, data transfer, sample time.

3. All Survey setup functions, e.g., survey profile number and direction, station or GPS number, test line number.

4. Survey monitoring functions, e.g., total field, noise level, profile number x or x-y coordinates.

5. System diagnostics e.g., lamp brightness, signal level, battery state.

Internal Clock: Resolution of 0.1 sec, drift: < I sec/day

Battery Life:

1. 12 VDC rechargeable gel cell, 6 hrs Magnetometer or 3 hrs Gradiometer usage. Magnetic effect less than I nT at 4 ft.

2. Internal backup battery for clock and non-volatile RAM

Software is supplied as part of the basic system and including functions for:

Operating Software:

1. Survey Modes:

    A) Search survey, B) Simple survey, C) Map survey, and D) Base station.

2. Data acquisition/ display:

    A) Acquire and store data and survey functions, B) Display profiles, total field to 0.1 nT resolution, gradient (differential) to 0.1 nT, survey/map parameters and diagnostics.

PC Support Software for installation on customer or Geometrics-supplied data processing computer:

1. Data transfer and corrections:

    A) Transfer of data from the field Magnetometer, Gradiometer, Differential GPS, or Base station to PC, B) Diurnal correction using base station data, C) Processing the corrected data into ASCII values of XYZ for the magnetometer and/or X, Y, ZI, Z2, Z3 for the gradiometer.

2. Optional bundled "Surfer for Windows" by Golden provides data presentation/plotting into a contour map or 3D isomagnetic map with text annotation and color blends.

MECHANICAL

Sensor: 23/8" dia., 63/4" long, 12 ounces (6cm x 15 cm, 340 grams) Staff/Harness: Staff for Magnetometer or Gradiometer, 1.5 lb to 2.5 lb (0.9 kg to 1.1 kg). Nylon chest harness with cables attached, 2 lb to 3 lb (1 kg to 1.3 kg) Battery: 3" H, 5" W, 8" *L,* 3.5 lbs (8 cm x 13 cm x 20 cm, 1.6 kg) attaches to harness. Console: 6" W, 3" H, 11" *L,* 3.5 lbs. (15 cm x 8 cm x 28cm, 1.6 kg), attaches to harness. Magnetic effect less than I nT at 4 feet.

ENVIRONMENTAL

Operating Temperature: -25°C to +50°C (-13°F to +122°F), Storage Temperature: -35°C to +60°C (-30°F to +140°F) Water Tight: To 3 ft (0.9 m) depth Shock: Drop 3 ft on a hard surface without damage.

OPTIONS

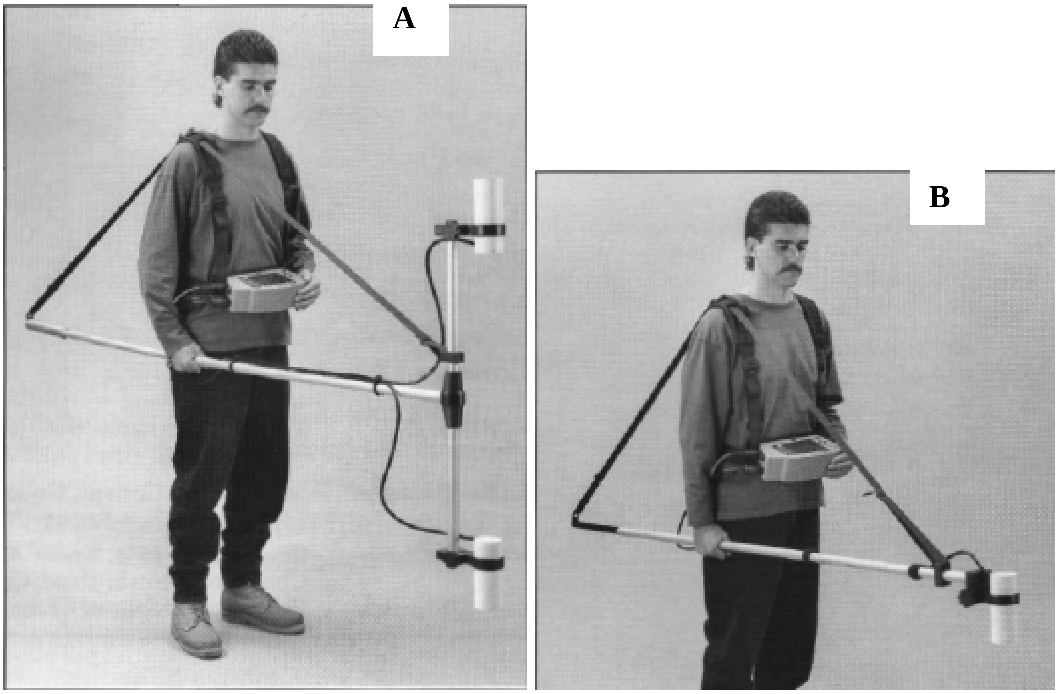
1. Gradiometer, horizontal and/or vertical configuration.

