Oxford Sinkhole Investigation

Town of Oxford

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1. Introduction

1.1 Project Overview

GHD Limited (GHD) was retained by the Town of Oxford (the Town) to carry out a geophysical and geotechnical investigation at a sinkhole on the Lions Club property at 4627 Main St., Oxford, NS (the Site, Figure 1). The development of a sinkhole at the Site has created an unplanned issue for the Town with regard to public safety and infrastructure stability. With known geological conditions in the region to promote sinkhole development (karst topography, regional bedrock conditions, geologic faults, etc.), the Town contracted GHD to provide project management and technical execution of the overall program.

1.2 Project Scope and Objectives

The scope of the project is to characterize the subsurface conditions within the vicinity of the sinkhole and nearby infrastructure with the following objectives:

- Determine the lateral and depth extent of the active sinkhole;
- Determine if the active sinkhole is connected to other karst features in the immediate area with the potential for further growth, or if other additional fractures, fissures, voids or caverns exist at the Site; and
- Determine if the sinkhole poses an immediate risk to the public, businesses, and critical infrastructure (utilities and Highway 321).

In order to achieve these objectives, a geophysical and follow-up geotechnical program were carried out to characterize the subsurface conditions within the vicinity of the active sinkhole and throughout the Lions Club property. The program was designed to provide critical information pertaining to subsurface conditions, such as depth of overburden and bedrock, presence and extent of voids, and overburden and bedrock strength.

Geophysical surveys provide a safe, non-intrusive and cost-effective method of collecting valuable subsurface information over a large area in a relatively short period of time. Geophysical data provides the ability to imagine subsurface conditions in two-dimensions (laterally and with depth) and help to optimize any subsequent intrusive investigations. This is especially important for geohazard programs, as geophysical surveys can often access areas that larger equipment (such as drill rigs, excavators, etc.) cannot, due to safety and ground stability concerns.

The follow-up geotechnical program was designed to provide valuable intrusive information at the Site, and to target results of the geophysical program. Together, the geophysical and geotechnical investigations provide critical subsurface information and allow for Site-wide interpretations regarding subsurface conditions.

1.3 Site Background

The focus of this technical report concerns the geophysical and geotechnical results, as per the objectives listed above. As such, this report is not intended to provide an extensive background on sinkhole development or regional geology, but rather focus on the current subsurface conditions at the Site. Existing literature regarding sinkholes, karst topography, and regional geology of Nova Scotia can be found in the references section of this report (not all are referenced in this report). In addition, a forthcoming report by Nova Scotia Energy and Mines will provide site-specific information pertaining to geology, hydrology, sinkhole monitoring, and additional details relevant to the Site (Tizzard et al., in press).

1.3.1 Sinkhole Identification

Members of the Lions Club first observed subsidence at the western end of the parking area at the Site in July, 2018. Over the following weeks, further subsidence continued and on August 20, 2018 a sudden collapse occurred and a sinkhole formed at the surface. The surficial extents of the sinkhole continued to expand over the subsequent months, to the point that the sinkhole currently measures approximately 40 meters across at its widest extent (southwest to northeast) in June, 2019.

At the time of this report, sinkhole growth at surface appears to have slowed, although new surface cracks continue to form in the immediate area surrounding the sinkhole. These cracks could be associated with continued growth of the sinkhole, or with the natural settling of sinkhole walls to reach their angle of repose.

1.3.2 Regional Geology

The following text is modified from a forthcoming report regarding the sinkhole by Nova Scotia Department of Energy and Mines (Tizzard et al., in press).

Surficial geology of the Oxford region is characterized by a combination of glacial and non-glacial sediments. Within the area of the Site, the surficial geology typically consists of two units; non-glacial alluvial deposits including gravel, sand, silt, minor clay content, and organics; and, Eatonville-Hants glacial till, which is characterized as a stony, sandy till (Surficial Geology of Cumberland, Colchester, and Hants Counties (Map 88-13, Sheet 10).

The Oxford Fault, which is mapped as striking southwest to northeast along the north side of Salt Lake, divides the bedrock geology at the Site between Ragged Reef Formation of the Cumberland Group and undivided Mississippian rocks of the Windsor Group. The Windsor Group consists of interstratified red beds, evaporates, and carbonates, which are believed to be the source of extensive karst and sinkholes in the region. Evaporite and carbonate rocks include gypsum, salt, anhydrite and limestone, all of which are variably soluble in groundwater. The Windsor Group also contains mudstone, minor sandstone, and conglomerate, whereas the the Ragged Reef formation is characterized by sandstone, conglomerate, mudstone, rare thin coal seams and bituminous limestone beds.

Evaporitic rocks and sinkholes in the Oxford area were recorded in early geological bedrock maps in 1886 (Barlow and Giroux 1886) and 1938 (Norman and Bell 1938). Bell (1944) attributed the formation of Black, Slade, Vickery and Park (Salt) lakes to the dissolution of water-soluble bedrock resulting in groupings of interconnected sinkholes. Subsequent mapping by Ryan et al (1990) further defined the area as an 'area of extensive karst with sinkholes and gypsum outcrop'. Bedrock in the Oxford area is overlain by 3 to 30 meters of sand, glacial till and fluvial deposits, obscuring the surface expression of the karst (Stea and Finck 1988). A thick deposit of gravelly sand conceals bedrock exposure at the sinkhole; however, gypsum outcrops approximately 400 meters to the south west in an area of extensive karst topography.

The northern and western limits of the Windsor Group in the Oxford area are interpreted to be in fault contact with the Upper Carboniferous Cumberland group. The nature of the southern and eastern contacts is unknown. Based on the presence of interbedded evaporites, slates and mudstones, the Windsor group strata are interpreted to be folded in diapiric structures regionally expressed in the east-northeast trending Claremont-Malagash anticline with localized zones of increased deformation (Boehner 1986). Regional geophysical surveys help define the extent of the Windsor Group and diapiric structures in the area, however is too coarse in scale to model individual voids in the subsurface (Nova Scotia's Onshore Petroleum Atlas and references therein).

1.3.3 Previous Work

Previous work at the site has been limited due to safety, technical, and funding constraints. The Nova Scotia Department of Energy and Mines have been assisting the Town with ongoing monitoring and safety at the Site since the sinkhole was discovered. This has included propagation crack identification and monitoring, basic water chemistry, and aerial imagery.

Basic water chemistry at the sinkhole and Salt Lake were measured in August, 2018 as part of a report commissioned by the Town, and indicated the electrical conductivity of the water in the sinkhole and Salt Lake was approximately the same (3580 µS/cm at the sinkhole; 3970 µS/cm at Salt Lake) (Fracflow, 2018). This indicates the water at the Site is relatively brackish, and suggests the surface water at the sinkhole and Salt Lake likely originates from the same source.

A ground penetrating radar (GPR) trial survey was performed in the fall of 2018; however, the survey was deemed unsuccessful as the GPR signal was unable to provide the depth of investigation required to satisfy the project objectives (most likely due to clay content and brackish pore fluid). Survey details and results of the GPR trials were unavailable at the time of this report.

