

ELECTRICAL RESISTIVITY SURVEY
Camargo Canyon Sewer Line Extension
Camargo Road - Madeira, Ohio

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1.0 Introduction

The area under investigation lies along an approximately 1,000-foot-long proposed sewer-line extension located within Camargo Canyon, east of Camargo Canyon Drive in Madeira, Ohio. The Camargo Canyon site is covered with heavily vegetated areas and tree lines. There are multiple clearings and "grassy paths" to the west of the railroad tracks on the site. A creek valley is present across the northern portions of the site and several culverts have been previously installed in the area. The intent of this geophysical project was to characterize the subsurface prior to construction and installation of the proposed sewer-line extension. Three geophysical electrical resistivity (ER) survey lines were used to determine subsurface conditions along the new sewer line. A vicinity map showing the location of the site is included as Figure 1 and a site map showing the location of the survey area in relation to the project site is illustrated in Figure 2. Figure 3 is a detailed aerial view or map illustrating the approximate locations of the ER lines laid out across the property in order to conduct the geophysical survey. Figure 4 is a geologic map of the site and the surrounding area.

2.0 Technical Background

The challenge for this project was to select the correct non-intrusive tools and techniques to evaluate the geological properties at the site. In general, a variety of geophysical techniques can be applied to the mapping of subsurface features; however, certain methods, sensitive to a range of contrasting physical properties, can possess attributes that make them more suitable than others, depending on the site-specific conditions. Contrasting physical properties that typically are observed to be useful for mapping soil and bedrock include electrical conductivity or resistivity, acoustic velocity, density, and magnetic susceptibility. Of these, electrical resistivity is commonly determined to have the greatest range of contrast and is most applicable for detailed characterization of the near subsurface. Given the desired depth of investigation (approximately 50 feet), and the need to image both the lateral and vertical extent of possible features, two-dimensional electrical resistivity (2-D ER) was selected as the method of choice to document the soil-sediment-rock profile beneath the site. A description of techniques used in this field study is presented in the portion of the report immediately following the Geological Setting section.

2.1 Geological Setting

The site possesses soils of the Eden silty clay loam as is noted in the USDA soil survey for Hamilton County, Ohio. This soil complex consists of silty clay loam for the first 5 inches of the subsurface, transitioning to silty clay from 5 to 28 inches and eventually to weathered bedrock at depths of 28 to 30 inches. The Eden silty clay loam is well drained but is not considered prime farmland. The parent material for the Eden silty clay loam is residuum weathered from limestone and shale. These soils typically mantle slopes of 25 to 40 percent. Overall, the site possesses brown to dark brown silty clay loam soils with weathered rock positioned very close to the surface.

Study of the interactive map viewer on the United States Geological Survey (USGS) National Geologic Map website reveals that the central and eastern portions of the site is positioned atop the undifferentiated Miamitown Shale and Fairview Formation and the remaining portion of the site, particularly areas of higher elevation, lies atop the Grant Lake Formation. The Miamitown Shale and Fairview Formation are stratigraphically immediately below the Grant Lake and are exposed at lower elevations within the valleys present on the site. The Miamitown Shale in southwestern Ohio consists of approximately 90% shale and mudstone with minor interbeds of limestone. The Miamitown Shale is approximately one to 10 meters thick. Fossils within this unit include gastropods and pelecypods. The Fairview Formation is noted to be 20 to 35 meters thick and is composed of subequal proportions of thin-bedded, fine-to-coarse grained skeletal limestone (50%) and gray, thin-bedded shales (50%) and minor siltstone. The Grant Lake Formation consists of primarily interbedded, calcareous, sparsely fossiliferous shale and planar-

bedded, fossiliferous, argillaceous limestone. Subordinate amounts of nodular-, wavy-, and irregular-bedded argillaceous limestone and calcareous, fossiliferous shale occur throughout the unit. The mean shale quantity percentage values range from 50% to 60% (Schumacher, Swinford, and Shrak, 1991). The generalized geologic map of the site (Figure 4) that specifically shows that the Grant Lake, Miamitown Shale, and Fairview Formations comprise all of the bedrock stratigraphic units for the site.

2.2 Two-Dimensional Electrical Resistivity (2-D ER)

Electrical resistivity is one of the most widely varying of the physical properties of natural materials. Certain minerals such as native metals and graphite, conduct electricity via the passage of electrons; however, electronic conduction is generally very rare in the subsurface. Most minerals and rocks are insulators, and therefore electrical current preferentially travels through water-filled pores in soil and rock via the passage of the free ions in pore waters *(i.e.*, ionic conduction). It thus follows that the degree of saturation, interconnected porosity, and water chemistry (*i.e*., concentration of total dissolved solids or TDS) are the major controlling variables of the resistivity of a given soil or rock. In general, electrical resistivity directly varies with changes in these parameters.

Fine-grained sediments, particularly those that are clay-rich are excellent conductors of electricity, whereas relatively coarser-grained materials such as sand and gravel in contrast, are much more resistive stratigraphic units. Carbonate rocks (*i.e.*, limestone and dolomite or dolostone) are very electrically resistive when they are unfractured, but they can possess significantly lower resistivity values if fractured and/or weathered and solutioned. In contrast, shale or clay-rich materials quite conductive. Void spaces in a clay matrix for example could actually appear to be more resistive than the clay. However, if after a protracted drought, sufficient rain falls to infill void spaces and the clay does not have sufficient time to absorb moisture, the resistive void can appear to be conductive. Thus, the interpretation of geophysical data requires the consideration of many lines of evidence.

