Geophysical Investigation
Saint Xavier Nature Preserve
106 Saint Xavier's Road
Latrobe, Pennsylvania

Prepared for:

Westmoreland Land Trust
218 Donohoe Road
Greensburg, PA 15601

February 5, 2024

Prepared by:

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THG Project No. 11612

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1.0 INTRODUCTION

1.1 BACKGROUND

The St. Xavier Nature Preserve (St. Xavier) is a 248-acre property conveyed to the Westmoreland Land Trust (WLT) by the Sisters of Mercy to be conserved as a nature preserve (**Figure 1**). The property formerly housed the St. Xavier Academy and Convent; both were destroyed by a fire in 1972. The general location of former structures can be inferred from historic photographs but the Sisters of Mercy conservation plan includes an interest in delineating the actual extent of former structures and mapping related materials that may still be present in the subsurface (**Figure 2**).

THG Geophysics, Ltd. (THG) conducted a geophysical survey to image the subsurface in the vicinity of the historic St. Xavier, totaling approximately 2.5 acres (**Figure 2**). The geophysical investigation was completed on November 20-21, 2023.

1.2 WORK SCOPE

The geophysical investigation scope of work included the use of 3-D ground penetrating radar (GPR) and frequency-domain electromagnetic terrain conductivity mapping (TCM) (**Figure 3**). Geophysical data were collected over accessible areas of the project limits. The GPR total survey area covered approximately 1.8 acres and was collected using a UTV-mounted assembly. The TCM survey area covered approximately 2.3 acres and was collected by THG personnel on foot (**Figure 3**). All geophysical data sets were collected in parallel paths across the survey area with unique survey parameters for each method.

At the time of the survey, the site consisted of a relatively flat, grassy field with some visible debris piles scattered throughout the area. A moderate rain event occurred during the second field day; however, no geophysical data sets were collected over both days and therefore background values are stable for all data sets.

2.0 GEOPHYSICAL INVESTIGATION

2.1 GROUND PENETRATING RADAR

GPR employs radio waves from 25 to 2,700 MHz frequency to map structures and features buried in the ground (Annan and Cosway, 1992). The GPR unit operates by transmitting radar waves (microwave band) downward from a transmitting antenna and receives the reflected energy at the receiving antenna. The reflected signal is output digitally and displayed as a radargram. Any contrast in dielectric properties appear as reflecting boundaries.

The frequency of a GPR antenna controls the depth of penetration and the data resolution. High frequency antennas do not emit energy as deep as low frequency antennas, but they can acquire higher resolution data than lower frequency antennas can. Building materials containing electrically conductive materials (i.e. clay soils, metallic reinforcement, etc.) rapidly attenuate the radar signal and therefore, decrease penetration depth. Subsurface soils containing electrically conductive materials (i.e. clays, groundwater, slag) rapidly attenuate the radar signal and therefore, decrease penetration depth.

THG utilized an ImpulseRadar Raptor GPR equipped with eighteen (18) 450 MHz channels to acquire 3-D GPR data over the area of interest (**Figure 4**). In this configuration, the Raptor GPR simultaneously acquires eighteen (18) profiles spaced approximately 3.5 inches apart, resulting in a swath of data 5.5 feet wide. By collecting multiple swaths of 3-D GPR data, a complete volume of data is generated that may be viewed as plan-view depth slices or as composite depth slices with a color scale highlighting the strongest reflections across a range of depths (**Figure 4**). Depth of penetration was approximately 4 feet bg.

2.2 TERRAIN CONDUCTIVITY MAPPING

2.2.1 Introduction

TCM is used to measure the electrical conductivity of subsurface soil, rock and ground water. Electrical conductivity (or its inverse, resistivity) is a function of the porosity, permeability, and the fluids in pore spaces (McNeill, 1980). TCM is an excellent tool for quickly mapping variations in subsurface materials.

The frequency-domain electromagnetic tool consists of a transmitter coil that radiates an electromagnetic field. The electromagnetic field induces eddy currents in the earth that generate a secondary electromagnetic field proportional to the magnitude of the current flowing within the coil. Quadrature and in-phase components of the secondary magnetic field are captured by the receiver in the form of an output voltage that is linearly related to subsurface conductivity (McQuown et al., 1991). The quadrature phase component (terrain conductivity) is measured in milliSiemens/meter (mS/m) and provides a measurement of conductivity. The TCM method is easy to deploy when integrated with a global positioning unit (Trimble Geo7XH) that provides continuous measurement of field position and elevation. Terrain conductivity measurements were acquired at a rate five (5) records per second.

The terrain conductivity value is an average conductivity of the effective depth of the survey tool at a given frequency. The effective depth is determined by the depth at which 75% of the cumulative sensitivity is achieved, or about 1.5 times the intercoil spacing (i.e., the distance between the receiving and the transmitting coils). The CMD Mini-Explorer 6L used in this survey is a multiple dipole tool with six (6) intercoil spacings to allow for effective penetration depths of approximately 1, 1.6, 2.6, 3.6, 5.2, and 7.5 feet. The tool measures the bulk conductivity of the entire skin depth specified by the intercoil spacing. Conductivity data were collected in parallel paths spaced approximately 10 to 20 feet apart (**Figure 5**).