2. Methodology

In order to achieve the objectives and optimize efficiencies and data sets, the project was organized in a phased approach consisting of the following tasks:

- Site visit and reconnaissance
- Geophysical Investigation
- Geotechnical Investigation
- Data Interpretation and Reporting

The following sections summarize each phase of the project and provide details pertaining to the various surveys and approaches implemented during the project.

2.1 Site Reconnaissance

Site visits and reconnaissance were carried out on November 2, 2018 and April 26, 2019. The objective of the site reconnaissance was to observe the sinkhole extents at surface and determine the optimal locations for geophysical survey lines, taking into consideration personnel safety, infrastructure (above and below ground), and general site conditions (ground stability, slopes, surface water, vegetation, etc.). Photos from the site reconnaissance are included in Appendix A.

Based on the site reconnaissance in April, 2019 it was determined that, due to the size of the sinkhole at surface, the presence of water and obstacles in the sinkhole, and the unstable nature of the sinkhole walls, no geophysical testing would be performed immediately over the sinkhole. Instead, geophysical survey lines would be located as close to edge as safely feasible, and safety precautions would be undertaken to ensure personnel safety (PFDs, tie-off points, etc.). Similarly, any geotechnical drilling locations would be limited to a 20 m buffer around the sinkhole, as to minimize the potential risks associated with heavy machinery at the Site and intrusive work around the sinkhole.

Despite the above, GHD remained confident after site reconnaissance in our ability to obtain high-quality geophysical and geotechnical data to achieve the project objectives.

2.2 Geophysical Investigation

The objective of the geophysical investigation was to provide information pertaining to the lateral and depth extent of the active sinkhole, as well as help determine if the sinkhole extends beyond its visible extents and could pose a risk to the public and nearby infrastructure. To achieve these objectives, seismic refraction, multi-channel analysis of surface waves (MASW), and electrical resistivity tomography (ERT) surveys were carried out along the same survey lines at various locations at the Site (Figure 2). ERT data were collected at the Site between May 9-10, 2019, and seismic data were acquired between May 15-17, 2019.

Where seismic data provides the compressional (P-wave) and shear wave (S-wave) velocities of the subsurface (i.e., structure, strength, and lithological contacts), the resistivity data compliments by providing information on groundwater (saline versus fresh), lithology type, and geohazards (air-filled zones) within the geological units. Together, all three data sets provide critical subsurface information and help to determine the lateral and depth extents of the active sinkhole and any other geohazards within the survey area. Detailed methodologies describing each geophysical technique are included in Appendix B.

All GPS coordinates referenced in this report are in datum NAD 1983 CSRS UTM Zone 20N.

2.2.1 ERT Survey

ERT data were collected using a 12-channel ABEM LS Terrameter with a Gradient Plus array. Electrode spacing varied with each line due to the property boundaries, survey design, and site logistics, and was selected to maximize the total depth of investigation along each survey line as much as possible. ERT survey locations and acquisition parameters are summarized in Table 2.1, below.

Table 2-1 ERT Survey Parameters

Survey Line	Start of Line	End of Line	Line Length (m)	Electrode Spacing (m)
ERT 1	431339.9 E; 5063978.6 N	431535.6 E; 5064009.6 N	200	2.5
ERT 2	431451.6 E; 5063953.2 N	431478.4 E; 5064028.1 N	80	1.0
ERT 3	431320.3 E; 5063964.2 N	431518.7 E; 5063956.4 N	200	2.5
ERT 4	431417.4 E; 5063926.0 N	431393.9 E; 5064002.7 N	80	1.0
ERT 5	431490.5 E; 5063919.7 N	431545.1 E; 5064025.3 N	120	1.5
ERT 6	431486.8 E; 5063920.1 N	431499.9 E; 5064018.7 N	100	1.0

The ERT data were processed using RES2DINV tomographic inversion software. The results are displayed as electrical resistivity cross-sections, and a colour map is used to indicate relative changes in resistivity (in ohm-m), where warm colours (reds and pinks) indicate high resistivities and cool colours (light and dark blues) indicate low resistivities.

2.2.2 Seismic Refraction & MASW Surveys

Seismic refraction and MASW data were recorded using two (2) Geode™-24 Channel Infield System seismographs and low frequency 4.5 Hz geophones, manufactured by Geometrics, Inc. Each array utilized 48 geophones spaced 2 m apart, with the seismic energy source placed in-line with, and offset an established distance from, the geophone array. A 16-lb sledgehammer was used as the seismic energy source for all the seismic records. Seismic shot locations varied between techniques and was every 12 meters along the line for seismic refraction and every 6 meters for MASW. As expected, acquisition was intermittently delayed and data had to be stacked more when in proximity to Highway 321, due to signal noise from vehicle traffic; however, data quality was very good enabling a depth of investigation of approximately 30 mbgs for the seismic surveys. Seismic survey locations and acquisition parameters are summarized in Table 2.2, below.

Table 2-2 Seismic Survey Parameters

Survey Line	Start of Line	End of Line	Line Length (m)
SEIS 1	431403.9 E; 5064005.6 N	431497.4 E; 5064006.3 N	94
SEIS 2	431443.0 E; 5063936.2 N	431477.8 E; 5064026.0 N	94
SEIS 3	431401.9 E; 5063968.4 N	431495.4 E; 5063959.0 N	94
SEIS 4	431417.4 E; 5063926.0 N	431390.0 E; 5064015.0 N	94
SEIS 5	431496.1 E; 5063930.8 N	431538.6 E; 5064016.2 N	94
SEIS 6	431487.0 E; 5063924.6 N	431500.2 E; 5064019.0 N	94

Seismic refraction and MASW processing was performed by GHD using commercially available software. For the seismic refraction processing, first break picks and were made in Pickwin and Plotrefa software was used for velocity inversions. MASW processing was undertaken using the Surf Seis package. The S-wave velocity model was generated by analyzing the frequency dispersion characteristics of the recorded surface waves on each shot record, and utilizing an inversion routine that solves for the best-fitting 1-D S-wave velocity with depth profile. The 1-D profiles are stitched together to produce a 2-D model of S-wave velocity. The P-wave and S-wave velocity models are displayed using colour maps, for which warm colours (reds and pinks) represent fast velocities and cool colours (blues and greens) represent low velocities.

2.3 Geotechnical Investigation

A geotechnical investigation was carried out following the geophysical program to target the geophysical results and provide intrusive information for correlation and interpretation purposes. A total of five (5) boreholes were advanced from surface to depths of approximately 19 to 44 mbgs at various locations to the east of the active sinkhole.

Drilling locations were selected based on a number of factors, including the geophysical results, rig access, and safety. No boreholes were drilled in the forested area to the west of the sinkhole for safety and access reasons. Table 2.3 below summarizes the borehole locations, depth drilled, and rationale for location.

