GEOPHYSICAL INVESTIGATION

Luck Stone Corporation
Proposed Edgefield Site
Edgefield, South Carolina

Prepared for:
S&ME, Inc.
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January 20, 2023
Revised January 24, 2023

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1.0 INTRODUCTION

1.1 BACKGROUND

The project site, located in Edgefield, South Carolina is undergoing preparations for development of a proposed rock quarry (**Figure 1**). As part of the site geotechnical investigation, S&ME, Inc. contracted with THG Geophysics, Ltd. to perform a series of geophysical surveys to investigate the subsurface of the site. The objective of this investigation was to image the subsurface of the site for potential bedrock fractures.

1.2 WORK SCOPE

THG collected eight (8) very low frequency (VLF) electromagnetic survey profiles and four (4) 2-D electrical resistivity (EI) profiles at the site (**Figure 2**). VLF was chosen as the best method to image the site based on its exceptional ability to locate bedrock fractures and its efficient data collection and high resolution. EI was chosen to supplement the characterization of fractures in the shallow subsurface. Geophysical data were collected January 6-9, 2023.

2.0 GEOPHYSICAL INVESTIGATION

2.1 ELECTRICAL IMAGING THEORY

2.1.1 Introduction

Electrical resistance is based upon Ohm's Law:

$$R = \frac{V}{I} \quad [ohms]$$

Where, resistance, **R**, is equal to the ratio of potential, **V** (volts) to current flow, **I** (amperes).

Resistivity is the measure of the resistance along a linear distance of a material with a known cross-sectional area. Consequently, resistivity is measured in Ohm-meters. This report presents the geophysical results as geo-electrical profiles of modeled resistance plotted as 2-dimensional profiles of distance and depth, in units of feet.

Electrical currents propagate as a function of three material properties (1) ohmic conductivity, (2) electrolytic conductivity, and (3) dielectric conductivity. Ohmic conductivity is a property exhibited by metals. Electrolytic conductivity is a function of the concentration of total dissolved solids and chlorides in the groundwater that exists in the pore spaces of a material. Dielectric conductivity is a function of the permittivity of the matrix of the material. Therefore, the matrix of most soil and bedrock is highly resistive. Of these three properties, electrolytic conductivity is the dominant material characteristic that influences the apparent resistivity values collected by this method. In general, resistivity values decrease in water-bearing rocks and soil with increasing:

a. Fractional volume of the rock occupied by groundwater;
b. Total dissolved solid and chloride content of the groundwater;
c. Permeability of the pore spaces; and,
d. Temperature.

Materials with minimal primary pore space (i.e., limestone, dolomite) or those which lack groundwater in the pore spaces will exhibit high resistivity values (Mooney, 1980). Highly porous, moist, or saturated soil will exhibit very low resistivity values.

In homogeneous ground, the apparent resistivity is the true ground resistivity; however, in heterogeneous ground, the apparent resistivity represents a weighted average of all formations through which the current passes. Many electrode placements (arrays) have been proposed (for examples see Reynolds, 1997); however, the Schlumberger array has proven to be an effective configuration for imaging bedrock. The following Schlumberger array was used in the collection of data:

$$R_i = \frac{\pi a^2}{b}\left[1 - \frac{b^2}{4a^2}\right]R; \; a = 5b$$

Where, $\boldsymbol{R_i}$, resistivity, is related to the number of poles, ***n***, the separation distance between the current source and current sink ***b***, and the pole spacing, **a**.

2.1.2 Methods

The resistivity survey was performed using the ARES II multi-electrode cable system (GF Instruments, s.r.o., Brno, Czech Republic). The survey was conducted using stainless steel electrodes and passive multi-electrode cables with switch boxes. The locations of all 1seven EI profiles were recorded in the field using a Trimble Geo-7XH global positioning system (GPS).

2.1.3 PROCESSING

A forward modeling subroutine was used to calculate the apparent resistivity values using the EarthImager2D program (AGI, 2002). This program is based on the smoothness-constrained least-squares method (deGroot-Hedlin and Constable, 1990; Loke and Barker, 1996). The smoothness-constrained least-squares method is based upon the following equation:

$$J^T g = (J^T J + \mu F) d$$

Where, **F** is a function of the horizontal and vertical flatness filter, **J** is the matrix of partial derivatives, **μ** is the damping factor, **d** is the model perturbation vector, and **g** is the discrepancy vector.

The EarthImager2D program divides the subsurface 2-D space into a number of rectangular blocks. Resistivities of each block are then calculated to produce an apparent resistivity pseudo section. The pseudo section is compared to the actual measurements for consistency. A measure of the difference is given by the root-mean-squared (rms) error.

2.2 Very Low Frequency Electromagnetics

The VLF method can be used to find steeply dipping structures that differ from their surroundings with regard to electrical conductivity. VLF transmitters send out low frequency military radio signals (15-30 kHz). When the low frequency field emitted by one of the transmitters strikes an anomaly, secondary currents are created that can be read and recorded by the WADI VLF instrument. The VLF transmitter located in Cutler, Maine, was used for this survey and maintained acceptable average signal strength of 20.

