# FINAL REPORT
# GEOPHYSICAL INVESTIGATION
# VILLAGE ALHAMBRA RETENTION POND SITE
# THE VILLAGES, FLORIDA

Prepared for Andreyev Engineering, Inc.
Oxford, FL

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August 16, 2018

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**Subject: Transmittal of Final Report for Geophysical Investigation**
**Village Alhambra Retention Pond Site - The Villages, Florida**
**GeoView Project Number 27266**

Dear Mr. Barfield,

GeoView, Inc. (GeoView) is pleased to submit the final report that summarizes and presents the results of the geophysical investigation conducted at the Village Alhambra Retention Pond site. Electrical resistivity was used to evaluate near-surface geological conditions within the retention pond. GeoView appreciates the opportunity to have assisted you on this project. If you have any questions or comments about the report, please contact us.

**GEOVIEW, INC.**

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## 1.0 Introduction

A geophysical investigation was conducted within accessible portions of the retention pond located at the Village Alhambra residential development in The Villages, Florida. Prior to this investigation, two dropouts occurred within the pond. This investigation was conducted on August 10 and 13, 2018.

The purpose of the investigation was to help characterize near-surface geological conditions and to identify subsurface features that may be associated with sinkhole activity within the pond. The results of the investigation are shown on Figure 1.

Site Geology

In general, the near-surface sediments consist of undifferentiated clays associated with the Hawthorn Group in this region. These near-surface clayey soils are underlain by the Ocala Limestone. The Ocala Limestone is a highly transmissive carbonate unit very susceptible to sinkhole activity. The lithological contact between these two units is can be highly weathered and often exhibits significant variations in relief due to erosional and karst-related geological processes.

## 2.0 Description of Geophysical Investigation

The ERI survey was conducted using the Advanced Geosciences, Inc. Sting R8 automatic electrode resistivity system. Ten ERI transects were performed using up to 49 electrodes with an “a spacing” of 7.5 ft. A dipole-dipole combined with an inverse Schlumberger electrode configuration was used with a maximum “n value” of six. The ERI data was analyzed using EarthImager 2D, a computer inversion program, which provides two-dimensional vertical cross-sectional resistivity model (pseudo-section) of the subsurface.

The positions of the geophysical transect lines were recorded using a Trimble GeoXH Global Positioning System (GPS). A Wide Area Augmentation System (WAAS) was used to augment GPS with additional signals for increasing the reliability, integrity, accuracy and availability of the GPS signal. By using WAAS, an accuracy of less than 3 ft in the horizontal dimension was achieved. A description of the ERI method and the methods employed for geotechnical characterization studies is provided in Appendix A2.2. A discussion of the modeling process used to create the ERI results is provided in Appendix A2.2.1.

## 3.0 Identification of Possible Sinkhole Features Using ERI Method

Sinkhole features are typically characterized by one of the following conditions on the ERI profile:

1. The occurrence of highly resistive material that extends to depth in a columnar fashion towards the top of the limestone. Such a feature may indicate the presence of a sand-filled depression or raveling zone.
2. The localized presence of low-resistivity material extending below the interpreted depth to the top of limestone. Such a feature may indicate the presence of a clay-filled void or fracture with the limestone or the presence of highly weathered limestone rock.
3. Any significant localized increase in the depth to limestone. Such a feature may indicate the presence of an in-filled depression (paleo-sink).

When comparing the results of the ERI method, the following considerations should be given. The ERI method, for example, describes the transition from clay to limestone as a transition, rather than a discrete depth. This transition is due to several factors including: a) The vertical density of the resistivity data decreasing with depth and b) The possibility that the upper portion of the limestone is weathered which would create a physical transition zone in terms of resistivity between the clay and competent (non-weathered) limestone and c) The limitations in the modeling process.

## 4.0 Survey Results

Results from the ERI survey are shown on Figure 1 and the individual data profiles are presented in Appendix 1. The ERI transects are of good quality (a discussion of the criteria used to determine the quality of an ERI inversion model is provided in Appendix A2.2.1).

In general, analysis of the ERI transects indicate the presence of low to moderate resistivity near-surface soil materials to a depth range of approximately 5 to 10 ft bls (represented in blue to green on the ERI transects). This low to moderate resistivity layer is likely associated with the Hawthorn Group clayey soils. The majority of the surficial low to moderate resistivity layer is underlain by an approximately 5 to 30-ft thick high resistivity layer (represented in yellow to red) underlain by an approximately 20 to 40-ft thick low to moderate resistivity layer. This sequence is followed by a deeper high resistivity layer to the maximum

depth of investigation of the ERI transects which ranged from approximately 43 to 82 ft bls. The lower sequence of high resistivity to low/moderate resistivity earth materials is most likely associated with variations in the Ocala Limestone Formation.

Three ERI anomalies were identified at the project site (Figure 1). The anomalies are labeled 1 through 3 on Figure 1 and on the corresponding ERI transect profiles. The ERI anomalies were characterized by the apparent breach of the high resistivity stratum into the underlying soils. It is noted that the three ERI anomalies were observed in corresponding locations on the transects, and are likely associated with larger karst features as shown on the figure.