Table 2-3 Borehole Details

Borehole Name	GPS Coordinates	Elevation (masl)	Depth (m)	Rationale
BH 01	431489.8 E; 5064004.6 N	8.13	19.0	Target resistive/competent feature on ERT/Seismic Line 1
BH 02	431491.1 E; 5063958.9 N	8.30	21.6	Target resistive feature on ERT Line 3; verify competent material
BH 03	431528.2 E; 5063992.9 N	7.85	30.8	Target conductive feature on northern half of ERT Line 5; verify competent material
BH 04	431483.8 E; 5063990.1 N	8.13	29.0	Target edge of resistive feature on ERT Line 6; verify competent material
BH 05	431484.1 E; 5063994.4 N	8.13	44.1	Drill to depth of evaporite / karst-related material

The Boreholes were drilled by means of a track-mounted drill rig equipped with solid stem augers for soil sampling and NQ coring for rock samples. The rig was operated by Logan Geotech from Stewiacke, NS. Sampling procedures were performed in accordance with the American Society for Testing and Materials (ASTM) Standard D-1586, which allowed soil samples to be secured at regular intervals with a standard «B» caliber split-spoon sampler of 51 millimeter (mm) diameter and provided the penetration resistance (“N-Value”) of the soils. Drill cores were boxed and removed from Site by GHD. Soil and rock samples were collected by a trained GHD geotechnical engineer for further analysis, as outlined in Section 3.2. All borehole logs and SPT results are included in Appendix C, and laboratory results are included in Appendix D (not finalized at time of draft report; to be included with final report).

2.4 Geotechnical Laboratory Testing

All of the recovered geotechnical soil and rock samples were transported to GHD’s Fredericton laboratory. Twelve (12) grain size analyses were conducted on representative soil samples recovered during the field investigation. These tests were conducted to complement and confirm the information collected during the geotechnical field program.

Geotechnical laboratory testing results are presented in Section 5, as well as in Appendix D. The drill cores from the geotechnical drilling program have been logged and photographed as part of this report, and the physical cores have been retrieved by Department of Energy and Mines and are planned to be stored at their core library in Stellarton, NS.

3. Results

3.1 Geophysical Investigation

3.1.1 Electrical Resistivity Tomography (ERT)

A total of 6 ERT lines were surveyed at the Site (Figure 3-8). The results are displayed as electrical resistivity cross-sections, and a colour map is used to indicate relative changes in resistivity (in ohm-m), where warm colours (reds and pinks) indicate high resistivities (> 100 ohm-m) and cool colours (light and dark blues) indicate low resistivities (< 30 ohm-m). A number of factors influence the resistivity of a specific material (grain size, pore fluid chemistry, etc.) but, in general, material such as clay and brackish water has a low resistivity, whereas material such as sand/gravel and fresh water will be more resistive (see Appendix B). Seismic P-wave velocities have been illustrated on the ERT sections to allow for improved visualization and interpretation between the two data sets.

ERT Line 1 was surveyed west to east and centered immediately along the north side of the sinkhole, and provides a depth of investigation of approximately 35 meters below ground surface (mbgs) (Figure 3). The upper 5 meters of the ERT section is characterized by elevated resistivity values (>100 ohm-m), which correlates with near-surface sands/gravel encountered at borehole BH01. The majority of the ERT section is characterized by relatively low resistivity values (< 30 ohm-m), with discrete zones of elevated resistivity at depth on the western and eastern ends of the cross section. The ERT results show a strong correlation with the lithology encountered in BH01, where elevated resistivities correspond to sand/gravel and sandstone bedrock, and low resistivities correspond to clay. The low resistivities in the ERT results could also be a response to the conductive pore fluid, which is further discussed in section 4.

ERT Line 2 was surveyed south to north and centered immediately along the east side of the sinkhole, and provides a depth of investigation of approximately 15 mbgs (Figure 4). Results along ERT Line 2 are similar to ERT Line 1, where the near-surface is characterized by elevated resistivity (sand/gravel), the central portion of the section is characterized by low resistivities, and zones of elevated resistivity at depth were mapped at the edges of the section. Based on lithology from BH02 and BH04, the zone of elevated resistivity at approximately 5 mbgs along the south and north ends of the section are likely a response to sand/gravel or conglomerate. The lower resistivity values through the central portion of the ERT section are likely a response to clay and/or conductive pore fluid.

ERT Line 3 was surveyed west to east immediately along the south side of the sinkhole, and provides a depth of investigation of approximately 35 mbgs (Figure 5). A zone of elevated resistivity extends from line position 95 m to the east end of the ERT line, and extends from a depth of approximately 5 mbgs to 12 mbgs. This unit correlates with a gravel layer encountered in BH02, which is located directly on the ERT line at line position 165 m. This gravel layer is discontinuous for

15 meters immediately adjacent to the sinkhole location. The resistivity cross section is characterized by lower resistivity values at depth, which is likely a response to the conductive pore fluid at the Site.

ERT Line 4 was surveyed from south to north in the forested area to the west of the sinkhole, and provides a depth of investigation of approximately 15 mbgs (Figure 6). The ERT results along Line 4 are characterized by elevated resistivity values in the upper 5 mbgs, with a deeper zone of elevated resistivities between line positions 15 m and 42 m, which extend to a depth of approximately 9 mbgs. This is likely a response to sand/gravel in the near-surface. The bottom portion of the cross section is characterized by relatively low resistivity values (<50 ohm-m). No boreholes were drilled west of the sinkhole due to safety and access restrictions, so no intrusive information exists to correlate the geophysical results along Line 4.

ERT Line 5 was surveyed from south to north along the eastern property boundary of the Lions Club, and provides a depth of investigation of approximately 20 mbgs (Figure 7). The upper 2-3 meters of the section are characterized by elevated resistivity values, likely a response to sand/gravel in the near-surface. A zone of elevated resistivity values was mapped at depth between line positions 20 m and 75 m, and extends to a depth of approximately 16 mbgs. This zone correlates with a gravel layer encountered in BH02, which is about 22 m offline. The northern end of the section is characterized by low resistivity values, which correlates with a clay layer encountered in BH03.

ERT Line 6 was surveyed south to north in the middle of the Lions Club parking lot, and provides a depth of investigation of approximately 15 mbgs (Figure 8). Similar to the other ERT sections, the near surface is characterized by elevated resistivity values; likely a response to sand/gravel. A relatively thick, continuous zone of elevated resistivity values was mapped between line positions 15 m and 65 m, and extends to a depth of about 12 mbgs. This zone correlates with the gravel layer encountered in BH02 and BH04. The northern portion of the section is characterized by low resistivity values, which correlates with the clay layer encountered in BH01.

3.1.2 Seismic Refraction and MASW

A total of 6 seismic refraction and MASW lines were surveyed at the Site (Figures 9-14). The P-wave and S-wave velocity models are displayed using contoured colour maps, for which warm colours (reds and pinks) represent fast velocities and cool colours (blues and greens) represent low velocities. In general, competent material is considered to be defined by P-wave velocities greater than 2500 m/s (seismic refraction results) and S-wave velocities greater than 750 m/s (MASW results). For this reason, seismic velocity contours have been illustrated on the seismic sections, to allow for easy visualization and interpretation of competent material/bedrock. For reference, Table 3.1 below summarizes representative P- and S-wave velocities for common materials (modified from Hunter, J.A. and Crow, H.L. (ed.), 2012, and Stanford Rock Physics Laboratory, no date).