2.2.2 Data Processing

TCM conductivity data were post-processed and inverted using Aarhus Workbench software (Aarhus GeoSofware, 2021). The quadrature phase measurements, *Q,* for each intercoil distance was transformed to resistivity, ρ_a, using:

$$\rho_a = \frac{\omega\ \mu_0 s^2}{4} \times \frac{Q_{primary}}{Q},$$

Where s is the intercoil spacing; $\boldsymbol{\omega = 2\pi f}$ is the angular frequency for the frequency, $\boldsymbol{f}$; and $\boldsymbol{\mu_0 = 4\pi 10^{-7}}$ is the magnetic permeability of free space.

Processing resistivity data from conductivity data consists of several steps designed to improve the signal-to-noise ratio and provide for a more successful inversion. First, negative data was removed from the dataset. The remaining data were averaged by applying a running mean with a specified filter length of one (1) meter. This filter is a function of distance; therefore, the number of measurements included in the filter is dependent on acquisition speed. The filter length was selected to reduce noise caused by factors such as instrument swing while ensuring that smaller subsurface structures are not “smoothed out.” Approximately 46,131 raw TCM measurements were acquired, of which 11,417 remained after applying the processing routine outlined above.

2.2.3 *Inversion*

Processed data are inverted with a smooth model 15-layer spatially constrained inversion (SCI) algorithm. An SCI is a 1-D inversion with 3-D constraints. There are constraints on resistivity along survey lines, between survey lines, and between vertical model layers. The strength of spatial constraints is scaled linearly with distance, effectively disabling constraints between measurements that are far from one another. Layer thickness logarithmically increases with depth beginning at 1-foot bg, providing a vertical resolution that decreases with depth.

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 resurveys of lines and locations. The QA/QC program indicates that all geophysical equipment functioned as designed during the survey.

3.0 GEOPHYSICAL ANALYSES

3.1 INTRODUCTION

The geophysical analysis for this project is focused on characterizing and delineating subsurface structures in the vicinity of the historic Saint Xavier's Academy and Convent (**Figure 2**). The scope of work included collection of 3-D GPR and TCM data to image the subsurface of the site (**Figure 3**). Approximately 1.8 acres of 3-D GPR data were collected in 5.5-foot-wide parallel swaths and approximately 2.3 acres of TCM data were collected in parallel paths spaced 10 to 20 feet apart (**Figures 4 and 5**).

Historic aerial imagery acquired by the United States Department of Agriculture (USDA) Farm Service Agency between 1957 and 1962 were analyzed for the locations of historic structures that can be correlated with the results of the geophysical investigation (**Figure 2**). Several building structures and walk/driveways are identified from the historic imagery and their approximate outlines are overlaid against geophysical data sets (**Figures 3 through 5**). Additionally, historic records suggest that following the razing of the Academy and Convent, demolished building materials were backfilled into the previous building footprint.

Generally, low TCM resistivity values are associated with conductive soils (e.g., clays), saturated materials, and highly weathered bedrock and high TCM resistivity values are associated with resistive soils (e.g., sand), dryer materials, and more competent rock. In circumstances where human activity has manipulated subsurface materials, unique conditions arise that affect traditional TCM interpretations. In some situations, demolished building materials are backfilled into the footprint of the previous structure and can result in poor material compaction, a high concentration of air within the materials and more resistive TCM values. Conversely, some demolished building materials that are backfilled into previous footprints can be very conductive (e.g., metals) and result in lower resistivity TCM values. Additionally, clean fill that is typically used to cap these types of building demolitions is often clay-rich and displays very low resistive TCM values.

The GPR interpretation is consistent with the TCM interpretation where less resistive (conductive) subsurface features reflect more energy and generate strong, high-amplitude reflections while more resistive materials absorb more energy and generate weaker, lower-amplitude reflections. Additionally, air-filled pockets within subsurface materials can cause GPR signals to reflect off the top and bottom of the void resulting in signal overlap and high-amplitude reflections.

3.2 3-D GPR DATA

GPR anomalies at this site are identified by the presence of strong reflectors that are interpreted to indicate the presence of disturbed subsurface materials. GPR data collected at the site displays several areas of consistently strong reflectors over different depth ranges (**Figure 4**). When overlaid against the approximate outlines of the historic Academy and Convent, locations of GPR anomalies identified at 1- to 2-foot and 2- to 3-foot depth ranges closely correlate to locations of historic structures. The correlation of GPR anomalies with the historic building footprints are interpreted as the presence of more conductive surficial soils that were placed over buried building debris (1- to 2-foot range) and poorly compacted debris (2- to 3-foot range) that were backfilled into the historic building footprint (**Figure 4**).

3.3 TCM DATA

TCM anomalies are identified by their contrast with background TCM values. Since material characteristics change with depth, the relationship between background and anomalous TCM measurements must be considered at each individual mean resistivity slice depth range.

At the shallowest mean resistivity depth range (0- to 1-foot bg), background TCM values are in the range of approximately 35 to 85 Ohms and anomalous TCM values are in the range of approximately 5 to 35 Ohms (**Figure 5**). Near-surface soils are often dryer than deeper soils resulting in more resistive TCM values. The low resistive TCM anomalies identified at this depth range are interpreted as areas where clay-rich soils were used to cap buried building debris within the footprint of the historic structures and/or areas where near-surface soils are unable to drain at the same rate as undisturbed surficial soils due to the presence of underlying debris. The location of these TCM anomalies corresponds very well to the approximate footprint of the historic structures (**Figure 5**).