When a field emitted by a transmitter strikes a body having low electrical resistance, secondary circuits are created in the body. Fraser filtering, a numeric algorithm is performed on the real part of the VLF data to enhance the anomaly indication. Fraser filtering is based upon the work of Karous and Hjelt (1983):

$$F_o = -\,0.102\, H_{-3} + 0.059\, H_{-2} - 0.561\, H_{-1} + H_0 + 0.561\, H_1 - 0.059\, H_2 + 0.102\, H_3$$

Where; F_0 is the filtered result and H-3 to H3 are the original VLF data.

Eight VLF profiles were collected using an ABEM WADI VLF meter **(Figure 2).** Data were processed using Ramag VLF modeling software and locational data was collected using a Trimble GEO-7XH GPS.

2.3 QUALITY ASSURANCE AND CONTROL

The interpretation of geophysical data is not an exact science since responses to induced disturbance are affected by many phenomena including buried metals, operator error, precipitation, and net changes in ground saturation conditions. Some sources of spurious data can be overcome through a QA/QC program and use of multiple geophysical methods. The quality control program employed with this study included frequent checks of the equipment and daily calibrations. The QA/QC program indicates that all geophysical equipment functioned as designed during the survey.

3.0 GEOLOGY

The site is regionally located in the Western Piedmont region of South Carolina. The bedrock, known as the Savannah River terrain, is characterized as a suite of metamorphic tectonites consisting mainly of migmatitic gneiss and schist and metasedimentary rocks. The most common rock types include biotite-amphibole paragneiss, sillimanite schist, and quartzite (SCDNR, 2023).

4.0 GEOPHYSICAL ANALYSES

4.1 INTRODUCTION

Eight (8) VLF profiles were collected across the site in an orthogonal orientation (south-north and west-east). In order to efficiently survey the entire approximately 385-acre site, parallel VLF profiles were spaced approximately 600-1,000 feet from one another **(Figure 2).** The VLF profiles imaged to a depth of 300 feet below grade; however, this does not take into account topography.

VLF Profiles 1-4 were acquired in approximately south to north orientation and Profiles 5-8 were acquired in an approximately west to east orientation (**Figure 2**). All profiles were collected using a 32-foot (10-meter) station separation.

In addition to fractures, anomalies can be generated by cultural sources. For example, power lines, subsurface utilities and metal fencing can also cause very strong anomalies. One subsurface pipeline was identified running approximately west-east along the northern portion of the site; however, all VLF profiles were terminated before crossing the pipeline. The VLF data quality is very good.

Electrical imaging data were collected at four (4) locations across the site. Profiles were positioned and oriented to image strong VLF fractures. Each profile was collected using a 3-meter (9.84 feet) electrode spacing in various cable configurations (**Figure 3**). The resulting 2-D profiles were able to image to depths of 60 feet below grade; however, strong elevation variations across the site limited the penetration depth of some EI profiles. Additionally, dense vegetation and steep terrain limited the viable locations for EI testing **(Figure 2).**

Generally, individual geologic units have a common apparent resistivity value. Low apparent resistivity values are typically associated with soils, saturated materials, and highly weathered bedrock; whereas, high apparent resistivity values are associated with rock (also increasing with rock competence). Clay materials can exhibit a range of apparent resistivity from 1-20 Ohm-m, sand can exhibit a range from 20-200 Ohm-m, and metamorphic units can exhibit a range from 10-5,000 Ohm-m.

4.2 DISCUSSION

Numerous fractures are interpreted to exist within the site footprint (**Figure 2**). The site is characterized by having a regional north-south fracture located to the west of the property. The VLF data indicate that a series of southwest-northeast fractures are interpreted to cross the entire site.

Locally a graben fracture system was located along VLF Profile 2. These features are generally excellent for groundwater production; however, proposed boring B-4 is listed as 4^{th} in potential for groundwater production as the first three (3) proposed boring locations are supported with EI profiles (**Figures 2 and 3**). Proposed boring B-3 is interpreted to intercept a vertical fracture.

Fractures were positioned on the map based on where they would theoretically intercept the ground surface. All interpreted fractures are located within the proposed pit and/or plant areas of the proposed quarry. Most of the interpreted fractures extend across the entire site (**Figures 2 and 3**).

Apparent resistivity values at the project site range from approximately 10 to 100 Ohm-m; consistent with the geology of the site. Ground conditions were variable from location to location; ranging from metamorphic rock such as gneiss to sandy, silty and clayey soils. EI profiles were positioned to image deeper portions of strong VLF anomalies, consistent with depths likely reached during anticipated geotechnical drilling. The locations of interpreted fractures from EI profiles correlate well with the locations and interpreted dip of VLF-interpreted fractures (**Figures 2 and 3**).

Based on the results of this geophysical investigation, eight (8) proposed well locations have been identified. Three (3) proposed locations were chosen based on the EI fractures and the strongest VLF anomalies (Locations B-1, B-2, and B-3; **Figure 2**). Additionally, five (5) additional well locations, based solely on the VLF profiles, were identified (B-4, B-5, B-6, B-7, and B-8; **Figure 2**).

5.0 CONCLUSION

Two geophysical (VLF and EI) methods were used to identify subsurface fractures at the Edgefield, South Carolina site. The interpreted fractures at the Edgefield site trend southwest to northeast (**Figure 2**). Fracture dips were interpreted in both directions perpendicular, respectively, to the trend of a fracture.