Table 3-1 Seismic Velocities of Common Materials

Material	Average P-wave velocity (m/s)	Average S-wave velocity (m/s)
Hard rock (granite, gneiss, etc.)	>4000	>1500
Rock and competent material (limestone, sandstone, etc.)	>2500	750-1500
Very dense soil and soft rock	1200-2500	360-760
Stiff soil	750-1200	180-360
Soil	<750	<180

Seismic Line 1 was surveyed west to east and centered immediately along the north side of the sinkhole, and provides a depth of investigation of approximately 30 mbgs (Figure 9). P-wave velocities greater than 2500 m/s were mapped at a depth of approximately 15-20 mbgs, and become deeper in the vicinity of the sinkhole. S-wave velocities greater than 750 m/s were also mapped at about 15-20 mbgs, and undulate in the vicinity of the sinkhole. These results correlate well with the lithology encountered in BH01, where sandstone bedrock was logged at a depth of about 13 mbgs. P- and S-waves in the upper 5 meters of the section are very low, suggesting the strength of the subsurface material along Line 1 is very weak in the upper 5 meters, especially in close proximity to the sinkhole.

Seismic Line 2 was surveyed south to north and centered immediately along the east side of the sinkhole, and provides a depth of investigation of approximately 30 mbgs (Figure 10). P-wave velocities greater than 2500 m/s were mapped at a depth of approximately 10-15 mbgs along the line, and become deeper in the vicinity of the sinkhole. A distinct dip in the P- and S-wave velocities was mapped in the vicinity of the sinkhole, where competent material elevation drops 5-10 meters, to a depth of approximately 15-20 mbgs in the refraction and MASW data sets. The refraction and MASW results correlate well with the lithology encountered in BH01 and BH04, which are 15-20 m offline. P- and S-waves in the upper 5 meters of the section are generally quite low, suggesting the strength of the subsurface material along Line 1 is weak in the upper 5 meters.

Seismic Line 3 was surveyed west to east along the south side of the sinkhole, and provides a depth of investigation of approximately 30 mbgs (Figure 11). P-wave velocities greater than 2500 m/s were mapped at a depth of approximately 10 mbgs along the line, and become deeper in the vicinity of the sinkhole. S-wave velocities are generally less than 750 m/s along the majority of the section, except for a few discrete zones at depth. The competent S-wave velocities correspond to the conglomerate unit encountered in BH02; however, the S-wave velocities suggest the conglomerate is not competent, which is likely the case based on visual inspection during the drilling program.

Seismic Line 4 was surveyed south to north in the treed area west of the sinkhole, and provides a depth of investigation of approximately 30 mbgs (Figure 12). P-wave velocities exceeding 2500 m/s were mapped at a depth of approximately 10-15 mbgs, and show an undulating surface along the line, with deeper extents in the central portion of the line. S-wave velocities are generally less than 750 m/s along the section, with low velocities (<300 m/s) in the upper 10 meters of the section, suggesting near-surface strength is low along the survey line.

Seismic Line 5 was surveyed south to north along the eastern boundary of the Lions Club property, and provides a depth of investigation of approximately 30 mbgs (Figure 13). P-wave velocities greater than 2500 m/s were mapped at a depth of approximately 10-15 mbgs, and become deeper between line positions 15 m and 55 m. S-wave velocities greater than 500 m/s show an undulating surface of more competent material around 10-15 mbgs. These results correlate with the lithology in BH03, which encountered conglomerate at approximately 10.8 mbgs. P- and S-waves in the upper 5 meters of the section are generally quite low, suggesting the strength of the subsurface material along Line 1 is weak in the upper 5 meters. Also important to note is the very low S-wave velocities (<150 m/s) at surface between line positions 20 m and 40 m, which correlates with the location of a depression at surface at the Site.

Seismic Line 6 was surveyed south to north in the middle of the Lions Club parking lot, and provides a depth of investigation of approximately 30 mbgs (Figure 14).P-wave velocities greater than 2500 m/s were mapped at a depth of approximately 10-15 mbgs, with and undulating surface at the south and north ends of the survey line. S-wave velocities greater than 750 m/s were mapped at a depth of about 15 mbgs, and show discrete depressions at line positions 30 m and 60 m. The seismic results correlate well with the boreholes in the vicinity of the survey line, thus providing confidence in the data sets.

3.1.3 3D Visualization

The geophysical data sets were imported to a 3D software package (Leapfrog 3D) to aid in visualization and interpretation. This approach assists with regional trends across the survey area and extrapolating between survey lines, as well as being able to see all 3 data sets at the same time. Screen shots of the geophysical results from the 3D visualization software are included in Figures 15-20, and a digital version of the 3D viewer is included as part of the deliverable for this project. While the 3D figures and digital viewer provides an excellent deliverable, they are intended for visualization purposes only. Any measurements, grids values, etc. should be taken from the individual 2D cross sections.

In general, the 3D fence diagrams show strong correlation of the ERT and seismic refraction results at line intersections (i.e., where an ERT line intersects another ERT line, the resistive properties of the subsurface correlate between the lines). Correlation of the MASW data at line intersections is strong at some locations, but relatively weak at others. This is likely due to, at least in part, the nature of the survey, whereby 1D MASW profiles are stitched together to create the 2D cross section. These data gaps in the MASW data set creates more interpolation in the MASW cross sections, though confidence in the overall data quality along each line remains quite high.

3.2 Geotechnical Investigation Results

3.2.1 Fieldwork Results

Ground Conditions Observed

The detailed subsoil conditions encountered at each borehole location are presented on the borehole logs included in Appendix C of this report.

The subsoil conditions encountered at the Site generally consist of a surficial native soil layer (i.e. glacial till composed of Clayey silty SAND/Sandy CLAY/SILT) overlying bedrock.

Table 3.2, below, presents an overview of the thickness of the stratigraphy layers along with bedrock depth and elevation at each borehole location. Elevation details are based on survey data courtesy of Department of Energy and Mines.

Table 3-2 Borehole Lithology Summary

Borehole No.	Ground Elevation (masl)	Thickness of native soil layer (m)	Bedrock Depth (mbgs)	Bedrock Elevation (masl)
BH 01	8.13	0.0 – 13.2	13.2 – 19.0	-5.07
BH 02	8.30	0.0 – 13.7	13.7 – 21.6	-5.40
BH 03	7.85	0.0 – 10.8	10.8 – 30.8	-2.95
BH 04	8.13	0.0 – 10.0	10.0 – 29.0	-1.87
BH 05	8.13	0.0 – 14.48	14.48 – 44.0	-6.35

The different soil units encountered across the Site are briefly described in the following paragraphs.

Additionally, it should be noted that the drilling conditions through the conglomerate material were difficult, whereby diamond drill bits were being completely worn by the material.

Overburden

The overburden observed at the Site is characterized as a glacial till deposit consisting of clay, sand and gravel mixtures. The consistency of the cohesive soils varied from stiff to hard with N values from the SPT varying between 13 and >100 across the Site, and N values increasing with depth. Granular soils density was estimated to be medium dense overall in the first 10 meters with some very dense layers located between 5.5 and 7.5 m meters and from 9.5 meters to 10.5 meters within BH 01. A total of 12 overburden samples were collected and sent for laboratory testing.

Bedrock

Bedrock at the Site is mostly composed of a red to brown conglomerate unit, interbedded with layers of brown, medium to coarse sandstone.

In general, the conglomerate bedrock observed in boreholes BH 02, BH 03m and BH 04 is considered to be of poor quality, based upon recoveries of the rock core. The conglomerate was found to be heavily fractured, with RQD values typically under 10%.