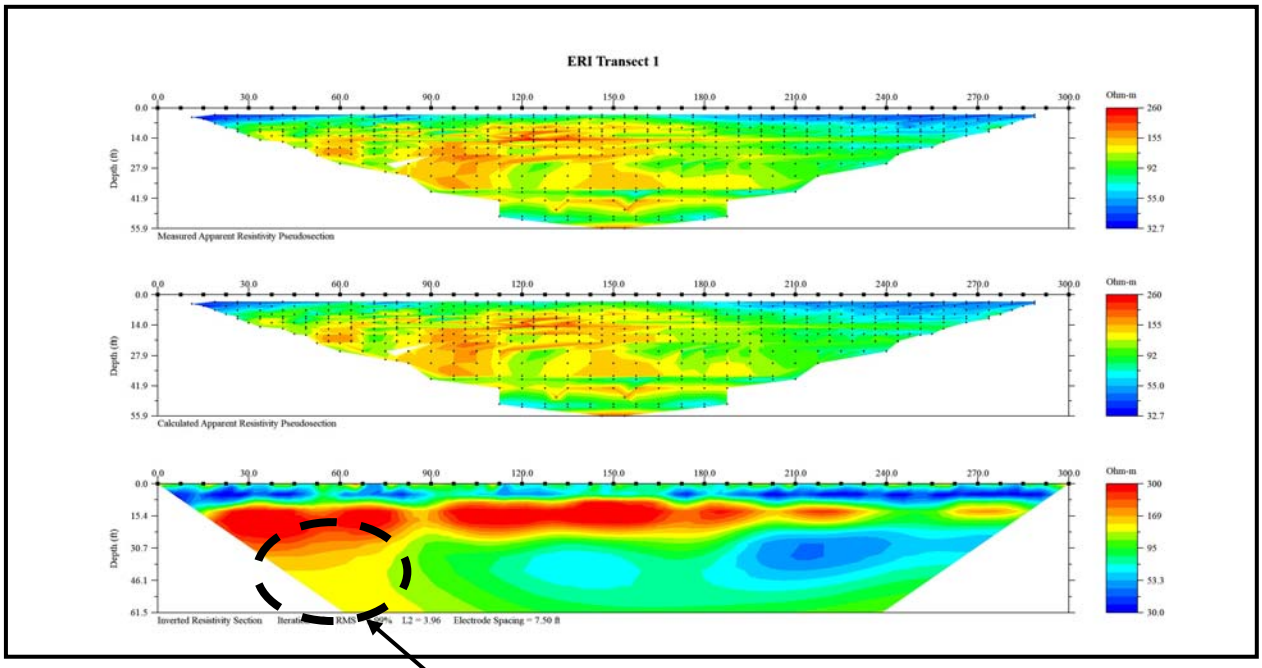
ERI Anomaly 1 corresponds to the location of the two observed dropouts in the pond. However, despite this correlation it is not possible based on the geophysical results to determine whether these identified anomalies have a potential for further collapse or raveling. Table 1 provides the coordinates for the apparent centers for each ERI anomaly. These coordinates were developed using a Trimble GEO-XH global positioning system (GPS) with sub 3-foot accuracy.

**Table 1 – ERI Anomaly Center Coordinates***

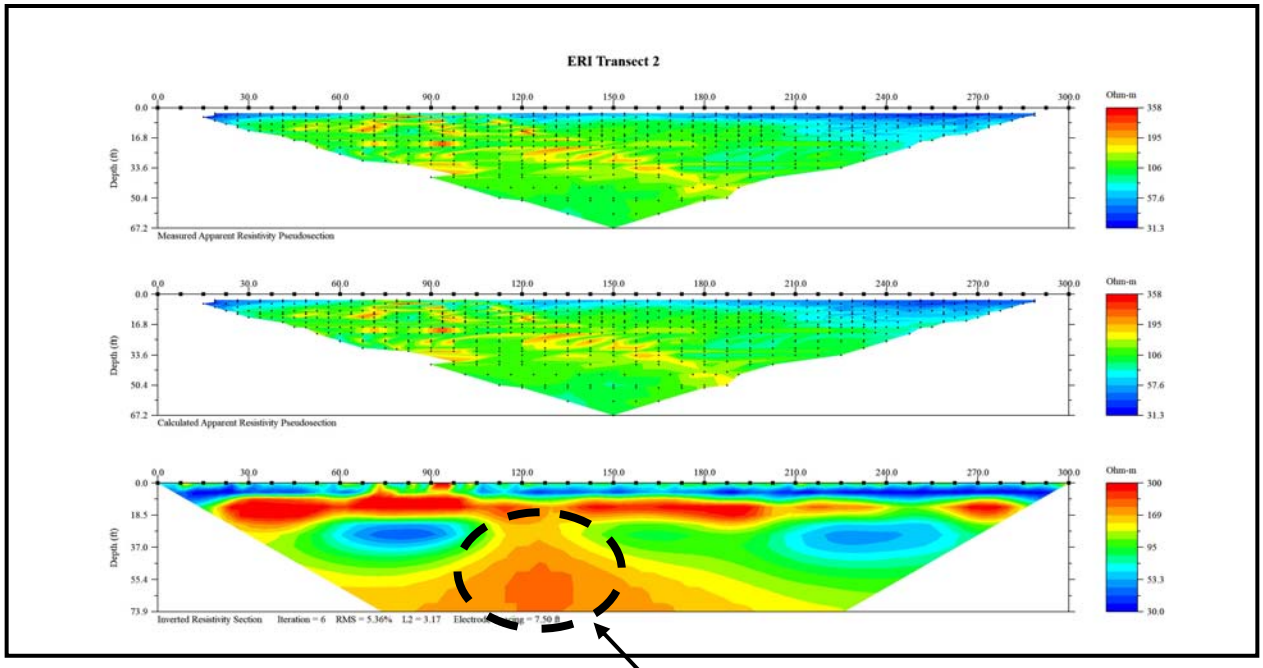
| Anomaly | Northing | Easting | Latitude | Longitude |
|---|---|---|---|---|
| 1 | 1679202.2 | 658580.75 | 28.95300671 | -81.99245143 |
| 2 | 1679170.13 | 658655.16 | 28.9529185 | -81.99221876 |
| 3 | 1679170.51 | 658532.77 | 28.95291957 | -81.99260146 |