2. GPS navigation (real time differential with radio link to GPS base station or FM-transmitted RTCM codes).

3. MagAID Anomaly Identification Software, for use in estimating position, size and depth of source bodies and buried objects.

Figure 2. Geonics G-858 Console.

Figure 3. Complete G-858 instrument gradiometer with sensors in the vertical position (A) and held in normal field carry position (B).



Geonics G856 Proton Precession Magnetometer (PPM)

RESOLUTION
0.1 nT

ACCURACY
0.5 nT

CLOCK
Julian date, accuracy 5 sec per month.

TUNING
Auto or manual, range 20,000 to 90,000 nT.

GRADIENT TOLERANCE
1000 nT/meter

CYCLE TIME
3 to 999 second standard, can be manually selected as fast as 1.5 sec cycle time.

READ

Manual, or auto cycle for base station use.

MEMORY

5700 field or 12500 base station readings.

DISPLAY

Six digit display of field/time, three digit auxiliary display of line number and day.

DIGITAL OUTPUT

RS-232, 9600 baud.

INPUT

Will accept external cycle command.

PHYSICAL

Console: 7 x 10.5 x 3.5 inches, (18 x 27 x 9 cm) 6 lbs (2.7 kg); Sensor: 3.5 x 5 inches (9 x 13 cm) 4 lbs (1.8 kg).

ENVIRONMENTAL

Meets specifications within 0E to 40EC (32E to 105EF). Will operate satisfactorily from -20E to 50EC (-4E to 122EF).

POWER

9 each 1.5 “D” Cells.

STANDARD ACCESSORIES

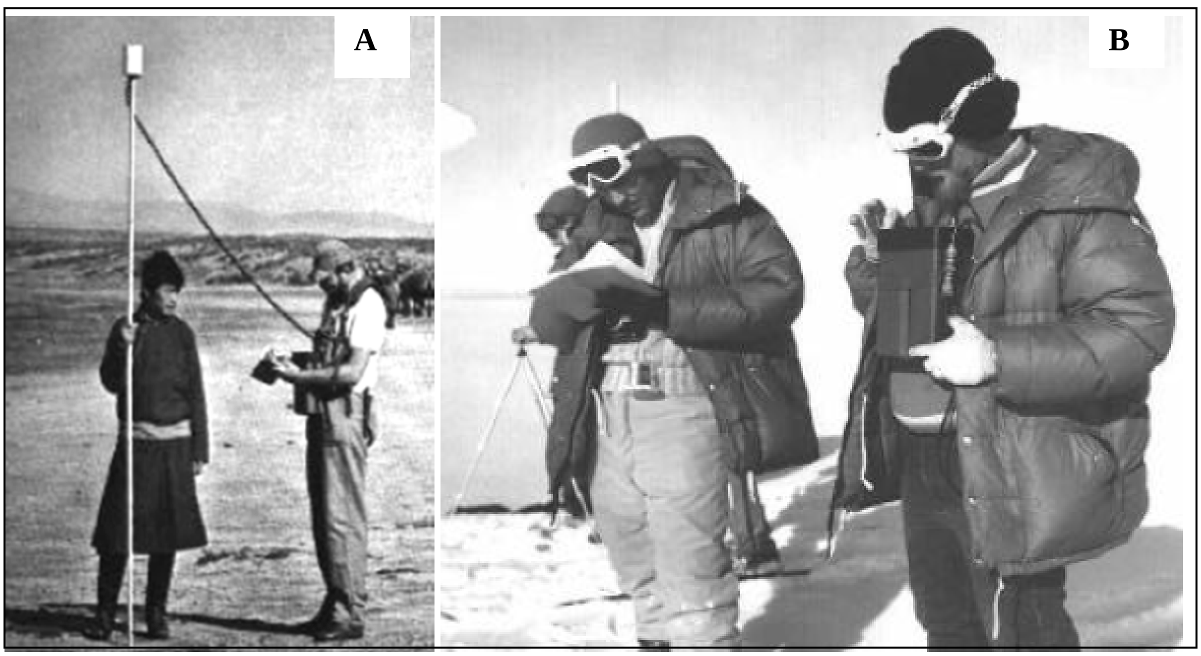
Sensor, staff, chest harness, two sets of batteries, RS-232 cable, operations manual, applications manual, and MagMap96 software.