In general, the sandstone bedrock observed in borehole BH 01 is considered to be of poor to average quality, based upon recoveries of the rock core. The sandstone was found to be heavily fractured, with RQD values typically around 65%. Most of the joints encountered were sub-horizontal, associated with bedding. At the bottom of the borehole, the sandstone was more competent.

Note that during the drilling, some water loss occurred while drilling through the gravel and conglomerate layers, likely due to the granular nature of the gravel and the poor cementation of the conglomerate units. Within the conglomerate unit, this resulted in the matrix composed of fine to coarse sandy material and silt to be washed away during the drilling process leaving the coarser granular material to freely move inside and around the bit. This phenomenon ultimately lead to the complete wear of the bit. In addition, a suspected one (1) foot void was encountered in borehole 3 at about 18 meters below ground surface, as the drill rods "dropped" about a foot at this depth.

Of the first 4 boreholes drilled during the geotechnical program (BH01-BH-4), none of the boreholes encountered evaporitic bedrock in the upper 30 m of the subsurface. Based on regional geology and karst terrain, it is assumed that evaporitic bedrock exists below the sandstone and conglomerate units, and is the source of the sinkhole at the Site. An extra day was added to the drilling program in an attempt to drill a deeper borehole in BH04 to intersect the evaporitic bedrock, but was unsuccessful as the conglomerate unit wore out the drill bit at 30 mbgs and the hole had to be abandoned.

As a result, a fifth borehole was drilled at the Site from July 26-27, 2019 with the sole objective of intersecting the evaporite / karst-related material. This objective was successfully achieved, as BH05 encountered karst material at approximately 40 mbgs. At this depth, the material recovered was characterized as a conglomerate-type material with a karst-related matrix, as the matrix and individual clasts within the conglomerate had a positive reaction to hydrochloric acid (HCl)- a test to confirm presence of evaporitic material. This confirms the presence of evaporite/karst material at depth, though much deeper than originally expected based on regional geology and outcrop of gypsum in the area.

Groundwater conditions

Groundwater levels were observed within the boreholes at the time of drilling. The recorded water levels were measured prior to installing the casing and allowing some time to stabilize. The levels are presented in Table 3.3, below. No piezometers were installed as part of this investigation.

Table 3-3 Depth to groundwater in boreholes

Borehole No.	Date	Water level (mbgs)
BH 01	2019-06-05	2.1
BH 02	2019-06-06	1.7
BH 03	2019-06-07	1.2
BH 04	2019-06-08	1.4
BH 05	2019-07-26	Not measured

It should be noted that groundwater levels are expected to fluctuate seasonally.

3.2.2 Laboratory Test Results

The laboratory testing program was conducted on representative soil samples recovered during the field investigation. Eleven grain size distribution tests were conducted to complete the information collected during the field work. The grain size distribution results are summarised in the tables below and are presented in Figure 3.1.

Table 3-4 Laboratory test results summary – BH01

Borehole No.	Sample	Depth (mbgs)	Clay/Silt (%)	Sand (%)	Gravel (%)
BH 01	SPT 2	0.6-1.2	21	56	24
	SPT 5	2.7-3.3	61	33	6
	SPT 8	4.5–5.1	13	29	58
	SPT 11	6.3-6.9	42	39	19
	SPT 14	8.1-8.7	52	33	15
	SPT 19	10.5-11.1	69	15	16

The Particle Size Distribution results presented in Table 3-4 shows that the native material varies with depth in BH01. The native material grain size distribution are consistent with a till deposit with the first five metres varying from a sand to a clay to a gravel layer while the next five metres are mainly a sandy clay/silt. The sandy clay/silt contains a clay/silt distribution ranging from 42% to 69%, a sand distribution ranging from 15% to 39% and a gravel distribution ranging from 15% to 19%.

Table 3-5 Laboratory test results summary – BH02

Borehole No.	Sample	Depth (mbgs)	Clay/Silt (%)	Sand (%)	Gravel (%)
BH 02	SPT 2	0.6-1.2	32	58	10
	SPT 4	2.1-2.7	38	45	17
	SPT 6	4.5-6.1	70	21	10
	SPT 9	9.0-9.6	21	53	26
	SPT 10	11.3-11.9	15	51	35

The Particle Size Distribution results presented in Table 3-5 shows that the native material is typical of a native glacial till and is fairly consistent with depth in BH02. The native material grain size distribution are consistent with a sandy clay/silt for the first ten (10) metres with a clay/silt layer at four and a half (4.5) metres and a gravelly layer at eleven (11) metres. The clayey sand/silt contains a clay/silt distribution ranging from 21% to 38%, a sand distribution ranging from 45% to 58% and a gravel distribution ranging from 10% to 26%.

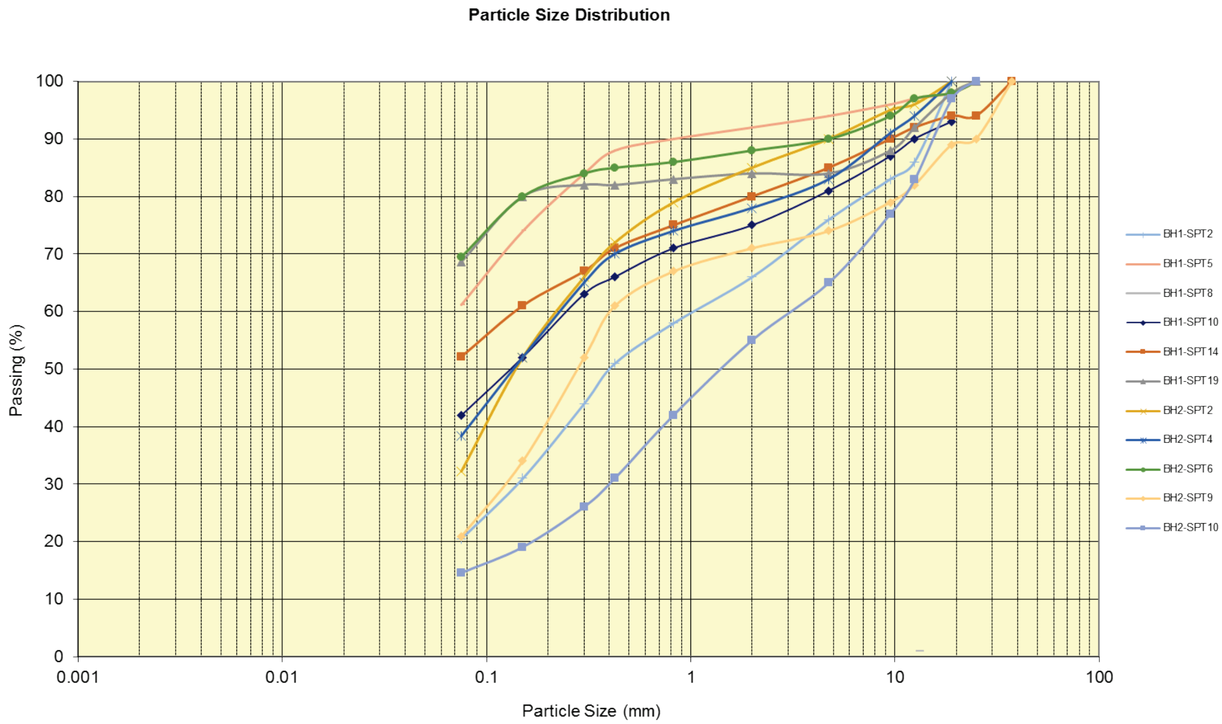


Figure 3-1 Particle Size Distribution Summary

4. Interpretation and Discussion

The geophysical surveys carried out at the Site by GHD were successful in mapping the various properties of the subsurface (lithology, structure, etc.) and, combined with the follow-up geotechnical investigation, provide the required information to achieve the project objectives. The following section outlines the main objectives of the project, and provides interpretation and discussion of the geophysical and geotechnical data as they relate to the objectives.