* US State Plane, Florida West 0101, NAD83 (Conus), Feet

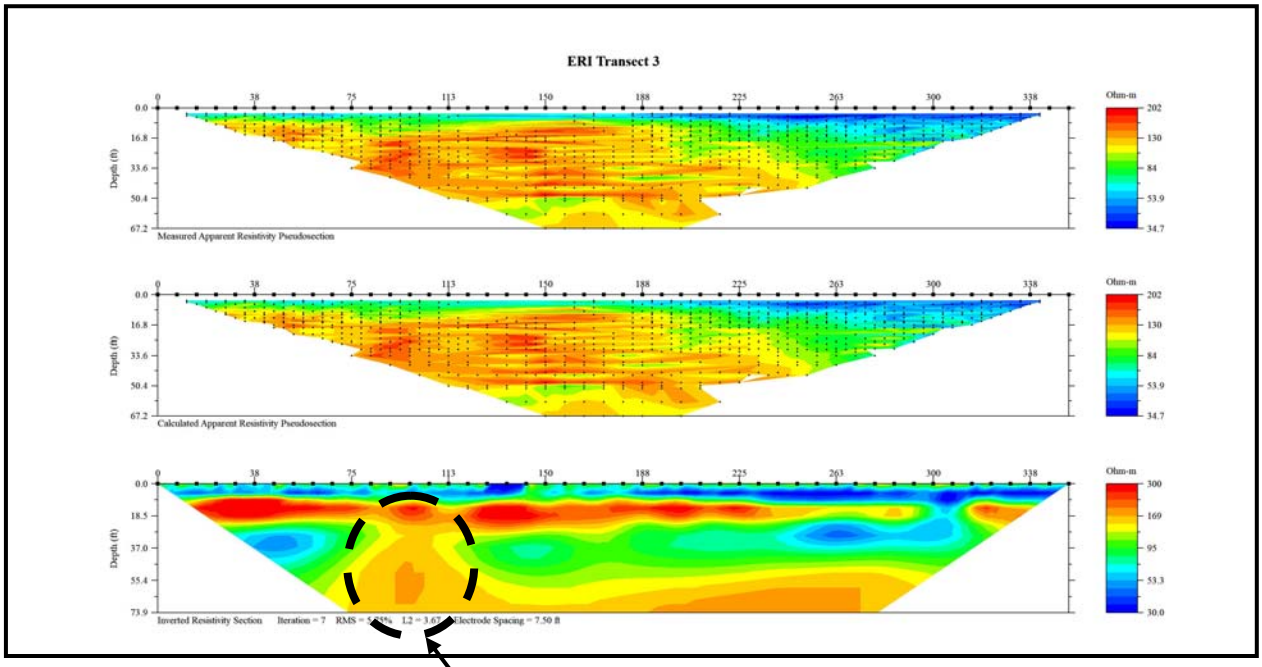