2.3 Electrical Resistivity Methods

While the resistivity meter used in sounding and profiling surveys typically has four electrodes connected via four separate cables, a multi-electrode system has 25 or more electrodes connected to the resistivity meter via a multi-core cable (see inset Diagram 1). Commercial multi-electrode systems first appeared in the late 1980s and since then have become a standard tool in many geophysical organizations. An internal switching circuitry controlled by a programmable microcomputer or microprocessor within the resistivity meter automatically selects the appropriate four electrodes for each measurement. This enables almost any array configuration to be used. By making measurements with different spacing at variable locations along the cable, a 2-D profile of the subsurface is obtained. Together with the parallel development of fast and stable automatic data inversion techniques that could be implemented on commonly available microcomputers, 2-D electrical imaging surveys became widely used in the early 1990s. There are many commercial multi-electrode resistivity systems capable of connecting up to several hundred electrodes at once, with electrode spacing practically varying from one to 20 meters. A recent development over the past 10 years is multi-channeled systems that can greatly reduce the survey time. Only two electrodes can be used as the current electrodes at a single time, but the voltage measurements can be made between many different pairs of potential electrodes. Commercial systems with four to 10 channels are widely available (Loke et al., 2013).

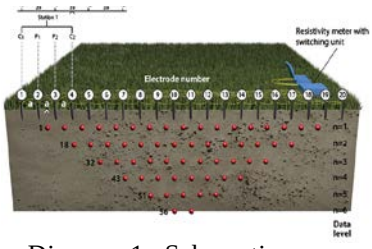


Diagram 1. Schematic diagram of a multi-electrode system, and a possible sequence of measurements to create a 2-D pseudosection.

3.0 Procedures

Standard Operating Procedures (SOPs) for ER begins with a site safety check. Each site is evaluated for possible safety concerns and the surveys are modified to take these into account. After the location of the survey line is determined, the overall distance of the survey is measured. The desired resolution is factored in and a spacing optimal to these parameters is determined. Tape measures are laid out and stainless-steel electrodes are placed into the ground at pre-determined positions. Depth of emplacement of the electrodes is determined by field conditions. Where possible, electrode stakes are driven approximately six inches below surface to minimize contact resistance. A few ounces of a salt-water solution are then poured at the base of each stake where needed to decrease contact resistance. The electrical resistivity cables are unrolled, and an electrode bulb is placed at each stake. The bulbs are then attached to the stakes. The AGI SuperSting R8/IP and Swift switch box are in turn attached to the cables. A final check of the setup is made to ensure proper working order of the laid-out survey line. A contact resistance test is then completed, and data recording is initiated.

3.1 ER Lines Conducted

A total of three ER lines were conducted for the geophysical investigation (Table 1; Figures 5 through 7), along the area of the proposed sewer line extension. Line A was positioned roughly perpendicular to the railroad on site and through the "Camargo Greenspace LLC," toward Camargo Road. Line B was placed along the eastern-most "grassy path," subparallel to the railroad, and Line C was conducted roughly perpendicular to Line B. Note that Line A was conducted with 42 electrodes and Line C with 41 electrodes due to limited line length in some portions of the site. Line orientation and electrode spacing (all variable) used for each of these lines are noted in Table 1 and their corresponding locations are depicted in Figure 3. Obtained values for the surveyed lines range from a minimum value of 8.0 (Line A) and 14.0 (Lines B and C), to a maximum value of 215 ohms meters for all lines. A combined dipole-dipole and strong gradient array was used (command file name DDSG) on each line. Two 12-volt batteries were used to power the system. Data were processed using the Advanced Geoscience Inc. (AGI) 2D-EarthImager software and noisy data points were removed. Good contact resistance was achieved, creating a very distinctive or non-scattered dataset requiring minimal removal of interfering data points.

Table 1 – Electrical Resistivity Lines Conducted

Field Name and Processed Name *	Report Figure	Electrode Spacing (feet)	Electrode 1 Position	Last Electrode Position	Length (feet)
CC0524LA	5	4	NW	SE	164
CC0524LB	6	7	SW	NE	385
CC0524LC	7	10	NW	SE	410
Note: See Figure 3 for ER Survey line map locations on the site					
*Naming Nomenclature: **S**ite **N**ame, **M**onth, **D**ay and **L**ine **L**etter					

4.0 Salient Results of Geophysical Survey

4.1 Line CC0524LA

Study of profile CC0524LA (Figure 5) suggests that the upper approximate 35 feet of the subsurface is unconsolidated moist to wet, silt loam, silty clay and clay-rich conductive earth material. These conductive soils are observable across the profile. In the area between stations 20 and 68, a slightly more resistive patch (green grading to orange colors) is present and may represent fill material from previous

culvert installation or removal. The geotechnical report from Ribway Engineering Group reveals a boring, B-005, in close proximity to station 130. B-005, in conjunction with the ER profile, reveals a very stiff to hard, lean clay with sand, gravel, asphalt and brick fragments (fill material) within the area to depths of 18 feet. A small, slightly less conductive zone is found under station 84, approximately 30 feet below the surface, and is likely the area in which a culvert was previously installed.