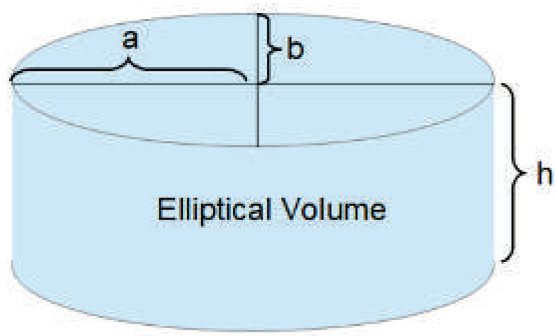
4.1 Objective 1- Sinkhole Extents

Determine the lateral and depth extent of the active sinkhole

As per visual identification at the time of the geophysical and geotechnical programs, the active sinkhole is elliptical in shape and measures approximately 40 m by 30 m at surface. Based on geophysical survey lines in the immediate vicinity of the sinkhole (Lines 1, 2, and 3), the seismic refraction and MASW data provide valuable insights to the structure of the active sinkhole. Seismic refraction results along Lines 1, 2, and 3 show a sharp lateral drop in P-wave velocities greater than 2,500 m/s in the immediate vicinity of the sinkhole. Line 2 (surveyed across the eastern edge of the sinkhole) mapped this feature very well, where the 2,500 m /s P-wave velocities drop from approximately 10 mbgs to 15 mbgs along the edge of the sinkhole. The same feature in Line 1 mapped a drop in P-wave velocities of 2,500 m/s from 15 mbgs to 20 mbgs in the vicinity of the sinkhole. This suggests that the bottom of the sinkhole, or at least the depth to competent material, is approximately 15-20 mbgs. These results are further supported by the MASW data, which mapped similar drops in S-wave velocities greater than 500 m/s in the immediate vicinity of the sinkhole.

ERT data provide insight to the lithology and pore water across the Site, but are not able to provide definitive information pertaining to the structure of the sinkhole. ERT data are generally a preferred geophysical technique for mapping voids and sinkholes; however, where the sinkhole is filled with conductive water instead of air, the ERT data mapped conductive features at depth and in the immediate vicinity of the sinkhole. As per water chemistry and borehole information, these conductive response are likely due to conductive pore water and/or clay. This information is valuable to the overall program and interpretation, but does not provide insight to the structure of the sinkhole.

Based on the known dimensions at surface and the seismic results at depth, a simplified volume of the sinkhole can be approximated, whereby:



Volume of an elliptical column = π x major radius (a) x minor radius (b) x height (h)

Assuming an elliptical area at surface of 40 m x 30 m, and a depth of 15 m, the volume of the sinkhole is approximately 14,130 m^3. Assuming a depth of 20 m would provide a volume of approximately 18,840 m^3. Of course, this is a simplified approach and assumes the sinkhole is uniform in shape, and does not account for any material that has already collapsed or been placed in the hole.

Based on borehole drilling results at BH05, the karst-related material exists at a depth of approximately 40 mbgs. This suggests that the sinkhole originated from a depth greater than the depth of investigation of the geophysical investigations, and that the competent material identified in the seismic data sets likely represents the depth to competent material (sandstone, dense conglomerate, etc.) that has fallen into the deeper void created by the sinkhole.

4.2 Objective 2- Sinkhole Growth Potential

Determine if the active sinkhole is connected to other karst features in the immediate area with the potential for further growth, or if other additional fractures, fissures, voids or caverns exist within the survey area

Based on regional mapping and data, the Site is located within a known karst region and is surrounded by similar sinkhole features. In fact, Salt Lake is believed to have formed as a result of the karst topography in the area. Therefore, on a regional scale, it is reasonable to assume the sinkhole at the Site is connected to the regional karst terrain of the area.

Focusing on the Site and the active sinkhole, one of the objectives of the program was to determine if the sinkhole had the potential for further growth or was connected to other karst features, or for other sinkholes to develop at the Site. The ERT data mapped elevated resistivity zones in the upper 5-10 mbgs, which are most likely not air-filled voids as the borehole drilling correlated these resistive features to sand/gravel or sandstone. In addition, the MASW results did not image any discrete zones at depth with S-wave velocities corresponding to air- or water-filled voids (i.e., S-wave velocity of ~ 0 m/s), which suggests there are currently no large voids in the subsurface along any of the geophysical survey lines to the depth of investigation of the various techniques. That said, the undulating bedrock/competent material layer mapped in the seismic refraction and MASW data sets does show correlation and trends across the site, and could represent pathways for present and future fluid movement/dissolution and sinkhole development. Of particular note is the dip in the competent layer at line position 60 m on MASW Line 6, and line position 60 m on MASW Line 5. This feature is in close proximity to the possible void encountered in BH 03 on Line 5, whereby the drill rods dropped about a foot at 18 mbgs, which correlates with the dip in bedrock observed in the seismic data sets. In addition, this feature lines up with the active sinkhole in 3D space and could show a connection between the active sinkhole and these undulating features.

The ERT data mapped a sand/gravel layer along the southern portion of the site, as verified in BH02. The sand/gravel layer has very low compressional and shear strength in the seismic refraction and MASW results, and is present in the immediate vicinity of the sinkhole. This could lead to further slumping or growth of the active sinkhole over time, assuming the void at depth associated with the karst terrain continues to expand, as the overlying material has very little strength to support itself with the lack of any underlying material. At a minimum, the active sinkhole walls will settle from their current, near-vertical state to an angle of repose of approximately 30-45 degrees.

A small, surficial depression was noted at the time of the geophysical program and is located on the eastern side of the Site in the vicinity of the intersection of Line 3, 5, and 6. S-wave velocities in the upper 5 m of the subsurface are very low in this area. Based on ERT results and lithology encountered in BH02, a near-surface sand/gravel unit is present at this location, and could act as a pathway for any downward migration of surface water, thus posing a potential long term risk for sinkhole/karst development.

The geological conditions that are present at the sinkhole, as mapped by the geophysical surveys, exist throughout the Site, suggesting that the potential for future sinkhole development is relatively high across the Site. The undulating bedrock/competent layer at depth, as mapped in the seismic data sets, would promote surface runoff to collect and, over time, dissolve any evaporitic bedrock underlying the Site. Unfortunately, it is nearly impossible to predict a timeline for this to occur, but understanding that the geological conditions are present for future sinkhole development is important. Based on the geophysical and geotechnical results, the potential does exist for additional sinkhole(s) to form at the Site.