# APPENDIX 1
# FIGURE AND ERI TRANSECTS



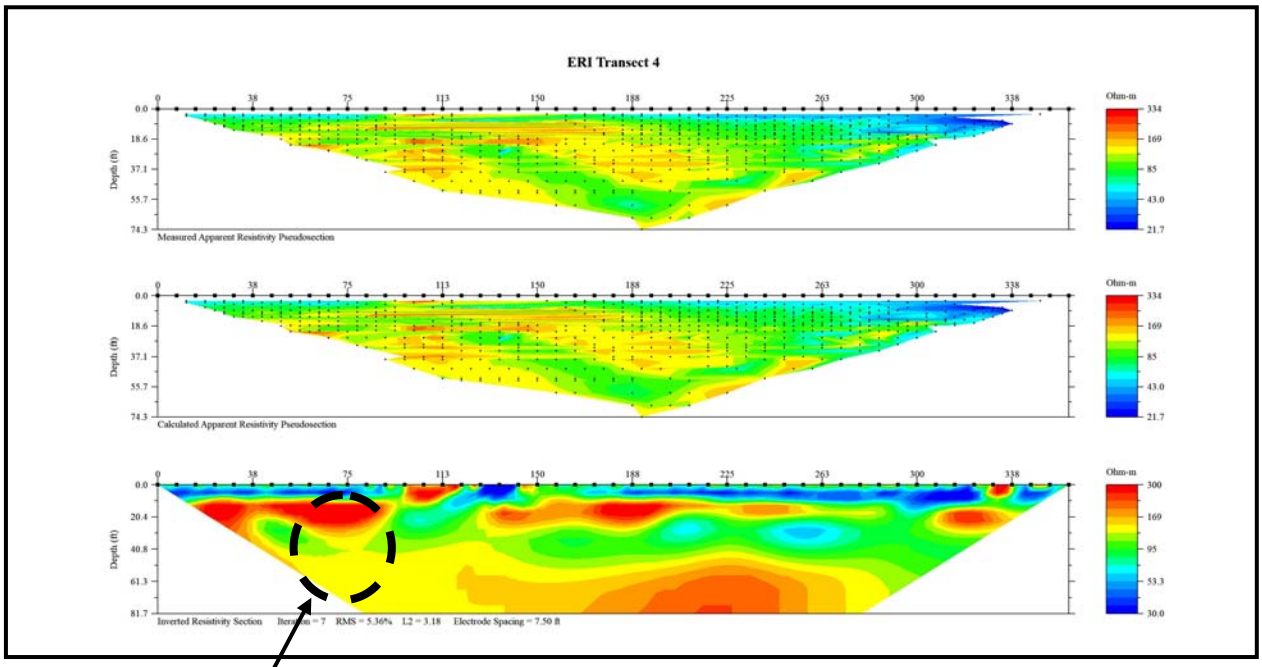

ERI Anomaly 3



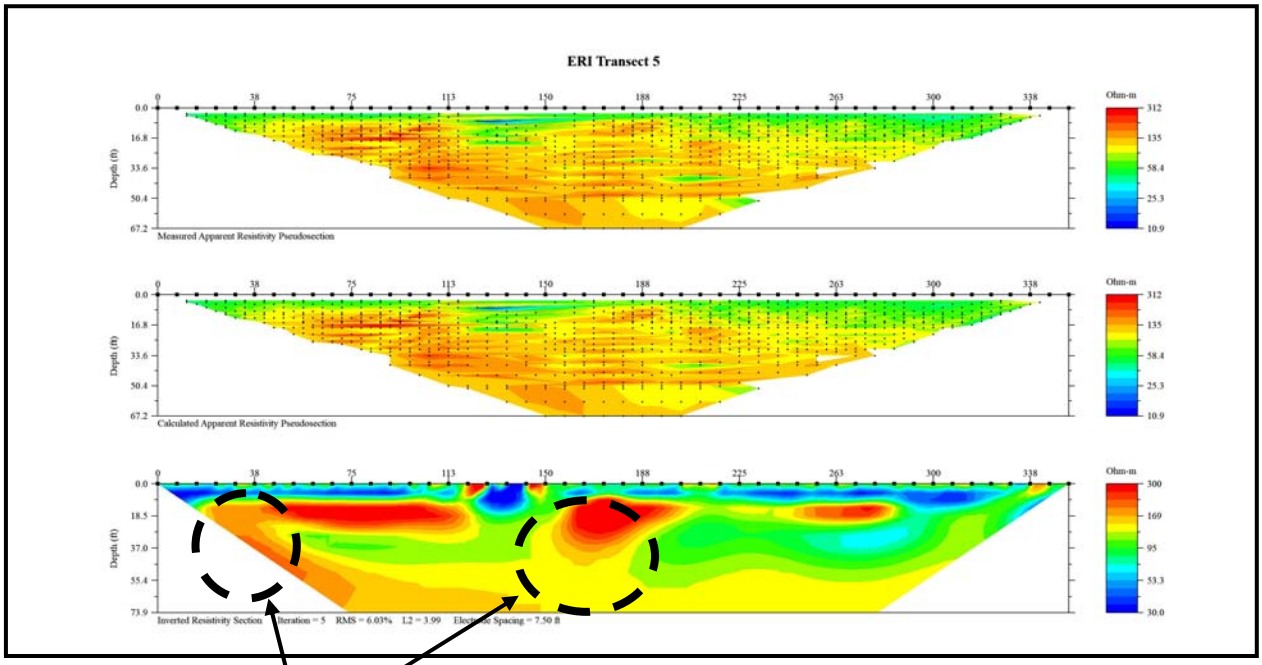