4.2 Line CC0524LB

The profile for CC0524LB (Figure 6) suggests an eight- to 20-foot-thick layer of conductive silt loam and clay material (blue colors) across the upper portion of the profile. Note that an area of more resistive sand and gravel material (green to orange colors) from stations 335 to 395 are present and is likely fill material from previous culvert installation in the area. This layer of silt loam and clay is considered undulatory and continuous across the profile. Below station 30, the ER data in conjunction with B-004 and near Manhole-2, suggests a transition to shale and interbedded limestone at a general depth of 15 feet. This layer of shale and interbedded limestone (green to orange colors) is continuous across the profile, but contains small lenses of more conductive material (light blue colors). The lenses of conductive material likely indicate an increase in shale composition and a decrease in resistive limestone in these areas.

4.3 Line CC0524LC

Investigation of profile CC0524LC (Figure 7) suggests the presence of thin layer of resistive material (yellow to orange colors) directly beneath the land surface, most likely representing glacial till and/or colluvium. Immediately underlying the colluvium/till unit is an approximate eight- to 20-foot-thick layer of silt loam and clay (green colors with light blue lenses). Approximately ten to 20 feet below the land surface is an eight- to 30-foot-thick layer of fractured shale and limestone (green to light orange colors). At the base of the fractured, weathered rock layer is a thick, continuous layer of interbedded shale and limestone extending to the bottom of the profile. Manhole-4 and boring B-002 lie 15 feet north of station 390. The boring log for B-002 documents moist clays to depths of nine feet with interbedded shale and limestone from nine to 13 feet deep, comparable to the stratigraphic modelled units displayed in the ER profile.

5.0 Summary of Findings

This proposed sewer-line extension is located directly west of Camargo Road in Madeira, Ohio. Based on the ER profiles and comparing boring logs from previously conducted borings on site, there appears to be a fairly continuous, unconsolidated, moist to wet silt loam, silty-clay loam and clay overlying the surveyed areas. This thick layer of silt loam and clay contains large lenses of relatively more resistive material interpreted as fill material in several areas under Profile A and toward the northern portion of Profile B. A thin layer of slightly more resistive material is observable within the first one to two feet of the subsurface across Profile C and is likely colluvium and/or glacial till. Till and colluvium can have quite variable grain size and quartz or silica-rich material (i.e., resistive). Profile C exhibits potentially competent bedrock across the surveyed areas (albeit the absolute value of resistivity is comparatively low), with a thick layer of limestone and interbedded shale approximately 30 to 40 feet below the surface. At lower elevations, in the areas where Lines A and B were conducted, ER data suggests thicker layers of silt loam and clay material and less limestone bedrock at depth in comparison to Profile C. Such an interpretation for lines A and B is consistent with the expectations of relatively great depths to bedrock associated with alluvial valleys filled with colluvial (i.e., downslope wash of sediment) and alluvial or outwash materials (all unconsolidated). Figure 8, Electrical Resistivity Overlay, provides a view of all the profiles in relation to the proposed sewer-line extension.

6.0 Limitations

This study included a limited set of geophysical readings across limited portions of the site. The results and interpretations of the geophysical survey performed are considered generally reliable and were conducted in a manner generally consistent with practitioners in the field of geophysical engineering. The methods used in this investigation are considered reliable; however, localized variations may exist in the subsurface conditions that have not been completely defined at this time. The resistivity results are not unique to geological features and more than one geologic feature or model may give similar results. Therefore, properly conducted soil test borings and other exploratory techniques are necessary to more completely determine the subsurface conditions at the site.

The site features presented on the site base map are for informational purposes only and no representation is made as to the accuracy or completeness of this information. It is recommended that a practicing geosciences or geotechnical engineering professional be contacted prior to conducting verification drilling or excavating activities.