4.3 Objective 3- Sinkhole Risk

Determine if the sinkhole poses an immediate risk to the public, businesses, and critical infrastructure (utilities and Highway 321).

The data and interpretation for this report are limited to the Site and, as per Objective 2 above, the potential for future sinkhole development is relatively high across the Site. That said, the geophysical data did not encounter any areas indicative of air- or water-filled voids along the surveyed locations, suggesting the area may be stable for the time being. Based on the geophysical and geotechnical investigation at the Site, the near surface overburden appears to be relatively competent and not an immediate risk to the Lions Club building or public safety. However, cover-collapse sinkholes (which the sinkhole at the Site appears to be) develop via dissolution and voids in the evaporitic bedrock and can occur suddenly with no obvious signs of collapse beforehand. Geophysical and geotechnical data was limited to the upper 35 mbgs, so any dissolution or voids developing at deeper depths were not detected by this program, which remains a risk for the Site.

The active sinkhole has been cordoned off for several months, and access to the Site has been restricted through a locked gate. There are obvious risks to the public in the immediate vicinity of the active sinkhole, as the near-vertical edges are unstable and continue to settle. Site access should continue to be restricted and a safety perimeter surrounding the sinkhole should remain.

The northwest corner of the Lions Club building is approximately 18 meters from the active sinkhole. Assuming the sinkhole walls continue to settle over time, the building may become unstable. Measures should be taken to monitor any settling and movement of the building, and access to the building should likely be restricted until the sinkhole walls reach their angle of repose or the sinkhole is remediated.

The dip of the competent material layer (i.e., bedrock) in the seismic data sets on Lines 5 and 6, combined with the possible void encountered during drilling of BH 03, suggests that other sinkholes may be developing in the subsurface. Given the proximity of Line 5 and BH 03 to Highway 321, there is a high risk of potential sinkholes developing over time and impacting critical infrastructure adjacent to the Site.

5. Conclusions

The geophysical and geotechnical investigations are considered successful in achieving the project objectives. The following conclusions can be made from the program:

- ERT data were successful in providing high quality resistivity data sets across the Site to depths ranging from 15-35 mbgs. The ERT data mapped a gravel unit in the vicinity of the sinkhole and along the southern portion of the survey area on ERT Lines 2, 3, 4, 5, and 6. Conductive zones in the ERT Data correlate with clay units, or possible responses to conductive pore fluid. No apparent responses to air-filled voids were mapped along the ERT survey lines.
- Seismic refraction data were successful in providing high quality P-wave data sets to a depth of approximately 30 mbgs. The refraction results show an undulating bedrock / competent material layer across the Site, whereby P-wave velocities >2,500 m/s have greater depth in the immediate vicinity of the sinkhole, and at various other locations within the survey area. The

seismic refraction data suggest the depth of the active sinkhole, or at least competent material, is approximately 15-20 mbgs at the time of the survey.

- MASW data provided S-wave data to a depth of approximately 30 mbgs along each survey line. The S-wave data mapped low velocities (<300 m/s) in the upper 5-10 m of the subsurface, and show an undulating bedrock / competent layer across the Site. Of particular note are the “depressions” in S-wave velocity at line position 60 m on Lines 5 and 6, as well as near the sinkhole on Line 1. The MASW data suggest the depth of the active sinkhole is approximately 20 mbgs.
- A total of 5 boreholes were completed at the Site, and lithologies from the drilling program correlate very well with the geophysical results, thus providing confidence in the geophysical data sets. In general, the Site is characterized by a surficial till composed of clay / sand / gravel underlain by conglomerate and/or sandstone, which is underlain by karst-related material. The karst-related material was encountered at a depth of approximately 40 mbgs at BH05, indicating the sinkhole originated from a greater depth than originally expected (personal communication).
- SPT data correlate with the geophysical results and generally indicate a typical increase in strength with depth. The N-values obtained from the SPT field test indicate that the subsurface generally varies between stiff to hard for cohesive soils and medium dense to very dense for granular soils. This means that the overburden material is generally considered competent and not an immediate risk to the Lions Club building or the general public; caveat being that a cover-collapse sinkhole could develop and compromise the overburden material.
- Based on visual observation at the time of the geophysical surveys, as well as the geophysical results, the sinkhole is elliptical in shape and measures approximately 40 m wide at surface, and extends to a depth of approximately 15-20 mbgs. Assuming an elliptical area at surface of 40 m x 30 m, and a depth of 15 m, a simplistic volume of the sinkhole is approximately 14,130 m3. Assuming a depth of 20 m would provide a volume of approximately 18,840 m3. Of course, this assumes the sinkhole is uniform in shape, and does not account for any material that has already collapsed or been placed in the hole.
- The geological conditions that are present at the sinkhole, as mapped by the geophysical surveys, exist throughout the Site, suggesting that the potential for future sinkhole development is relatively high across the Site. Unfortunately, it is nearly impossible to predict a timeline for future sinkhole development, but given the geophysical and geotechnical results, and the proximity of the Lions Club building to the sinkhole, the long term risk to the Lions Club is considered to be high.
- The dip of the competent material layer (i.e., bedrock) in the seismic data sets on Lines 5 and 6, combined with the possible void encountered during drilling of BH 03, suggests that other sinkholes may be developing in the subsurface. Given the proximity of Line 5 and BH 03 to Highway 321, there is a high risk of potential sinkholes developing over time and impacting critical infrastructure adjacent to the Site.
- Recommendations and a brief commentary regarding remedial options are provided in a separate memorandum.

6. Limitations of Liability, Scope of Report, and Third Party Reliance

This report has been prepared and the work referred to in this report has been undertaken by GHD for the Town of Oxford (The Town). Any use, reliance on, or decision made by any person other than the Town based on this report is the sole responsibility of such other person. The Town and GHD make no representation or warranty to any other person with regard to this report and the work referred to in this report and they accept no duty of care to any other person or any liability or responsibility whatsoever for any losses, expenses, damages, fines, penalties or other harm that may be suffered or incurred by any other person as a result of the use of, reliance on, any decision made or any action taken based on this report or the work referred to in this report.

The investigation undertaken by GHD with respect to this report and any conclusions or recommendations made in this report reflect GHD's judgement based on the site conditions observed at the time of the site inspection on the date(s) set out in this report and on information available at the time of preparation of this report. This report has been prepared for specific application to this Site and it is based, in part, upon visual observation of the Site, sub surface investigation at specific locations and depths, and analysis of specific geophysical parameters and geologic materials during a specific time interval, all as described in this report.

It is also important to emphasize that the geophysical and geotechnical results are based on actual survey locations at the time of the program and that subsurface conditions may vary at other locations. The subsurface conditions can also be significantly modified by construction activities on or near the Site (i.e. excavation, dewatering and drainage, blasting, etc.). These conditions can also be modified by exposure of soils or bedrock to humidity, rainfall, dry periods or frost.

Unless otherwise stated, the findings cannot be extended to previous or future site conditions, portions of the Site which were unavailable for direct investigation, sub surface locations which were not investigated directly, or chemical parameters, materials or analysis which were not addressed.