At the mean resistivity depth slice ranges of 3 to 4 and 6 to 7 feet bg, background TCM values are in ranges of 0 to 50 Ohms (**Figure 5**). Unlike the 0- to 1-foot depth range, where TCM anomalies are less resistive than background values, TCM anomalies in these deeper depth ranges are more resistive than background values. The more resistive TCM anomalies identified at these mean resistivity depth slice ranges are interpreted as poorly compacted, more resistive fill materials that were backfilled into building footprints. The location of these TCM anomalies corresponds well to the approximate footprints of the historic structures (**Figure 5**).

5.0 CONCLUSION

THG completed a geophysical investigation at the St. Xavier Nature Preserve that formerly housed the Saint Xavier's Academy and Convent, both of which were destroyed by a fire in 1972 (**Figure 2**). The objective of the geophysical investigation was to image the subsurface of the site to identify anomalies that may be indicative of the historic building footprint and/or remaining buried debris from the building's demolition. The geophysical investigation included the use of 3-D GPR and TCM methods (**Figure 3**).

GPR data collected at the site display several areas of consistently strong reflectors over different depth ranges that correlate very well to the approximate locations of the footprint to these historic structures as determined through historic aerial imagery (**Figure 4**). The correlation of GPR anomalies and the footprint to these historic buildings is interpreted to represent the presence of more conductive surficial soils that were placed over buried building debris and poorly compacted debris that were backfilled into these building footprints during the structure's demolition.

TCM data collected at the site displays several anomalous features over different depth ranges that correlate very well to the approximate locations of the historic structures (**Figure 5**). At the shallowest mean resistivity slice depth range, the TCM data display several low resistive anomalies that are interpreted as areas where clay-rich soils were used to cap buried building debris within the footprint of the historic structures and/or areas where near-surface soils were unable to drain at the same rate as undisturbed surficial soils due to the presence of debris below. Deeper mean resistivity slice depth ranges display resistive TCM anomalies that are interpreted as poorly compacted, more resistive fill materials that were backfilled into the historic building footprints.