Figure 1 Vicinity Map

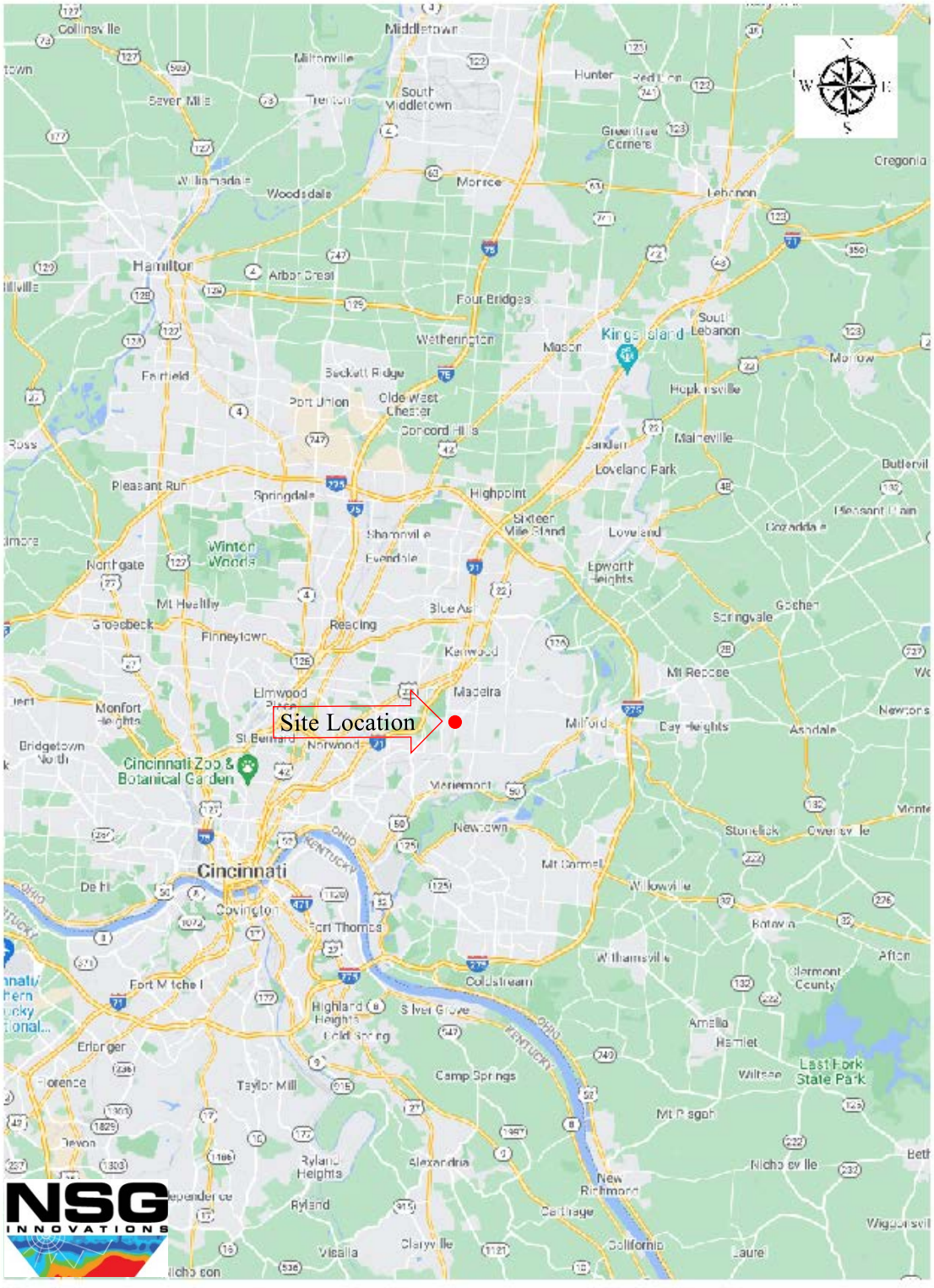


Figure 2 Site Map