ERI Anomaly 1



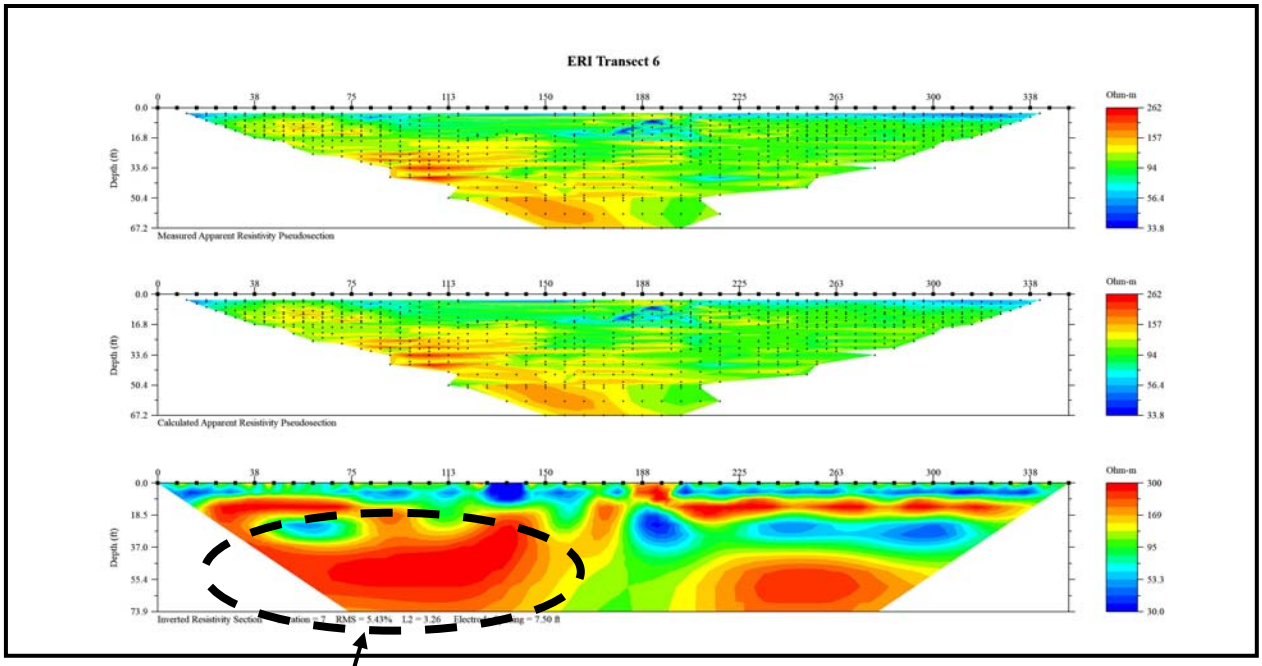

ERI Anomaly 1




ERI Anomaly 1