OPTIONS

Gradiometer attachment, external power/sensor cable, external power/RS-232/sensor cable, rechargeable battery and charger set.

Figure 4. Geonics G-856 console.

Figure 5. Geonics G-856 Instrument being utilized in field investigations in Tibet (A) and the Arctic (B).



The Noggin 250 MHz smart cart self contained radar system (Fig. 6) will be deployed for the GPR survey. Vendor information for this equipment is provided below. www.sensoft.ca

Noggin 250 MHz Smart Cart Self-Contained Radar System

SIZE

25 x 16 x 9 inches (63 x 41 x 23 cm)

WEIGHT

16 lbs (7.3 kg)

POWER

8 watts/ 12 V @ 0.7A DC

PERFORMANCE FACTOR

＞160 dB

TRANSDUCER PATENTED DIPOLE

125 - 375 MHz

SHIELDING FRONT TO BACK

＞20dB

NOGGIN TO PC

115KB, RS232

DEFAULT DEPTH WINDOWS (USER DEFINABLE)

2.5, 5, 7.5, 10, 15m (50, 100, 150, 200, 300ns)

AQCUISITION RATE (DEPENDS ON CONTROL SYSTEM)

100,000 samples/sec

PC & DVL OUTPUT

Digital image in .PCX format

DVL OUTPUT

Digital (raw) 16 bit 2's complement

INTEGRATED GPS

Point mark or continuous recording

OPERATING TEMPERATURE

-40 to 40°C

ENVIRONMENTAL

IP66

Figure 6. Noggin 250 Smart Cart in field use.

All of the instruments described in this Appendix will be integrated with a Trimble AG132 GPS with sub-meter accuracy (Fig. 7). Vendor information is provided below.

(http://trl.trimble.com/docushare/dsweb/Get/Document-9665/Ag124_132RevC1.pdf).

Trimble AG132 GPS

INSTRUMENT FEATURE

- 12-channel GPS receiver
- L-Band satellite differential correction receiver
- Dual-channel digital medium frequency beacon receiver
- Two programmable RS-232 serial ports: NMEA-0183 output/RTCM SC104 input
- Operation manual
- Magnetic mount for antenna
- Sub-meter differential accuracy
- 2 line, 16 character liquid crystal display 4 button keyboard
- Combined L1 GPS, satellite differential and beacon antenna
- 5 meter ruggedized antenna cable,
- Standard cable, GPS receiver to PC cable
- TSIP Interface Protocol I/O

PHYSICAL CHARACTERISTICS

AgGPS 132 Housing

Size - 14.5cm W x 5.1cm H x 19.5cm D
Weight - 0.76kg
Power - 7W (max), 10 to 32 VDC
Operating Temp - -20°C to +65°C
Storage Temp - -30°C to +85°C
Humidity - 100% condensing, unit fully sealed
Casing - Dust proof, waterproof, shock resistant

Combined Antenna

Size - 15.5cm D x 14cm H
Weight - 0.55kg
Operating Temp - -30°C to +65°C
Storage Temp - -40°C to +85°C
Humidity - 100% condensing, unit fully sealed
Casing - Dust proof, waterproof, shock resistant

PERFORMANCE CHARACTERISTICS

GPS Receiver

General - 12-channel, parallel tracking, L1 C/A code with carrier phase filtered measurements and multi-bit digitizer
Update rate - 1 Hz standard; 10 Hz optional
Differential speed accuracy - 0.16 km/h

Differential position accuracy - Less than 1 meter horizontal RMS. At least 5 satellites, PDOP <4 and RTCM SC-104 standard format broadcast from a Trimble 4000RS or equivalent reference station.
Time to first fix - <30 seconds, typical

Figure 7. Trimble AG132 GPS instrument drawing (A) and back panel of receiver (B).