Figure 3 Line Location Map

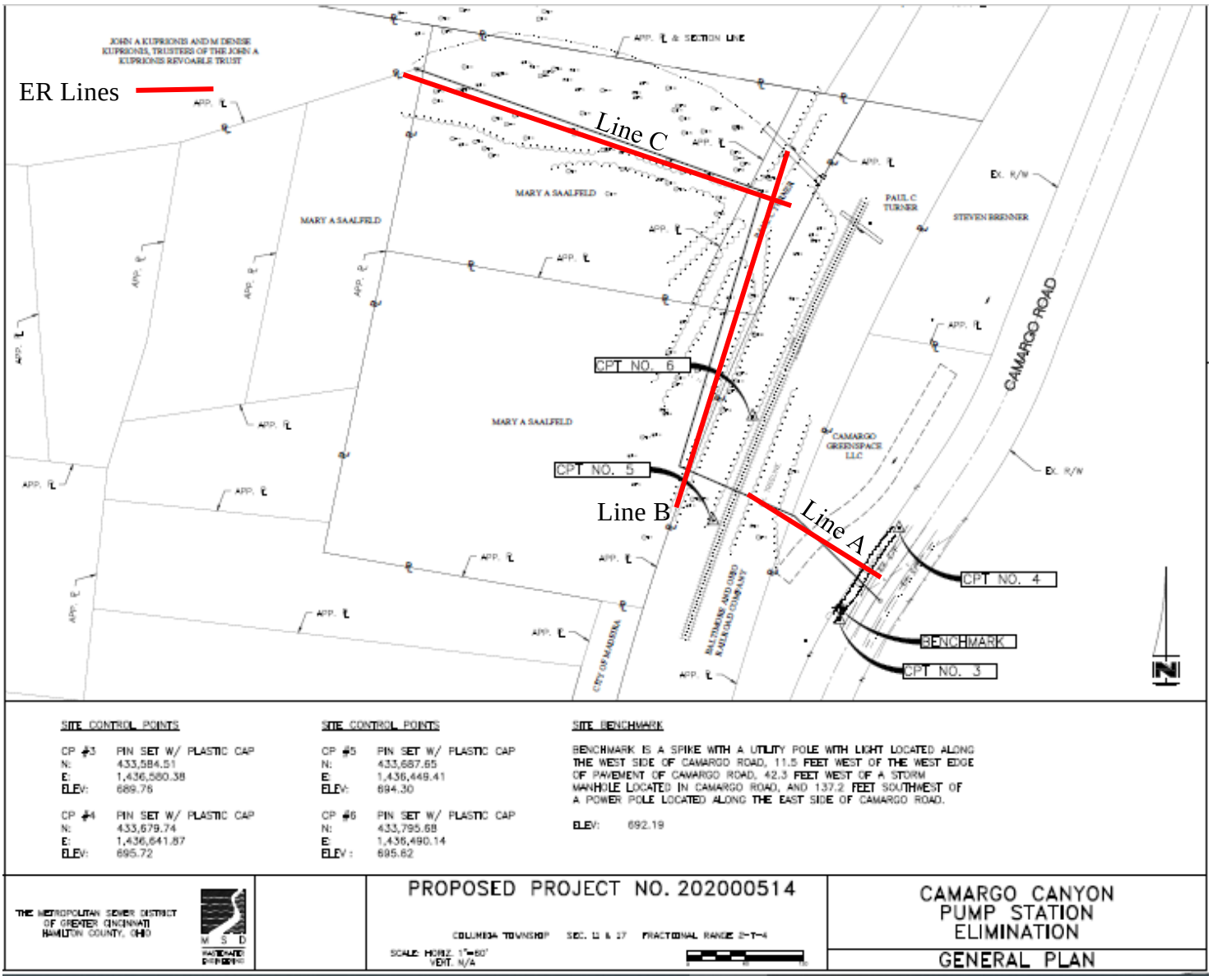
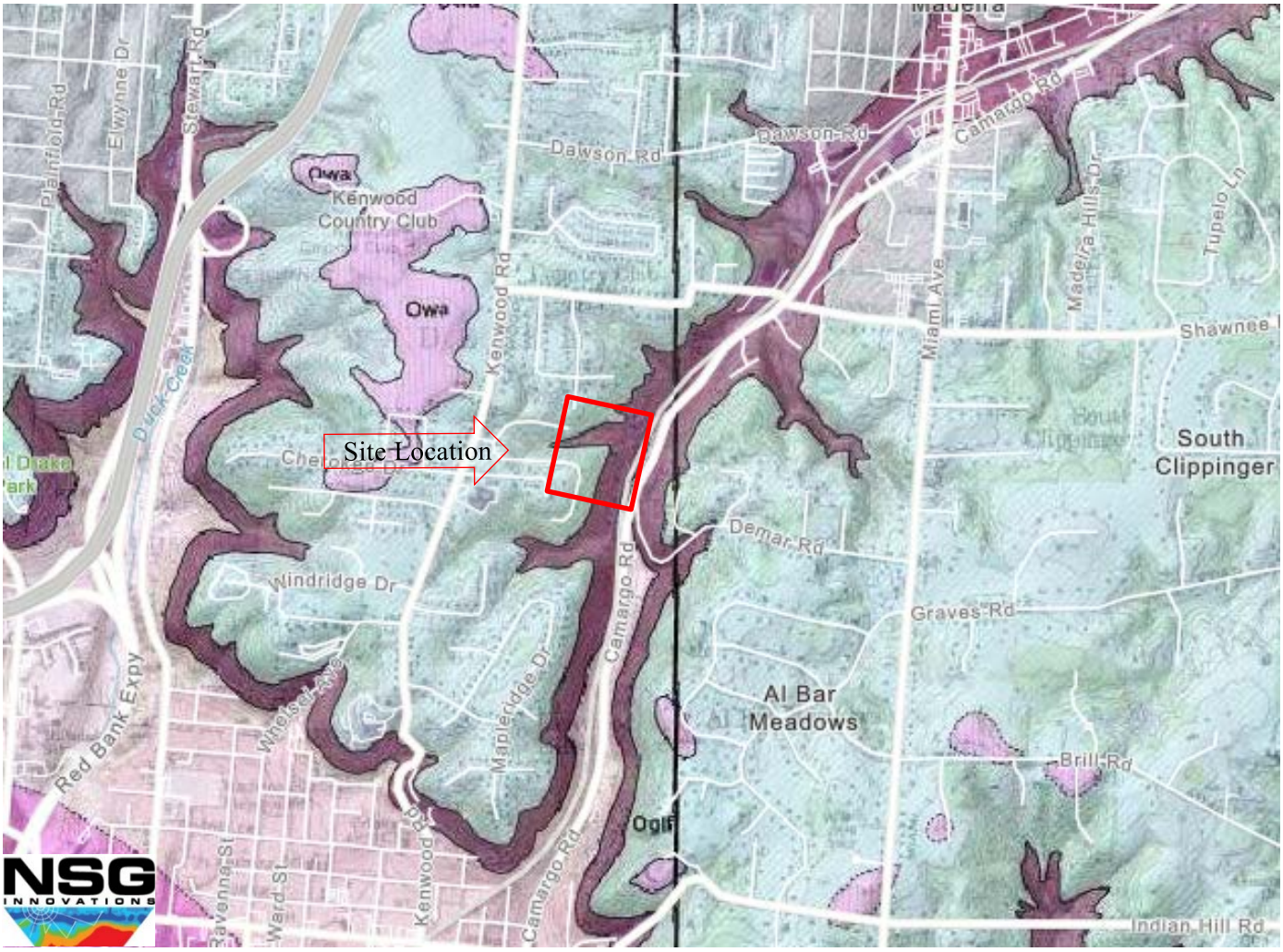