ERI Anomaly 2

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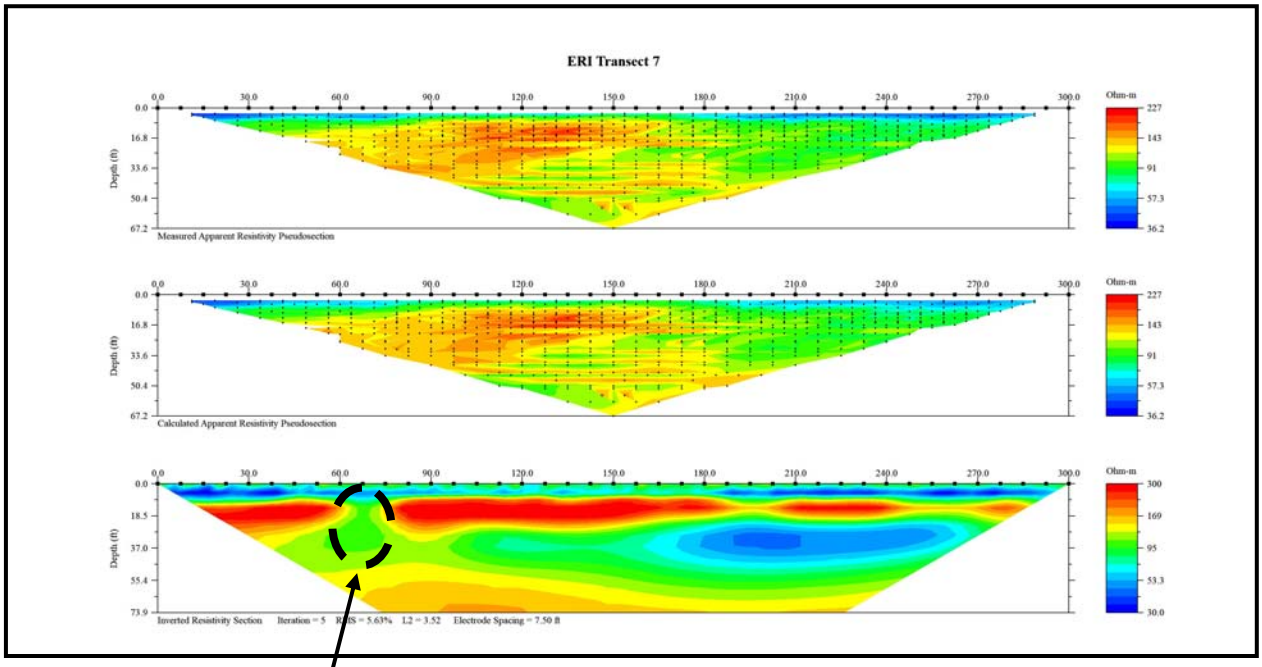