Eight (8) proposed drilling locations were identified across the site; three (3) are supported by EI and VLF interpretations while five (5) additional locations are supported by VLF profile interpretation. Considering VLF anomaly strength and locations of EI anomalies, proposed drilling locations were limited to the pit and plant area.

6.0 REFERENCES

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deGroot-Hedlin, C. and Constable, S. (1990), Occam's inversion to generate smooth, two-dimensional models from magnetotelluric data. Geophysics, V. 55, 1613-1624.

Karous and Hjelt (1983). Linear filtering of VLF dip-angle measurements: Geophysical Prospecting, v. 31, p. 782-794.

Loke, M. N., and Barker, R. D. (1996). Rapid least-squares inversion of apparent resistivity pseudosection by quasi-Newton method. Geophysical Prospecting, V. 44, 131-152.

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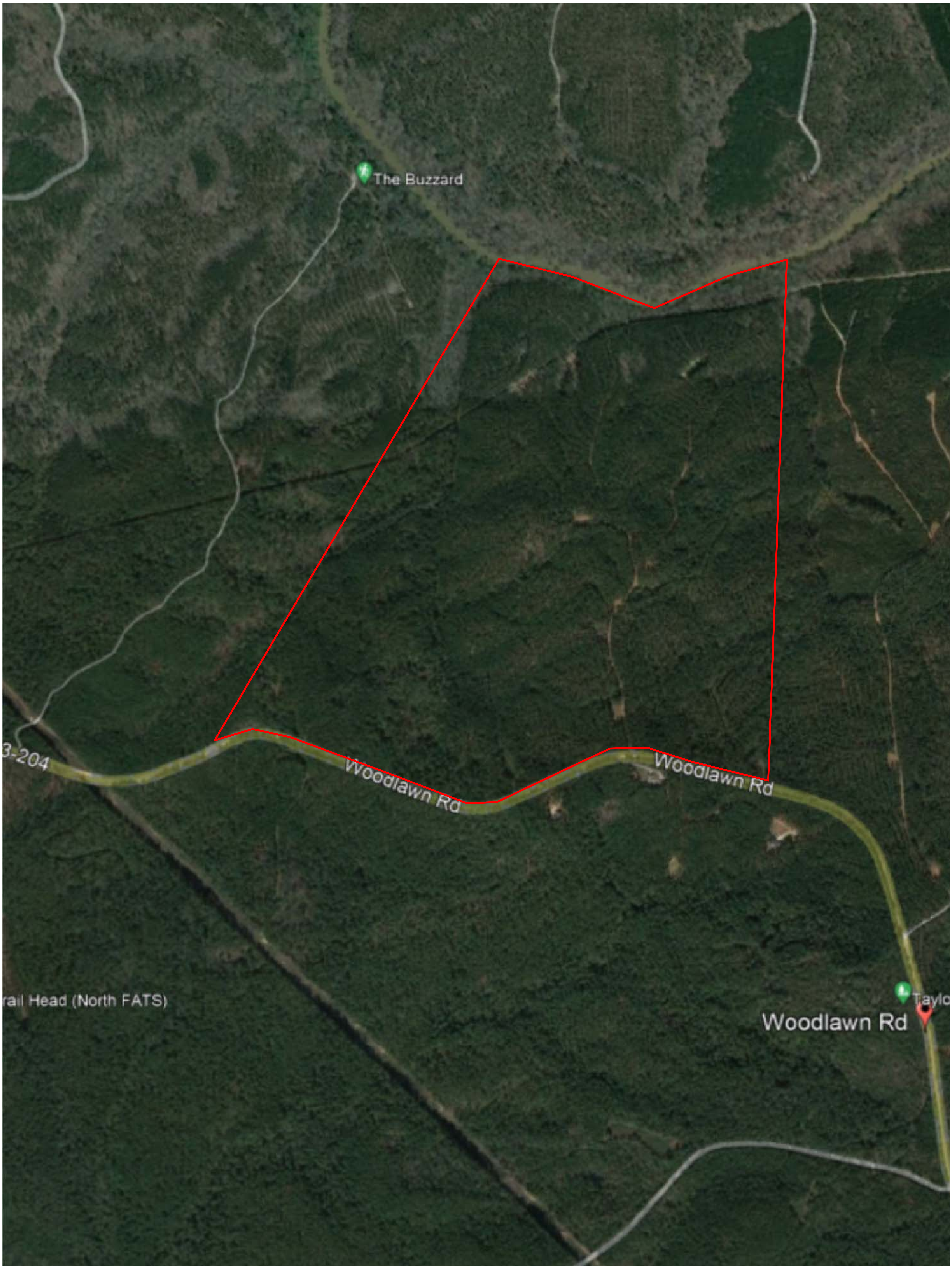

Legend

Survey Area

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CHK	PJH	1/21/2023
REV		
PROJ. MGR.	MLT	1/21/2023

SCALE: Not to Scale

SOURCE: Google Earth, 2022

PROJECT:

Geophysical Survey
Proposed Luck Stone Quarry
Edgefield, South Carolina

DRAWING NO.:

Figure 1
Site Location Map

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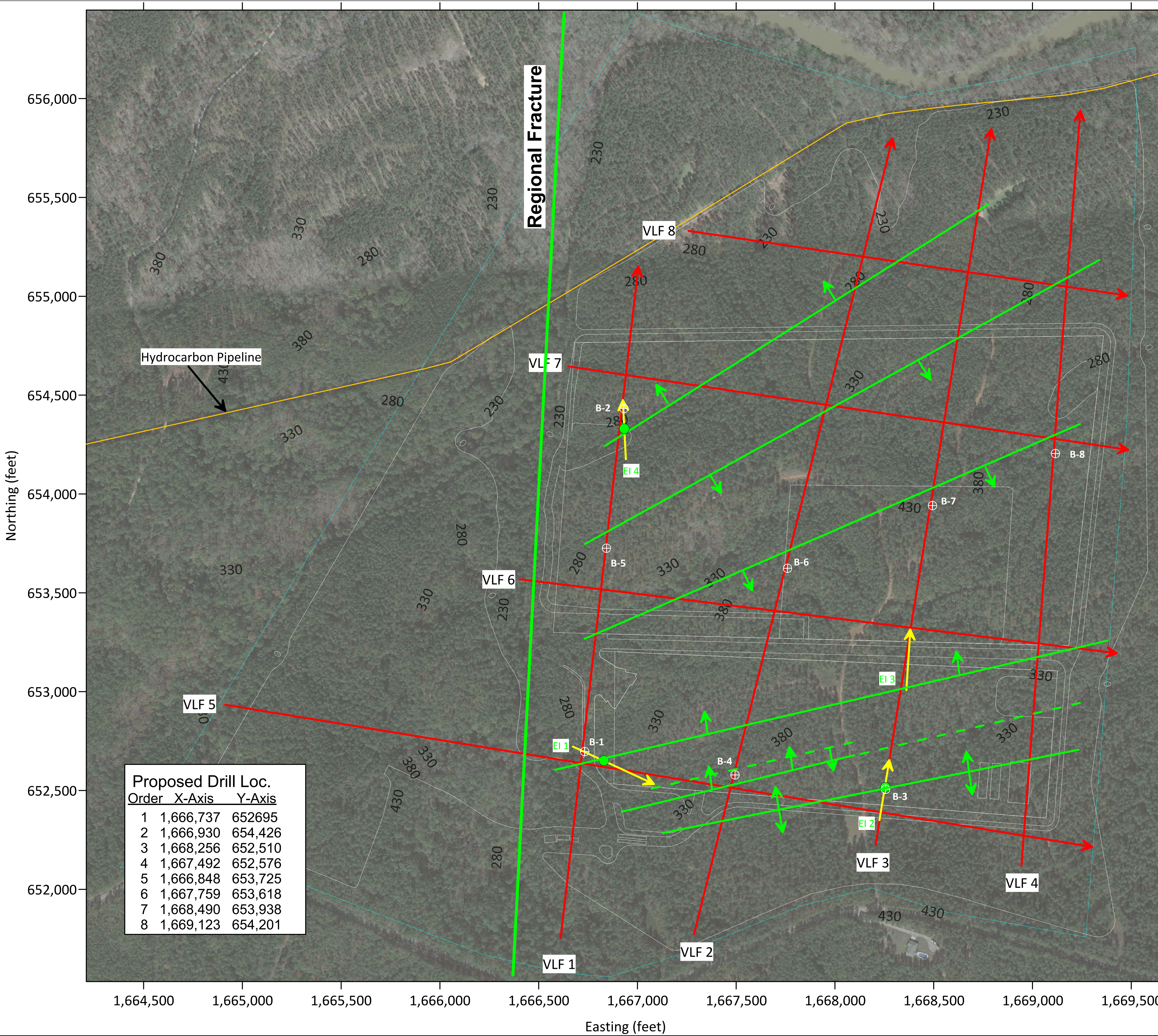
PROJECT NO.: 459-11217

SHEET TITLE: DWG11217F1



Proposed Drill Loc.

Order	X-Axis	Y-Axis
1	1,666,737	652695
2	1,666,930	654,426
3	1,668,256	652,510
4	1,667,492	652,576
5	1,666,848	653,725
6	1,667,759	653,618
7	1,668,490	653,938
8	1,669,123	654,201

True North Approximate

Legend

- VLF Profile (arrow indicates direction)
- EI Profile (arrow indicates direction)
- Interpreted Fracture - EI Profile
- Interpreted Fracture and Dip Direction
- Interpolated Fracture Orientation
- Project Limits
- Proposed Boring Location (B-1)

0 ft 500 ft 1000 ft 1500 ft

1 inch = 500 feet

Notes

Geophysical survey was conducted January 6-9, 2023 using an ABEM Wadi VLF meter and a GF Instruments ARES II electrical resistivity meter.

Real-time positioning of data using fully integrated Trimble Geo-7X global positioning system set to NAD 1983 US State Plane (South Carolina) coordinate system in US Survey feet.

Locations and depths are approximate.