Figure 4 Geologic Map



Owa - Waynesville Formation and Arnheim formation Undivided

Oglf - Grant Lake Formation

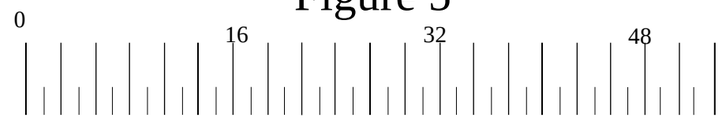
Omf - Miamitown Shale-Fairview Formation Undivided

Ok - Kope Formation

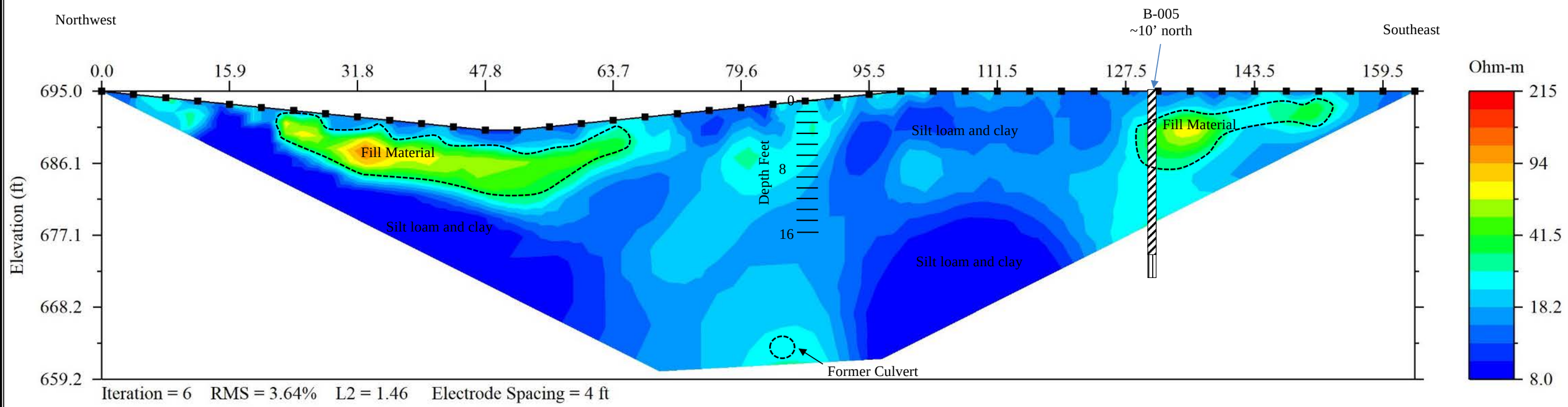
Op - Point Pleasant Formation

Electrical Resistivity Profile CC0524LA
Figure 5

Figure 5 CC0524LA



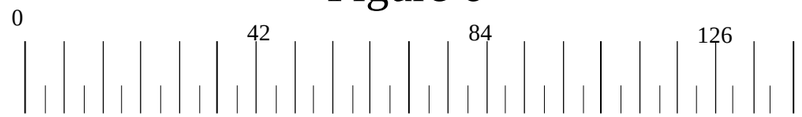
Electrical Resistivity

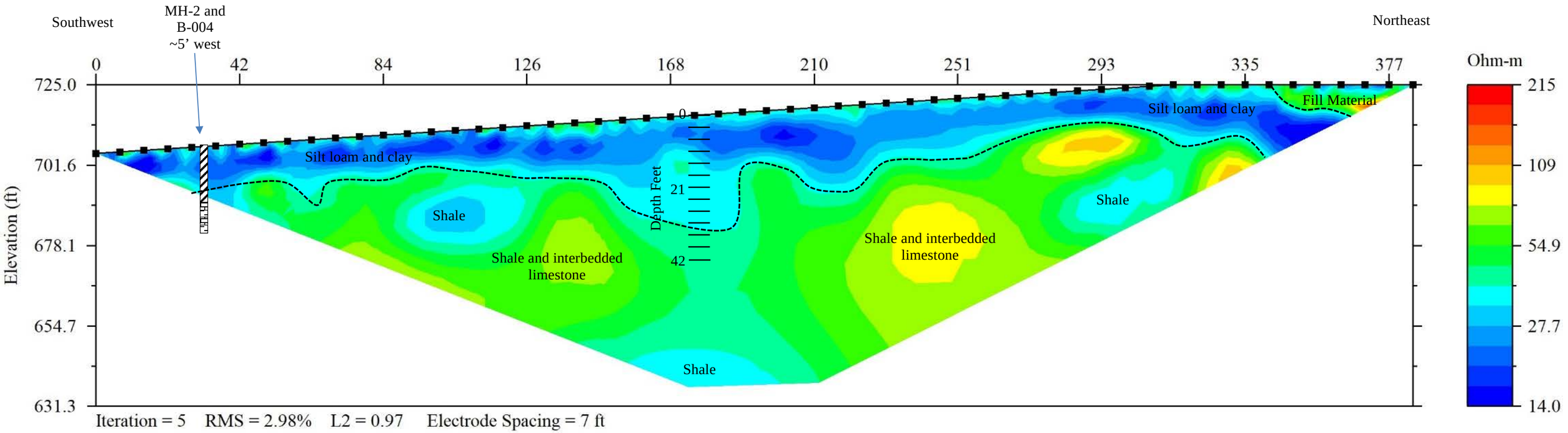


NSG INNOVATIONS	NSG Innovations, LLC Near Surface Geophysics 501 Nutwood Street Bowling Green, KY	Figure 5, Electrical Cross Section Drawn By: Thomas Brackman	Horizontal Scale (feet): as shown Vertical Scale (feet): as shown		Electrical Resistivity Survey MSDGC Camargo Canyon Camargo Road Madeira, OH