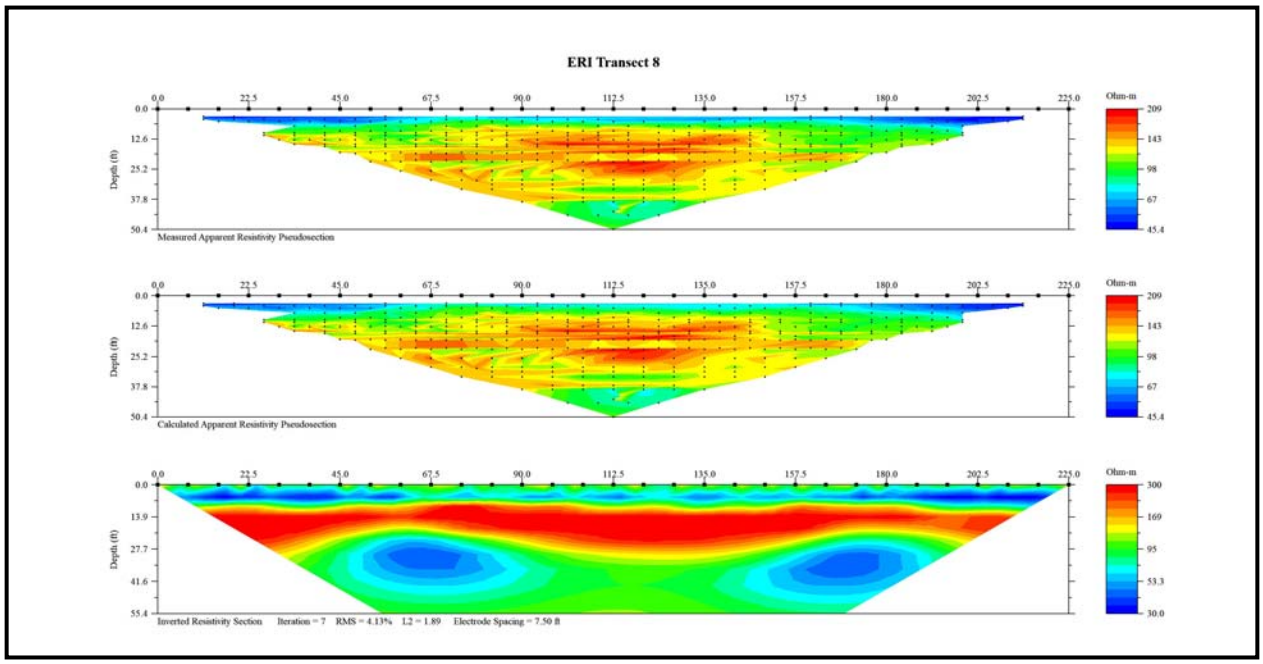
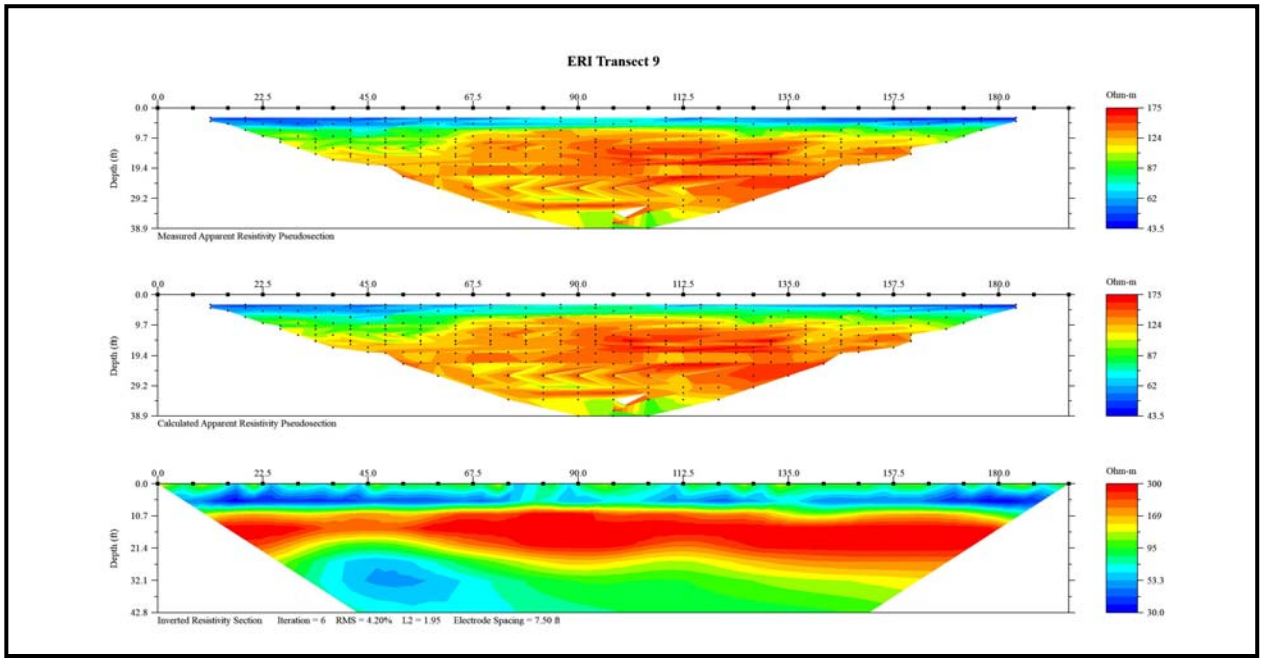
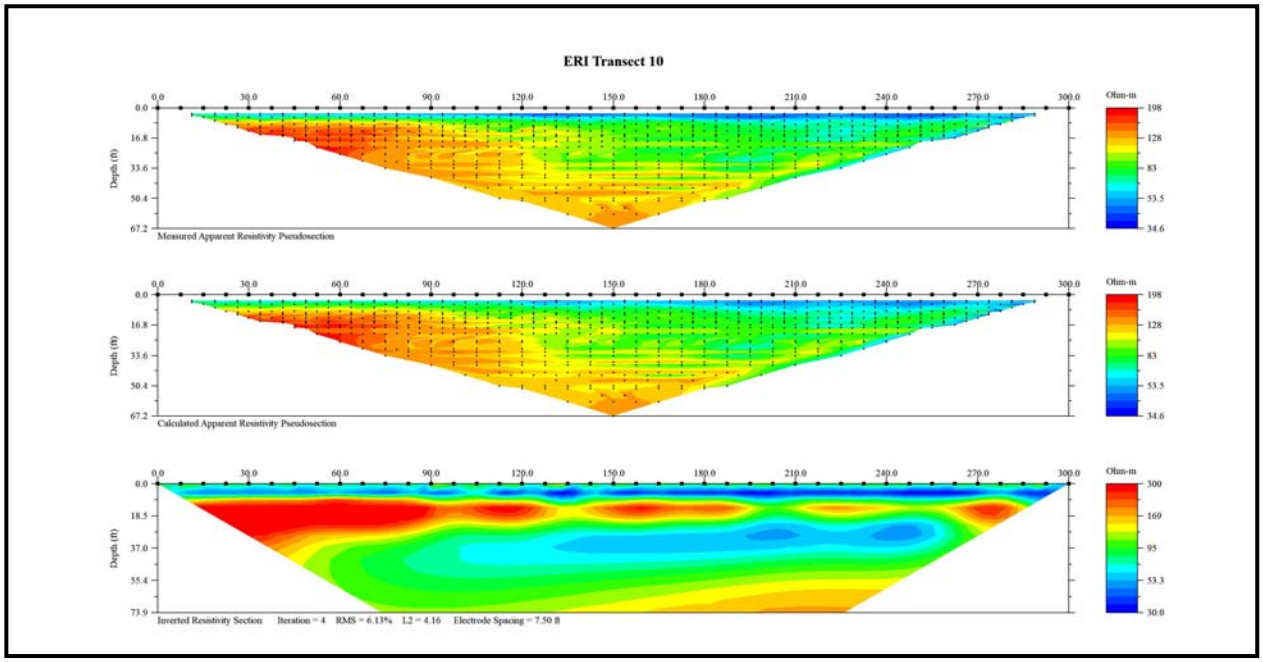