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SCALE: 1 in = 500 ft

SOURCE: Google Earth, 2023

PROJECT:
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DRAWING NO.:
Figure 2
Geophyisical Survey Map

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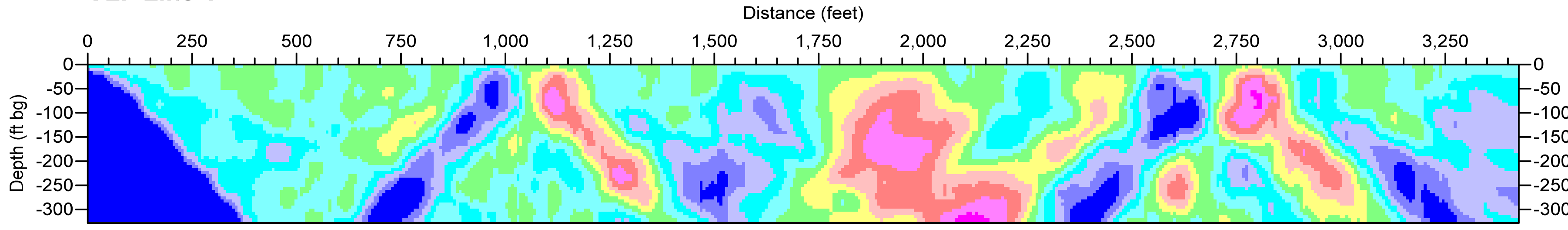
SHEET TITLE: DWG11217F2

VLF Line 1



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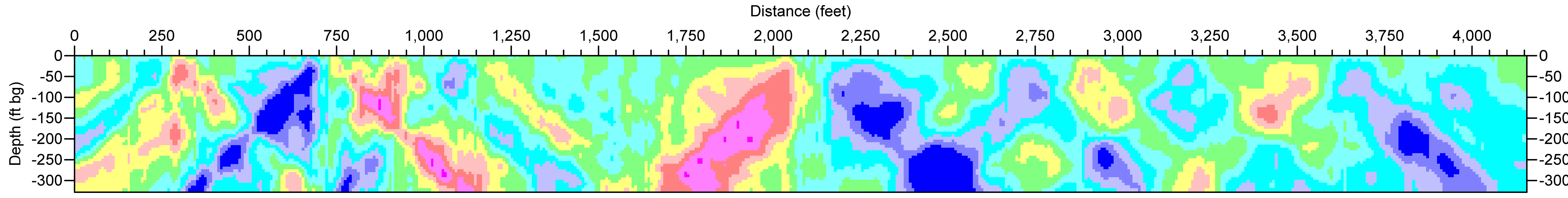

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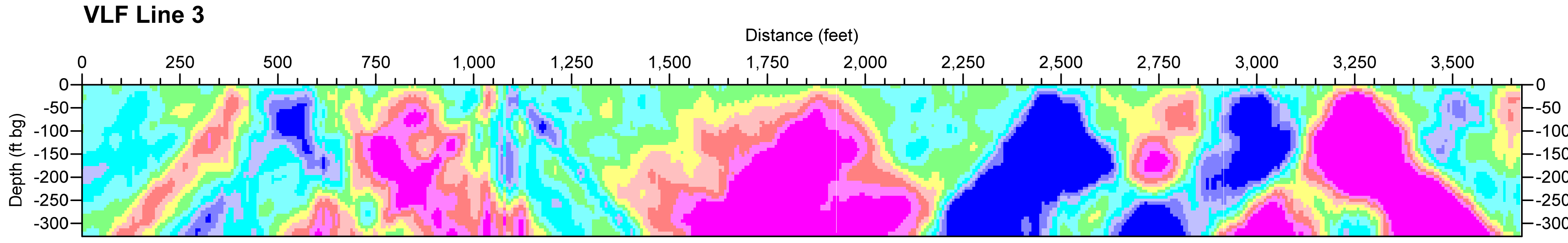

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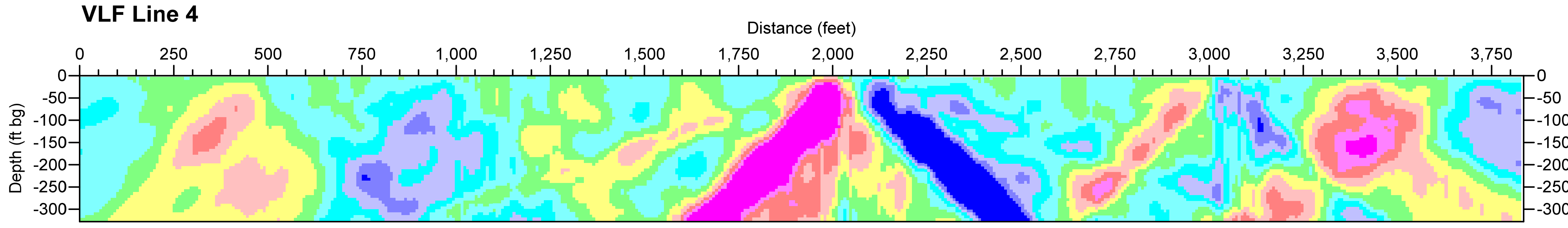