Electrical Resistivity Profile CC0524LB
Figure 6

Figure 6 CC0524LB





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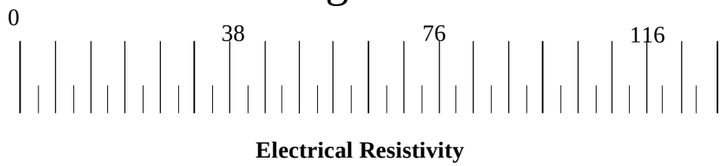
Electrical Resistivity Profile CC0524LC
Figure 7

Figure 7 CC0524LC



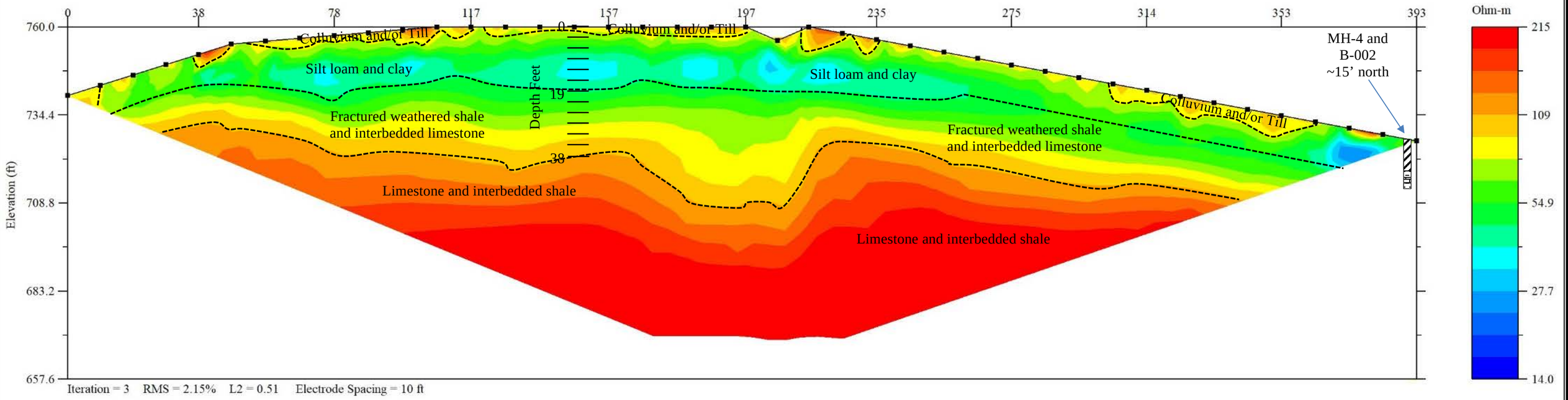


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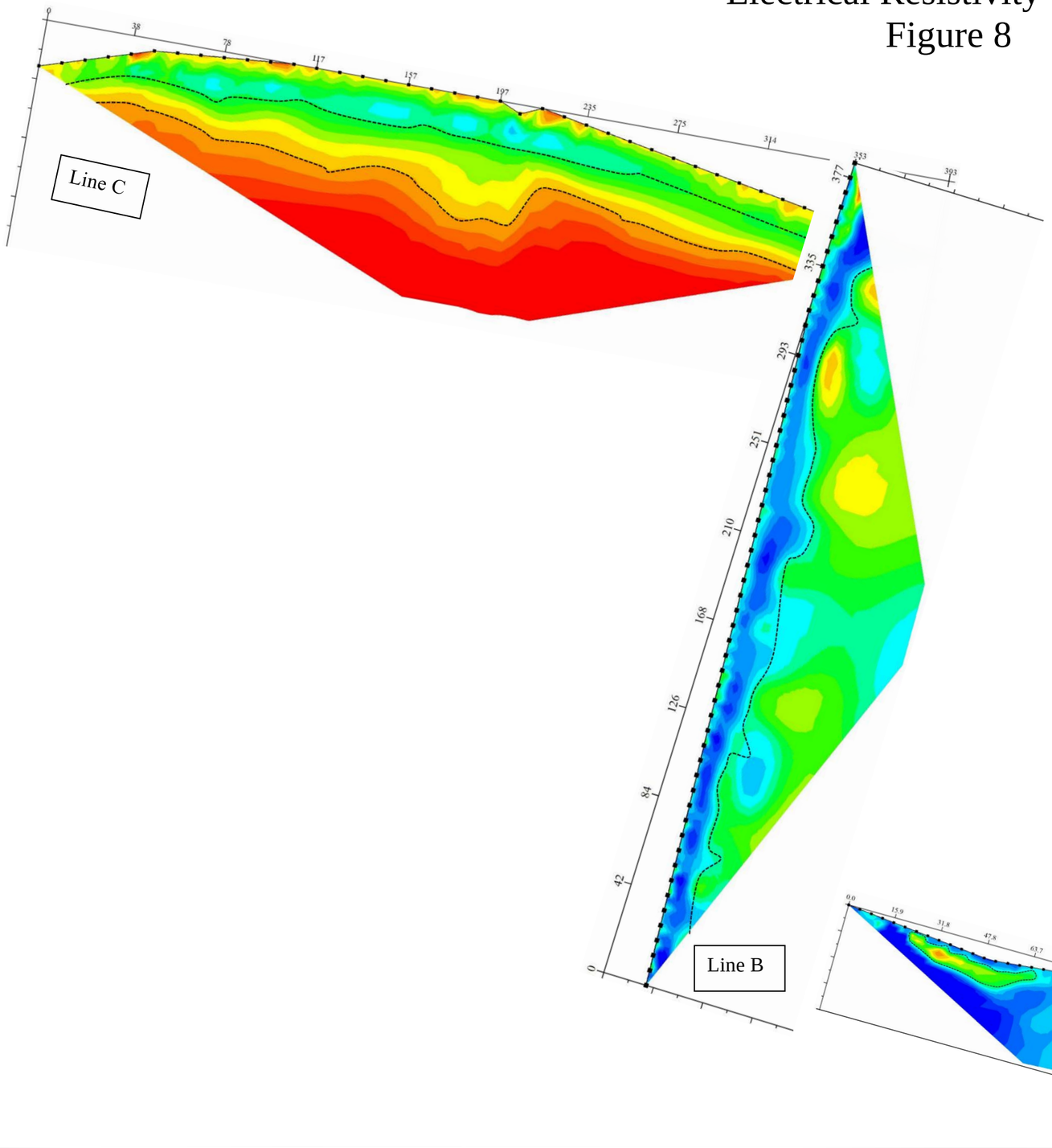