ERI Anomaly 3




ERI Transect 9
Depth (ft)
Ohm-m
Measured Apparent Resistivity Pseudosection
Calculated Apparent Resistivity Pseudosection
Inverted Resistivity Section Iteration = 6 RMS = 4.20% L2 = 1.95 Electrode Spacing = 7.50 ft


ERI Transect 10
Depth (ft)
Ohm-m
Measured Apparent Resistivity Pseudosection
Calculated Apparent Resistivity Pseudosection
Inverted Resistivity Section Iteration = 4 RMS = 6.13% L2 = 4.16 Electrode Spacing = 7.50 ft

# APPENDIX 2
# DESCRIPTION OF GEOPHYSICAL METHODS, SURVEY METHODOLOGIES AND LIMITATIONS

## A2.1 On Site Measurements

The positions of the geophysical transect lines were recorded using a Trimble GeoXH Global Positioning System (GPS). These GPS systems typically have an accuracy of 1 to 3 ft.

## A2.2 Electrical Resistivity

Electrical resistivity surveying is a geophysical method in which an electrical current is injected into the earth; the subsequent response (potential) is measured at the ground surface to determine the resistance of the underlying earth materials. The resistivity survey is conducted by applying electrical current into the earth from two implanted electrodes (current electrodes $C_1$ and $C_2$) and measuring the associated potential between a second set of implanted electrodes (potential electrodes $P_1$ and $P_2$). Field readings are in volts. Field readings are then converted to resistivity values using Ohm's Law and a geometric correction factor for the spacing and configuration of the electrodes. The calculated resistivity values are known as "apparent" resistivity values. The values are referred to as "apparent" because the calculations for the values assume that the volume of earth material being measured is electrically homogeneous. Such field conditions are rarely present.

Resistivity of earth materials is controlled by several properties including composition, water content, pore fluid resistivity and effective permeability. For this study the properties that had the primary control on measured resistivity values are composition and effective permeability. The general geological setting of this project area is clay overlain by limestone.

For this study a dipole-dipole combined with an inverse Schlumberger resistivity array configuration was used. The dipole-dipole array is different that most other resistivity arrays in that the electrode and current electrodes are kept together using a constant spacing value referred to as an "a spacing". The current and potential electrode sets are moved away from each other using multiples of the "a spacing" value. The number of multiples is referred to as the "n value". For example, an array with an "a spacing" of 5 ft and a "n value" of 6 would have the current and potential electrode sets spaced 30 ft apart with a separation between the two electrodes in the set of 5 ft. By sampling at varying "n values", greater depth measurements can be achieved. Inverse Schlumberger data is collected with the

current set of electrodes being kept with a fixed separation (L spacing) and the potential electrodes a minimum distance of 5L from the inner current electrodes. Dipole-dipole resistivity data is usually presented in a two-dimensional pseudo-section format. Inverse Schlumberger data is usually presented as a vertical profile of resistivity distribution below the center point between the two current electrodes. The dipole-dipole and inverse Schlumberger data is combined and presented as either a contour of the individual data points (using the calculated apparent resistivity values) or as a geological model using least squares analysis. Such least squares analysis was used for this study using the computer software program (EarthImager 2D) developed for the equipment manufacturer. Apparent resistivity values are calculated using the following formula for a dipole-dipole configuration: $\gamma_a=\pi(b^3/a^2-b)\nabla V/I$:

Where:

$\gamma_a=$ apparent resistivity
$\pi=$ 3.14
a= "a spacing"
b= "a spacing" x "n value"
$\nabla V=$ voltage between the two potential electrodes
I= current (in amps)

For a Schlumberger configuration the apparent resistivity is calculated using: $\gamma_a=\pi([s^2-a^2]/4)\nabla V/aI$:

Where:

$\gamma_a=$ apparent resistivity
$\pi=$ 3.14
a= spacing between the inner set of electrodes"
s= distance between the outer electrode and nearest inner electrode
$\nabla V=$ voltage between the two potential electrodes
I= current (in amps)

A2.2.1 Inversion Modeling of ERI Data

The objective for inversion modeling of resistivity data is to create a description of the actual distribution of earth material resistivity based on the subsurface geology that closely matches the resistivity values that are measured by the instrumentation. This modeling is done through the use of EarthImager™, a proprietary computer program developed by the equipment manufacturer. When evaluating the validity of the inversion model several factors need to be considered. The RMS, or root mean square error, expresses the quality of fit

between the actual and modeled resistivity values for the given set of points in the model. The lower the RMS error the higher the quality of fit between the actual and modeled data sets. In general, inversion models with an RMS error of less than 5 to 10 percent are acceptable. The size of the RMS error is dependent upon the number of bad data points within a data set and the magnitude of how bad the data points are. As part of the modeling process bad data points are typically removed, which decreases the RMS error and improves (with limitations) the quality of the model. The quality of fit between the actual and modeled resistivity values is also expressed as the L-2 norm. When the modeled and actual data sets have converged, the L-2 norm reduces to unity (1.0 or smaller).

However, as the number of data points is reduced, the validity of the inversion model is diminished. Accordingly, when interpreting a particular area of an inversion model the number of data points used to create that portion of the model must be taken into consideration. If very few points are within a particular area of the model, then the modeled solution in that area should be considered suspect and possibly rejected.

The entire ERI transect should be considered suspect if a model has a high RMS error and a large number of removed data points. It is likely that sources of interference have affected the field readings and rendered the modeled solution invalid. Such sources of interference can include buried metallic underground utilities, reinforced concrete slabs, septic leach fields or electrical grounding systems. Accordingly, all efforts need to be made in the field to locate, to the degree possible, the ERI transect lines away from such features. The locations of such features also need to be mapped in the field so their potential effects can be considered when interpreting the modeled results.