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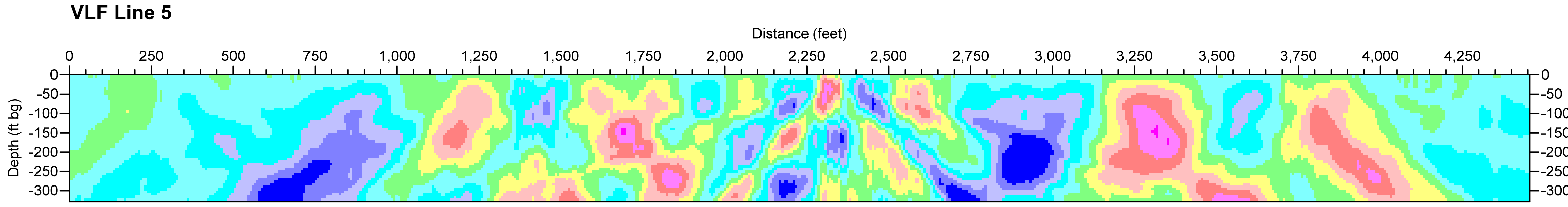
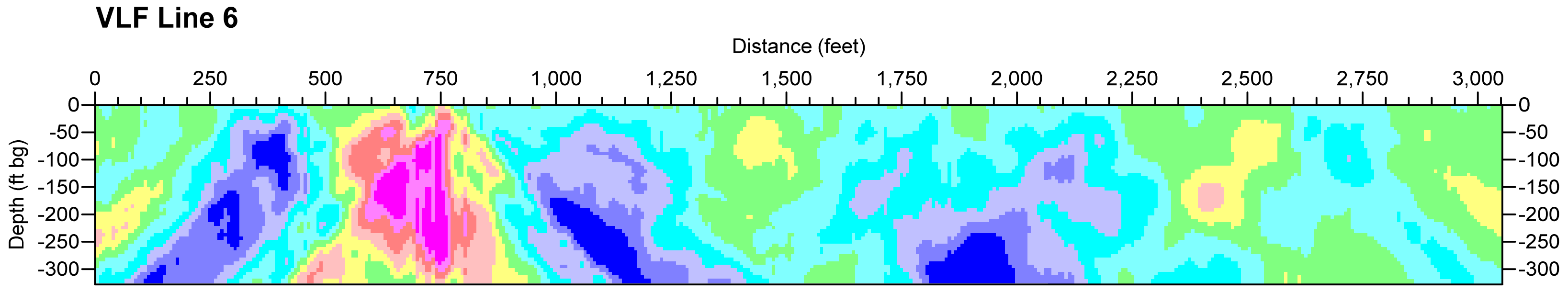


VLF Line 6



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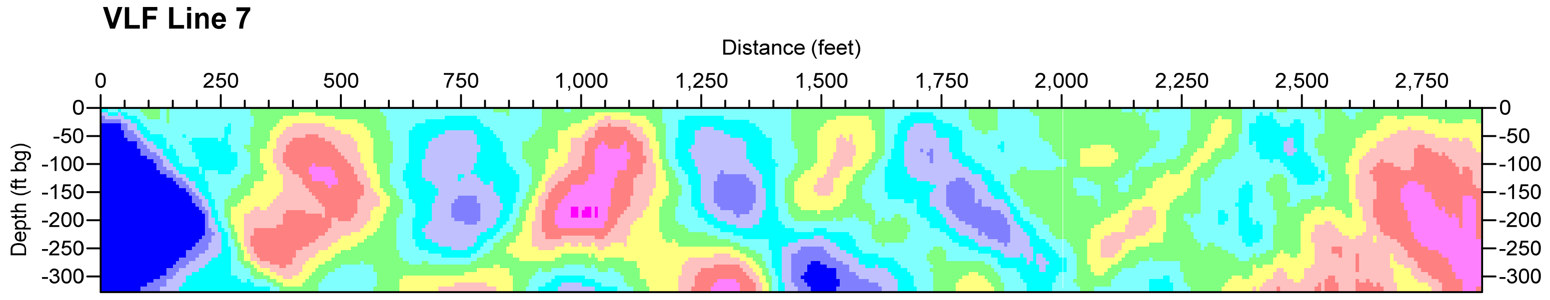
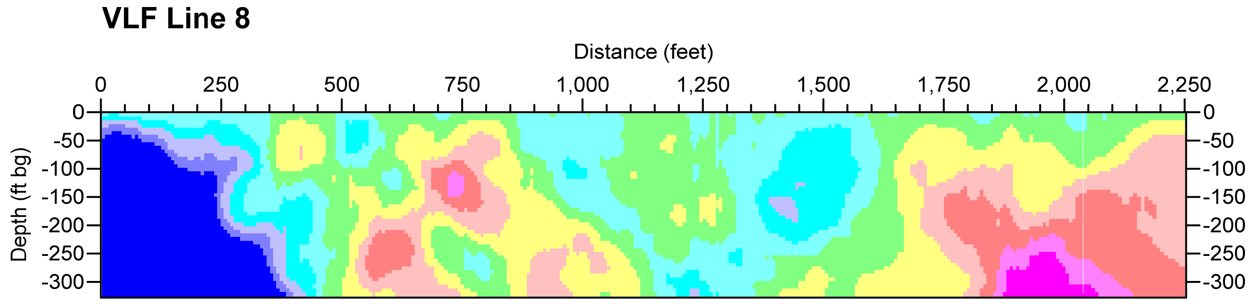