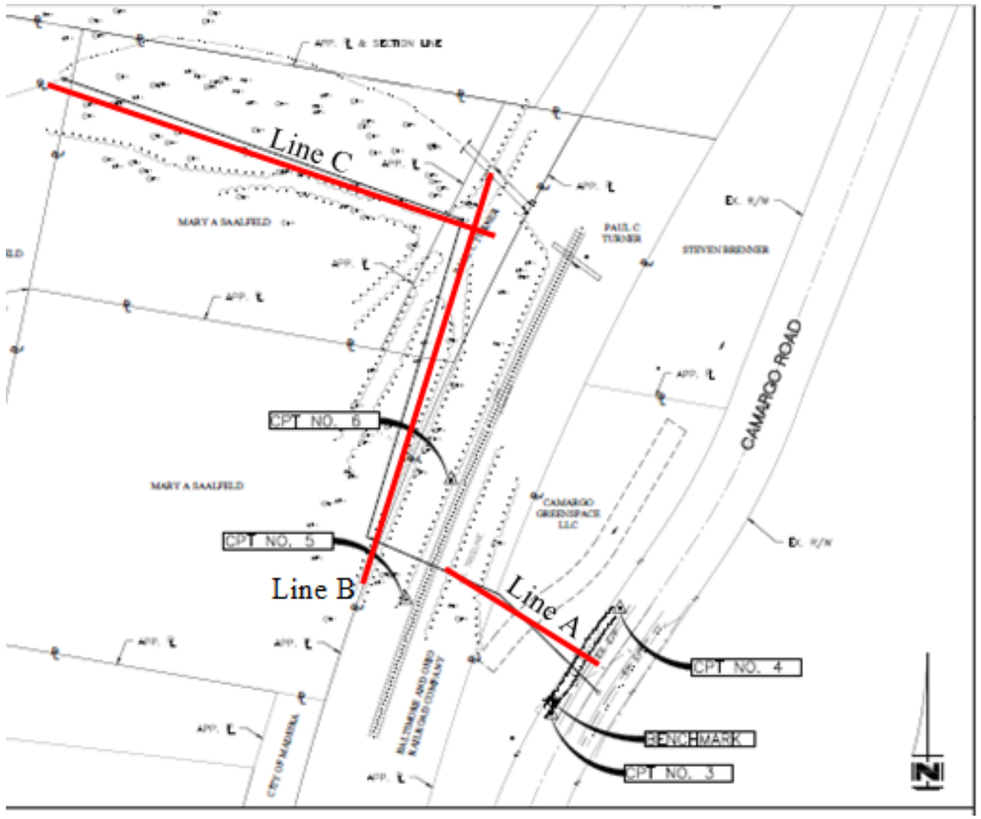
Figure 8 ER Overlay

Electrical Resistivity Overlay
Figure 8





NSG INNOVATIONS	NSG Innovations, LLC Near Surface Geophysics 501 Nutwood Street Bowling Green, KY	Figure 8, Electrical Resistivity Overlay Drawn By: Thomas Brackman	Horizontal Scale (feet): as shown Vertical Scale (feet): as shown		Electrical Resistivity Survey MSDGC Camargo Canyon Camargo Road Madeira, OH