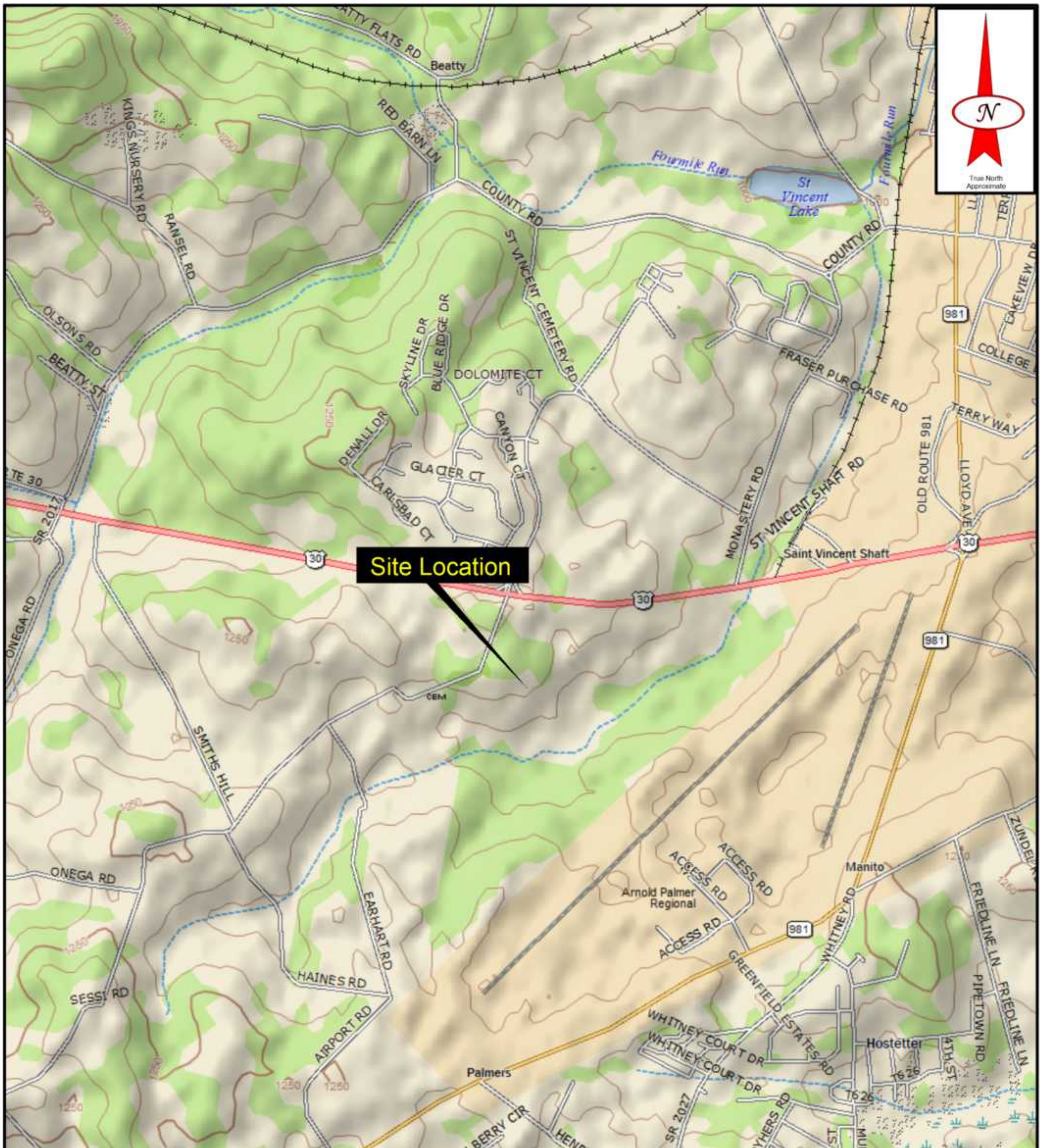
6.0 REFERENCES

Aarhus GeoSoftware (2021). Aarhus Workbench. Software. Skolegade 21, 18000 Aarhus C, Denmark.

Annan, A. P. & W. Cosway (1992). Ground Penetrating Radar Survey Design, Symposium on the Application of Geophysics to Engineering and Environmental Problems 1992. January 1992, 329-351

McNeill, J. D. (1980). Electromagnetic terrain conductivity measurement at low induction numbers. Geonics Limited. Technical Note. TN-6. 1-15 pp.

McQuown, M. S., S. R. Becker, et al. (1991). Subsurface characterization of a landfill using integrated geophysical techniques. Proceedings of the Fifth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, May 13-16, 1991, Las Vegas, NV, Water Well Journal Publishing Co.



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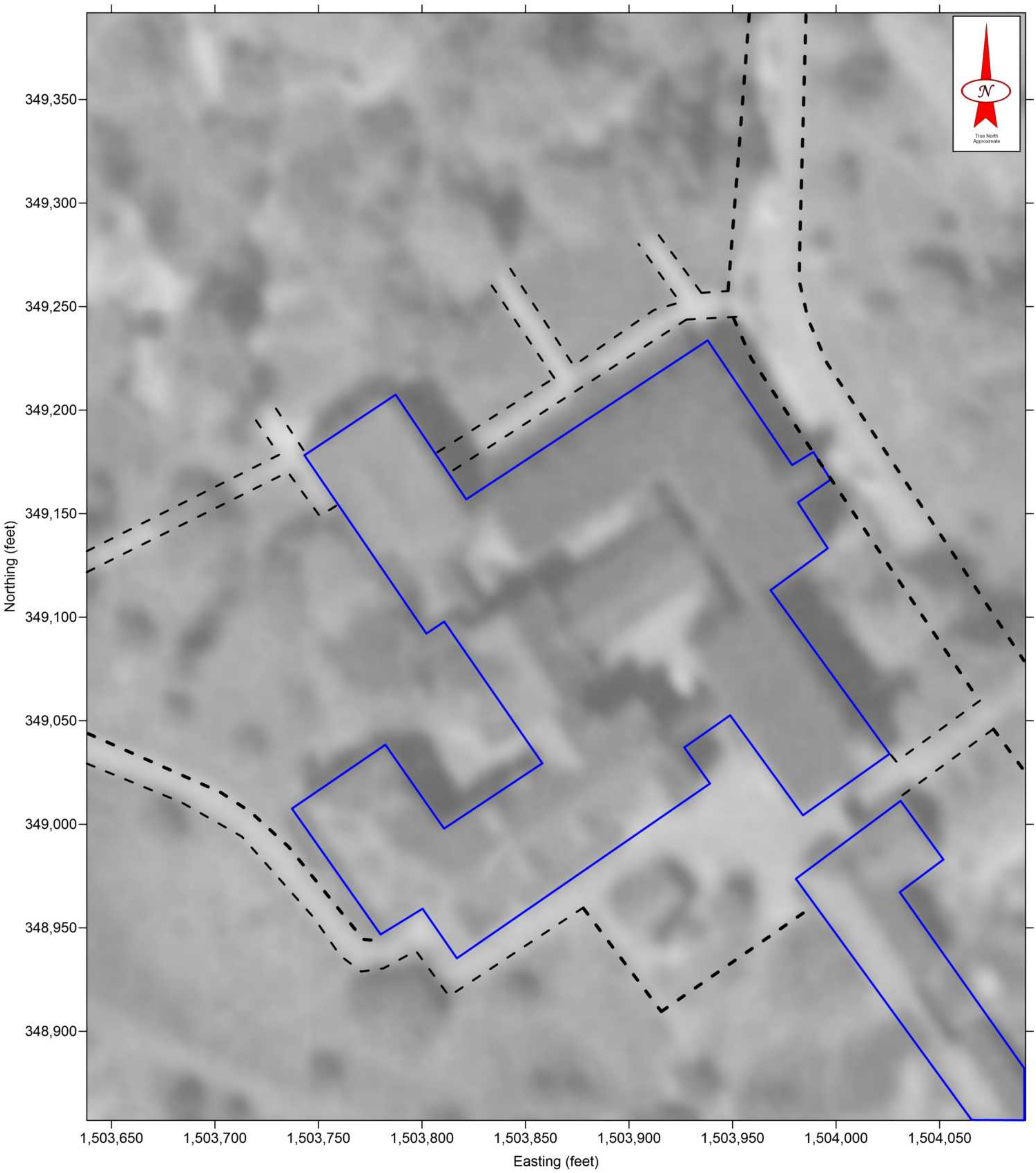
0 ft 1000 ft 2000 ft 3000 ft 4000 ft 5000 ft