VLF Line 8



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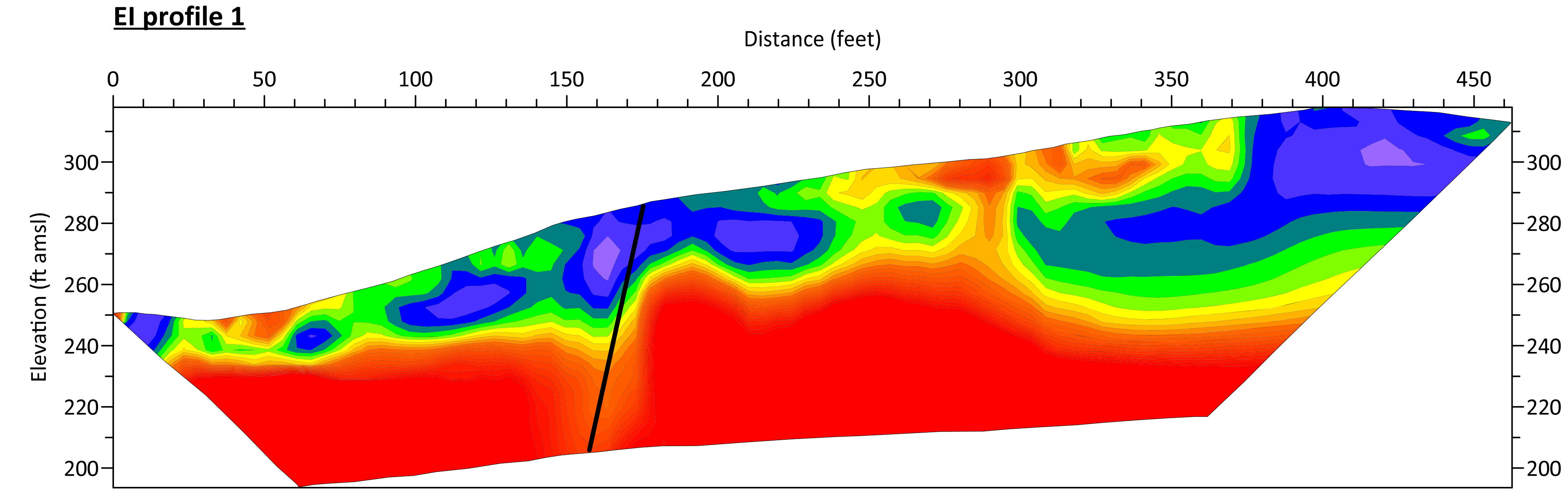
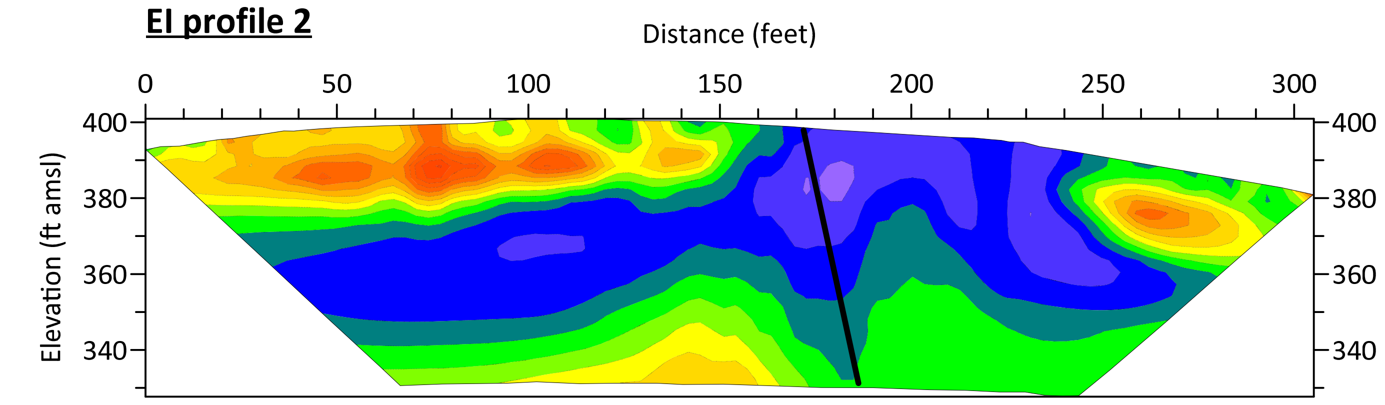
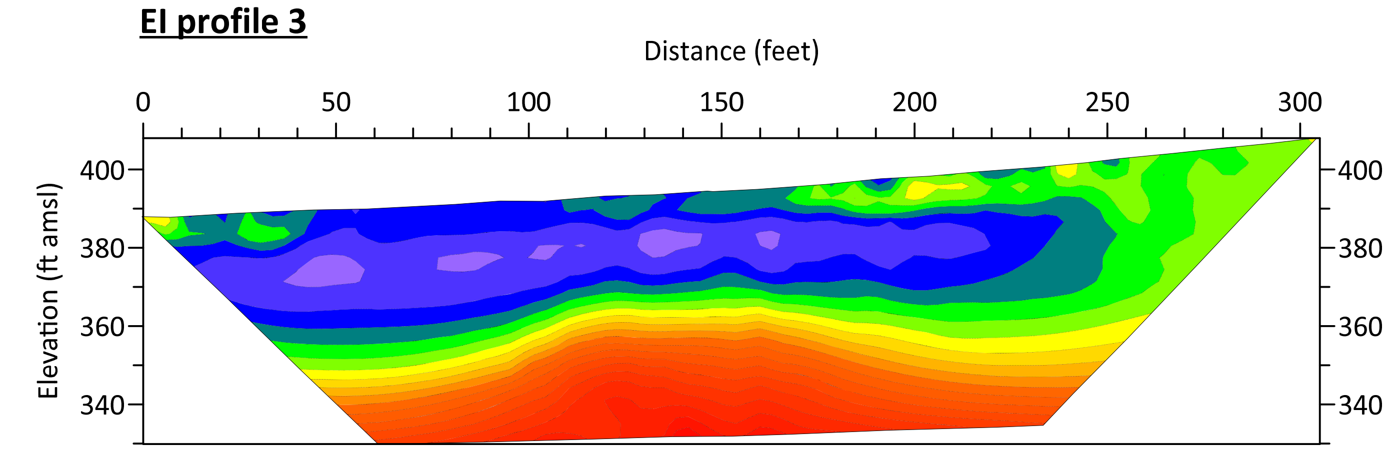