Figure 1
Site Location Map

Geophysical Investigation
106 Saint Xavier's Road
Latrobe, Pennsylvania

SCALE: 1:24,000	PROJECT NO.: 11612	DRAWING NO.: DWG11612F1
DATE : 2/2/2024		
DRAWN BY: MES	SOURCE: 1993 Latrobe (PA) USGS 7.5 Minute Topographic Quadrangle	
CHECKED BY: PJH		



SCALE: 1 inch = 50 feet

0 ft 50 ft 100 ft 150 ft 200 ft

Legend

Approximate Historic Building Footprint

Approximate Walk/Driveway

Notes

Geophysical survey was conducted November 20-21, 2023, using an Impulse Radar Raptor 3D GPR array equipped with 450 MHz antennas and a GF Instruments CMD Mini-6L frequency-domain electromagnetic conductivity meter.

Real-time positioning of data using Trimble Geo-7XH and Juniper Systems Geode GPS equipped with ATLAS RTK corrections and set to NAD 1983 US State Plane (Pennsylvania South) in feet.

Locations are approximate.

Historic Imagery Source:
USDA Farm Service Agency. 1957-1962 Statewide B&W. PASDA.

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DRN	MLT	1-30-24
DES	AXB	1-11-24
CHK	PJH	2-2-24
REV		
PROJ. MGR.	KSM	2-2-24
SCALE:	1 inch = 50 feet	
SOURCE:	See Notes	

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DRAWING NO.: **Figure 2**
1957-1962 Historic Aerial Imagery

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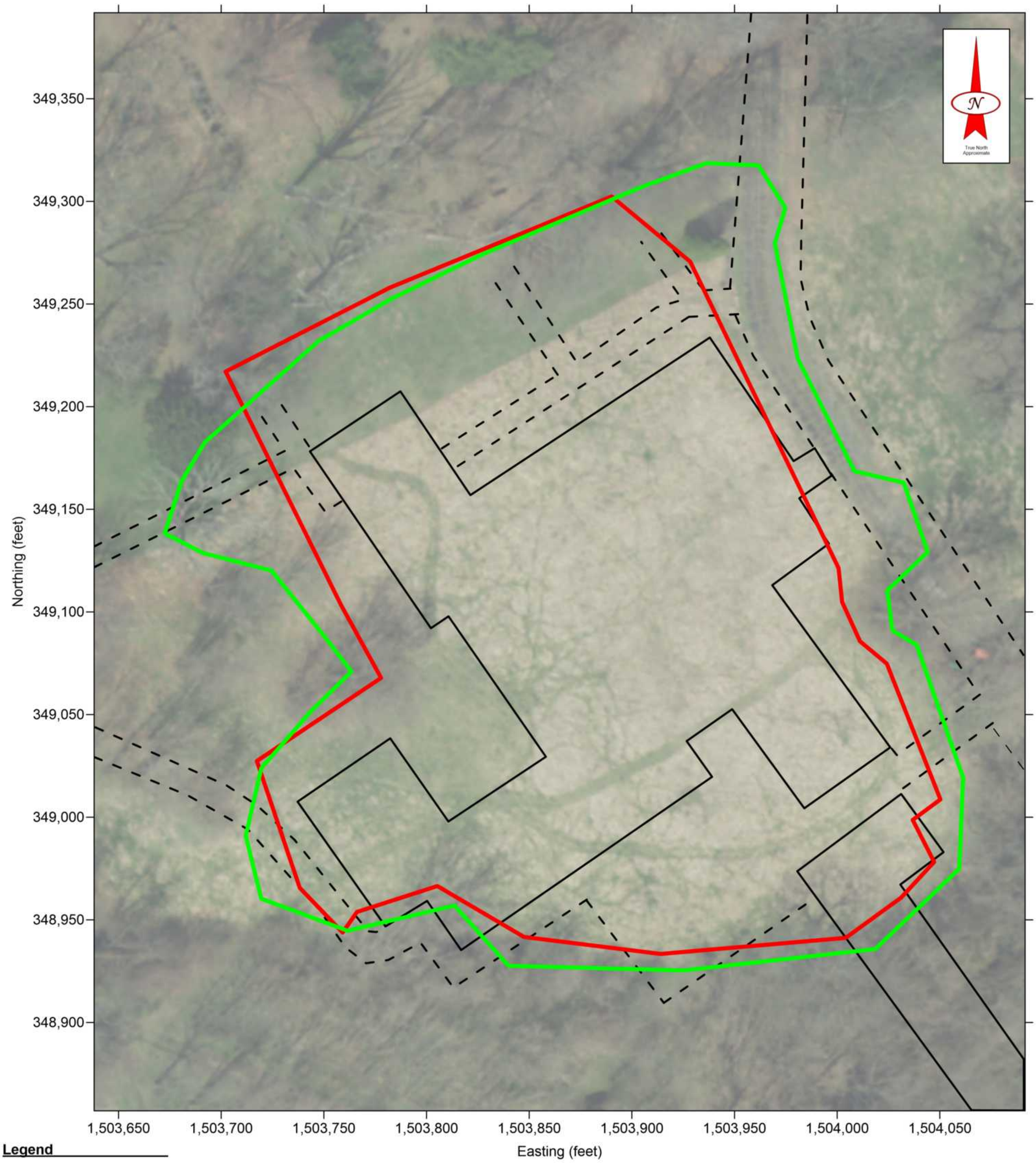
PROJECT NO.: 11612

SHEET TITLE: DWG11612F2



Legend

Approximate Walk/Driveway Footprint (historic imagery fig. 2)

Approximate Building Footprint (historic imagery fig. 2)

3-D GPR Survey Area (Fig. 4)

Terrain Conductivity Survey Area (Fig. 5)

SCALE: 1 inch = 50 feet

0 ft | 50 ft | 100 ft | 150 ft | 200 ft

Notes

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DRN	MLT	1-30-24
DES	AXB	1-11-24
CHK	PJH	2-2-24
REV		
PROJ. MGR.	KSM	2-2-24
SCALE:	1 inch = 50 feet	
SOURCE:	PASDA, 2018	

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DRAWING NO.: **Figure 3** Geophysical Survey Layout Map

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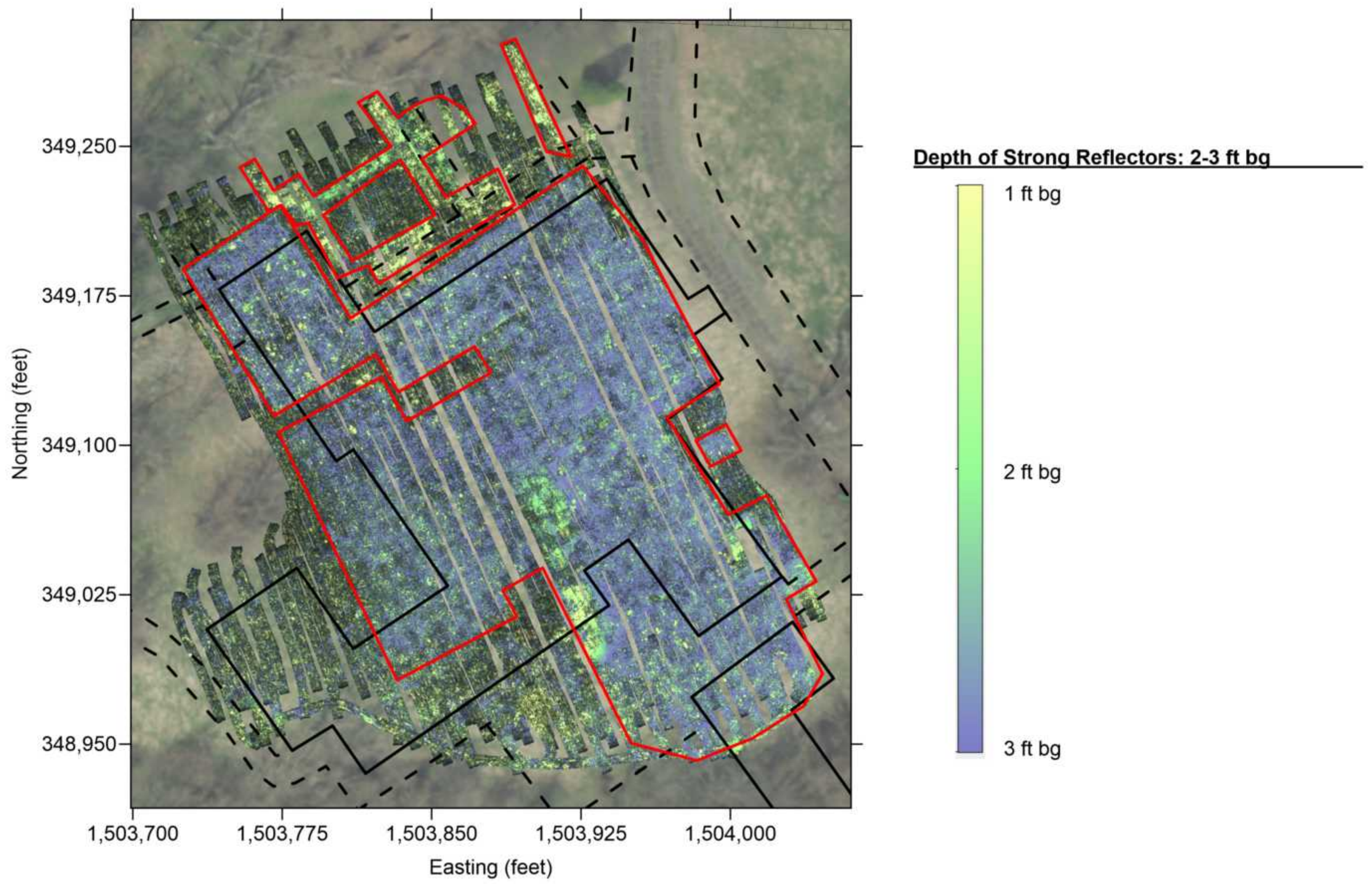
SHEET TITLE: DWG11612F3



True North Approximate

Legend

- Approximate Walk/Driveway Footprint (historic imagery Fig. 2)
- Approximate Building Footprint (historic imagery Fig. 2)
- GPR Anomaly

Notes

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Real-time positioning of data using Trimble Geo-7XH and Juniper Systems Geode GPS equipped with ATLAS RTK corrections and set to NAD 1983 US State Plane (Pennsylvania South) in feet.