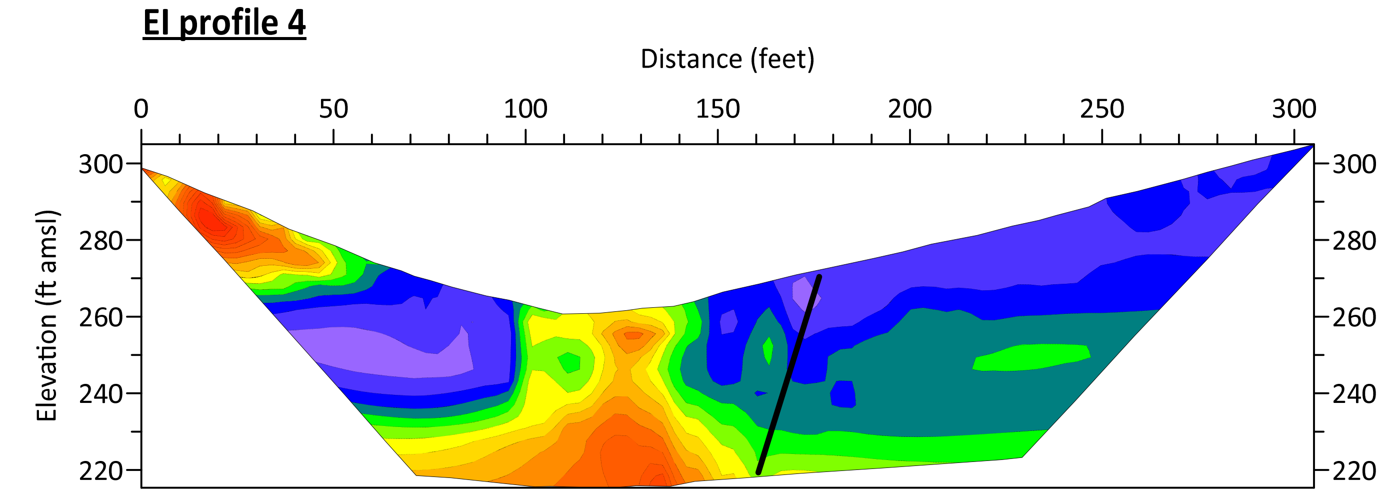
EI profile 2



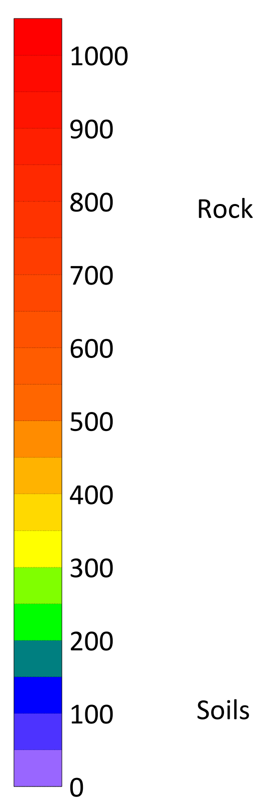
EI profile 3



EI profile 4



Apparent Resistivity (mS/m)



Legend

Interpreted Fracture

Notes

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Real-time positioning of data using fully integrated Trimble Geo-7X global positioning system set to NAD 1983 US State Plane (South Carolina) coordinate system in US Survey feet.

Locations and depths are approximate.

VLF Profile Scale:
- horizontal: 1 inch = 400 feet
- vertical: 1 inch = 328 feet

EI Profile Scale: 1 inch = 50 feet

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PROJECT: Geophysical Investigation Luck Stone - Edgefield Site Edgefield, South Carolina

SCALE: 1 in = 500 ft

SOURCE: Google Earth, 2023

DRAWING NO.: Figure 3 VLF Data - Electrical Imaging Data

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PROJECT NO.: 459-11217

SHEET TITLE: DWG11217F3