Locations are approximate.

SCALE: 1 inch = 75 feet

0 ft | 75 ft | 150 ft | 225 ft

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DRN	MLT	1-30-24
DES	AXB	1-11-24
CHK	PJH	2-2-24
REV		
PROJ. MGR.	KSM	2-2-24
SCALE:	1 inch = 75 feet	
SOURCE:	ImpulseRadar CrossPoint	

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DRAWING NO.: Figure 4
3-D GPR Composite Depth Slices

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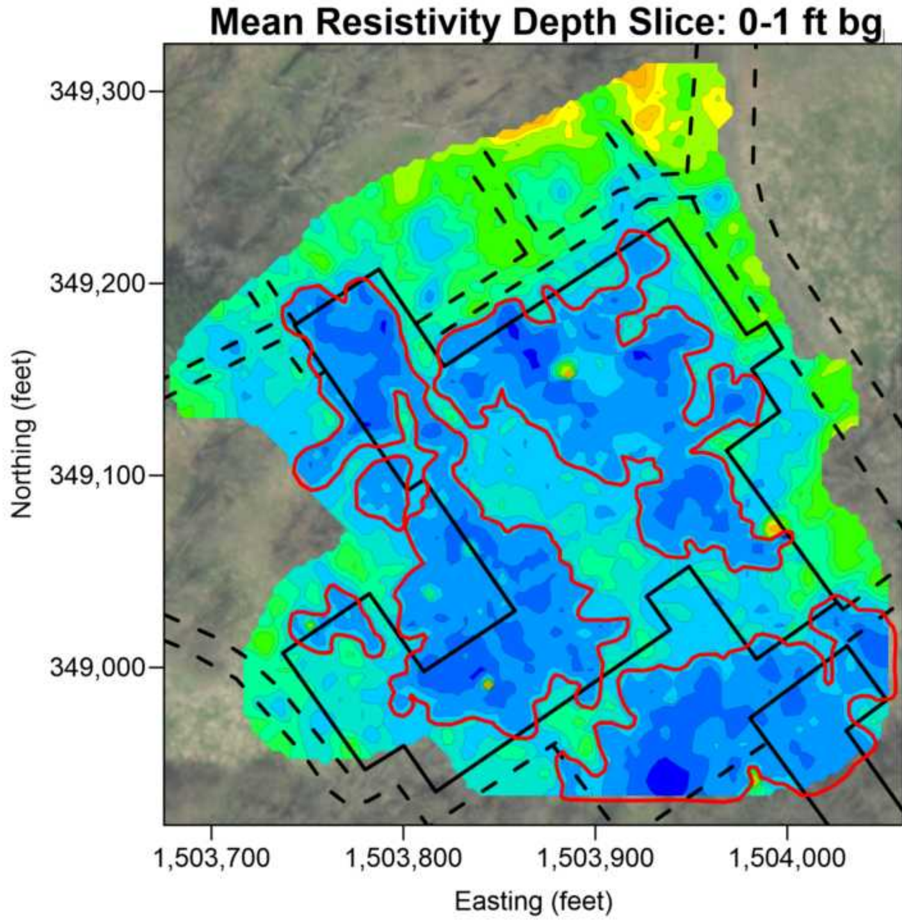
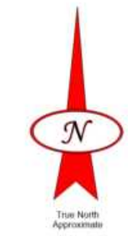
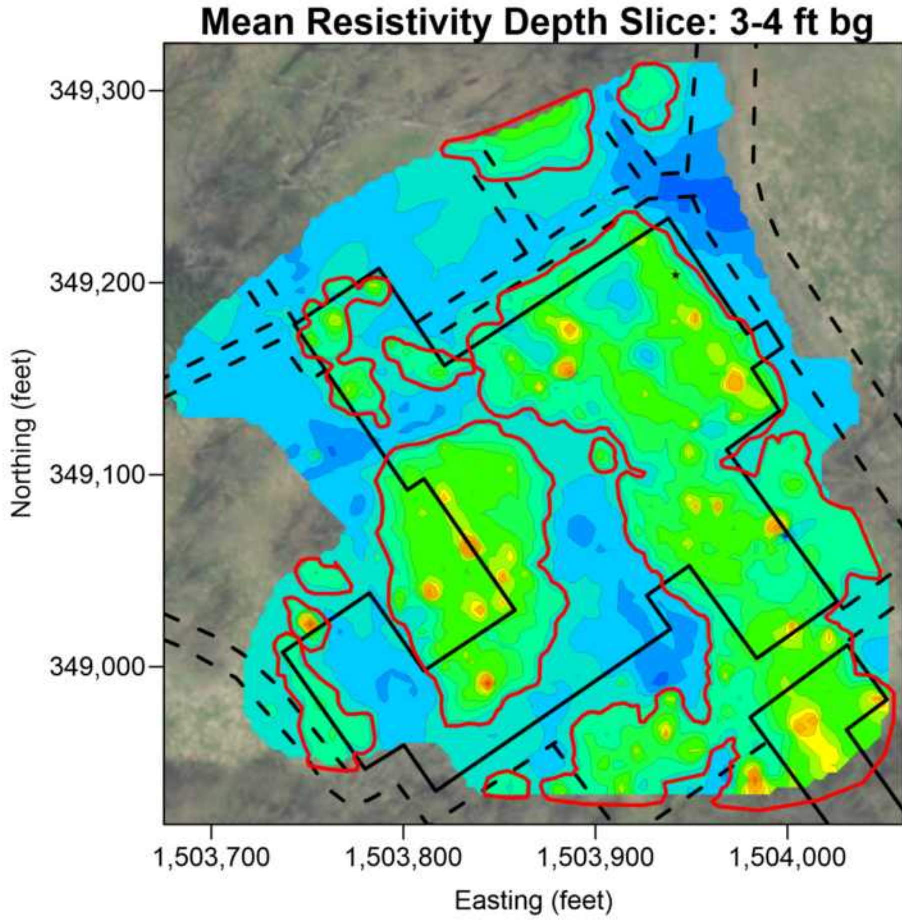
SHEET TITLE: DWG11612F4

Mean Resistivity Depth Slice: 0-1 ft bg

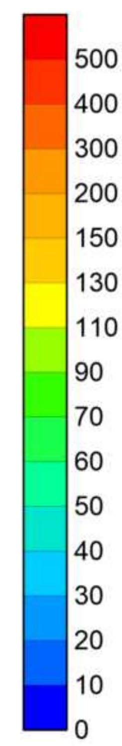




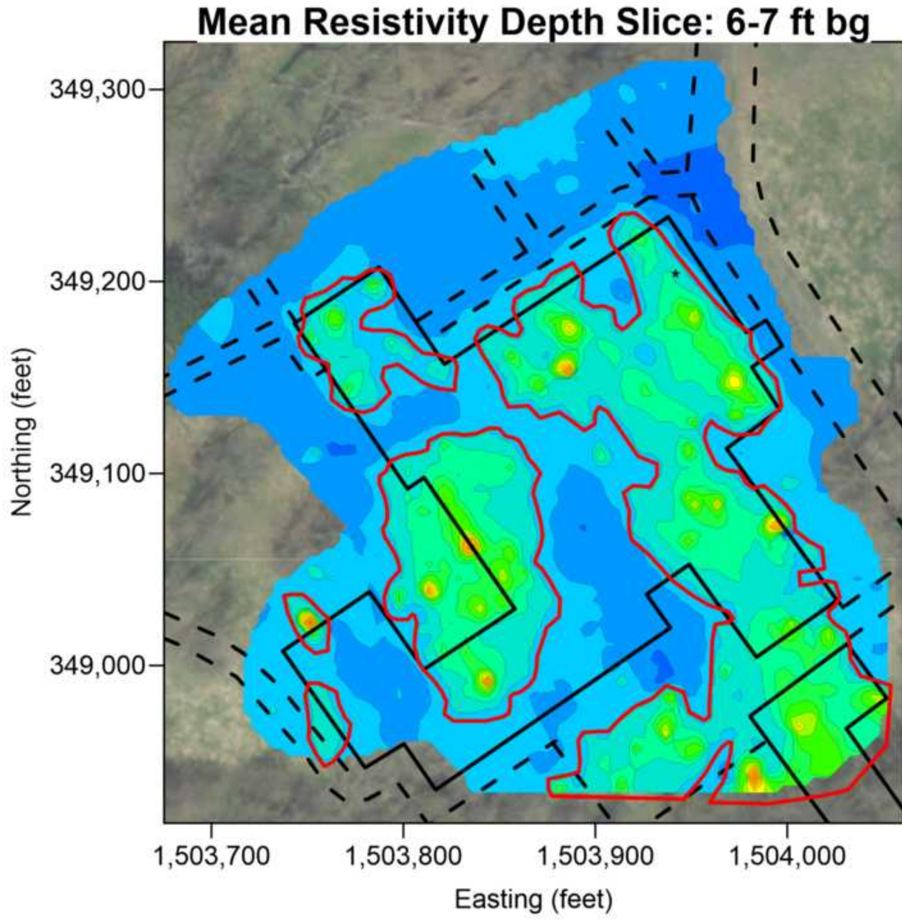
Mean Resistivity Depth Slice: 3-4 ft bg



Resistivity (Ohms)



Mean Resistivity Depth Slice: 6-7 ft bg



Legend

- Approximate Walk/Driveway Footprint (historic imagery Fig. 2)
- Approximate Building Footprint (historic imagery Fig. 2)
- TCM Anomaly

Notes

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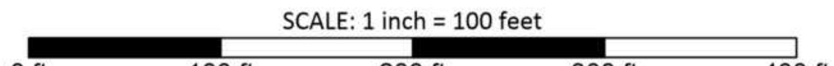
Locations are approximate.

SCALE: 1 inch = 100 feet



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DRN	MLT	1-30-24
DES	AXB	1-12-24
CHK	PJH	2-2-24
REV		
PROJ. MGR.	KSM	2-2-24

SCALE: 1 inch = 100 feet

SOURCE: Aarhus Workbench

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DRAWING NO.: **Figure 5**
TCM Data: Mean Resistivity Depth Slices

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