If Site conditions or applicable standards change or if any additional information becomes available at a future date, modifications to the findings, conclusions and recommendations in this report may be necessary. The recommendations made in this report are in accordance with our present understanding of the Project, the current site use, ground surface elevations and conditions, and are based on the work scope approved by the Client and described in the Report.

Other than by the Town, copying or distribution of this report or use of or reliance on the information contained herein in whole or in part, is not permitted without the express written permission of the Town. Nothing in this report is intended to constitute or provide a legal opinion.

7. Closing

All of which is respectfully submitted,

GHD

Dan Parker, P.Geo.

Geoscience Lead, Atlantic Canada

Oliver Galvier

8. References

Barlow, S.; Giroux, N. J. 1886; Province of Nova Scotia and part of New Brunswick, sheet no. 4 Cumberland Coal Field, Spring Hill; Geological Survey of Canada, Multicoloured Geological Map 230, scale 1:253,440.

Bell, W.A. 1944: Carboniferous rocks and fossil floras of northern Nova Scotia; Geological Survey of Canada, Memoir 238, 277 p.

Boehner, R. C. 1986: Salt and Potash Resources in Nova Scotia; Nova Scotia Department of Mines and Energy, Bulletin No. 5, 346 p.

Cole, L.H. 1930: Salt occurrences in the Maritime Provinces in The salt industry of Canada; Department of Mines, Canada, Mines Branch, Publication No. 716, p. 2-19.

Fracflow Consultants Inc. 2018: Preliminary Sinkhole Assessment, Oxford Lions Park; Town of Oxford; 13 p.

Hunter, J.A. and Crow, H.L. (ed.), 2012. Shear Wave Velocity Measurement Guidelines for Canadian Seismic Site Characterization in Soil and Rock; Geological Survey of Canada, Open File 7078, 227 p. doi:10.4095/291753

Malagash Salt Company 1953: Core Drill Exploration – Oxford, NS; Nova Scotia Department of Mines and Energy, Assessment Report 11E/12C 42-E-47(00).

Norman, G. W. H. and Bell, W. A. 1938; Oxford Sheet, West Half, Cumberland and Colchester Counties, Nova Scotia; Geological Survey of Canada, "A" Series Map 410A, scale 1:63,360.

Nova Scotia Department of Mines 1925: Annual Report on the Mines 1924; Drill logs and report, p. 233-234.

Nova Scotia Department of Mines 1927: Annual Report on the Mines 1926; Drill logs and report, p. 139-141.

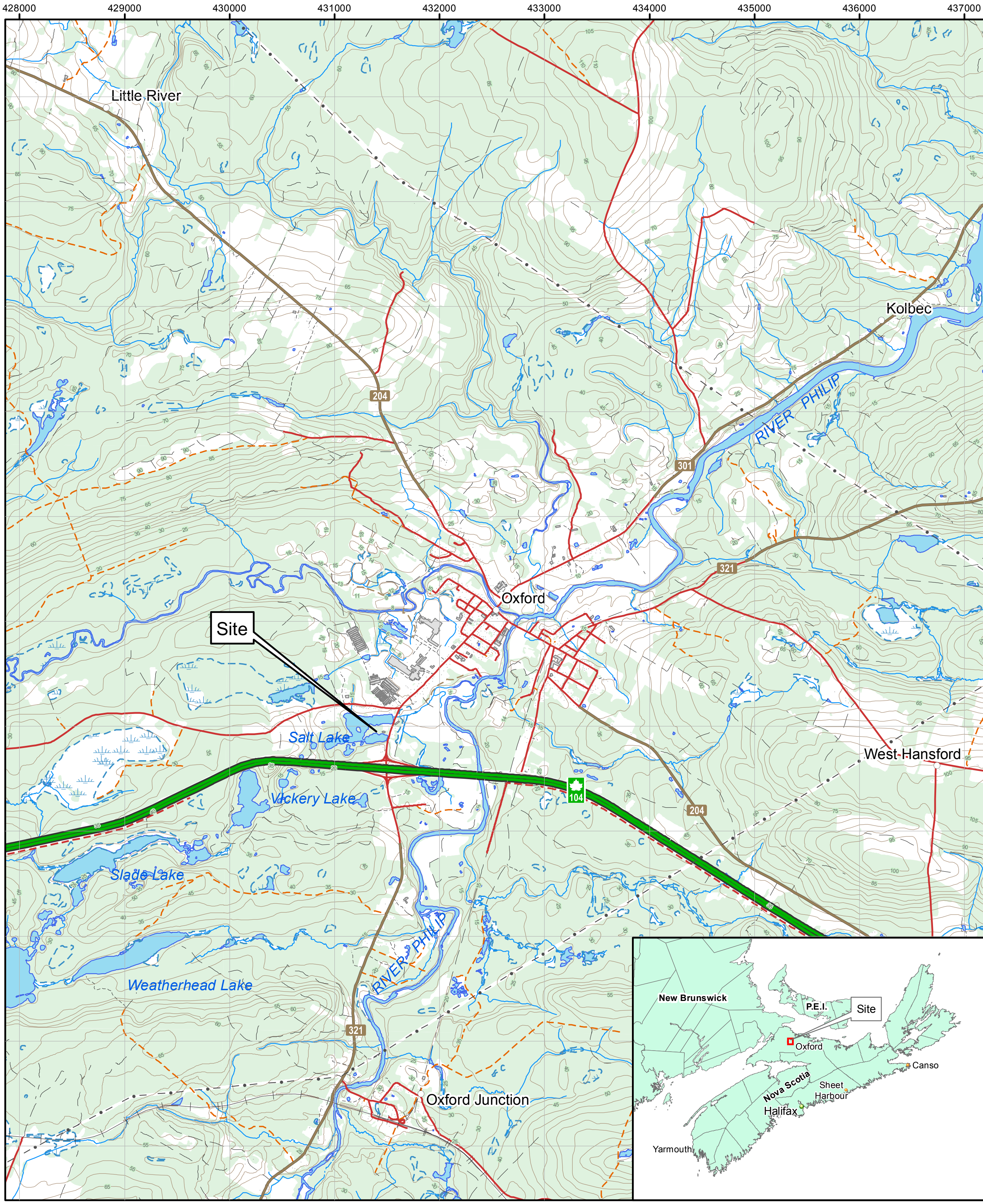
Nova Scotia's Onshore Petroleum Atlas - https://energy.novascotia.ca/onshore-atlas-version-1-2017

Ryan, R. J., Boehner, R.C. and Deal, A. 1990: Cumberland basin geology map, Oxford and Pugwash, Cumberland County; Nova Scotia Department of Mines and Energy, Map 90-13, scale 1:50,000.

Stanford Rock Physics Laboratory, no date. Conceptual Overview of Rock and Fluid Factors that Impact Seismic Velocity and Impedance.

Stea, R.R. and Finck, P.W. 1988: Surficial Geology Cumberland, Colchester and Hants County Sheet 10; Nova Scotia Department of Mines and Energy; Map 88-13, scale 1:100,000

Tizzard, A., Demont, G. J. and Brushett, D. M. 2019: in Geoscience and Mines Branch, Report of Activities 2018- 2019; Nova Scotia Department of Energy and Mines, Report ME 2018-002 (in press; yet to be published).



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Metres

Coordinate System:
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GHD

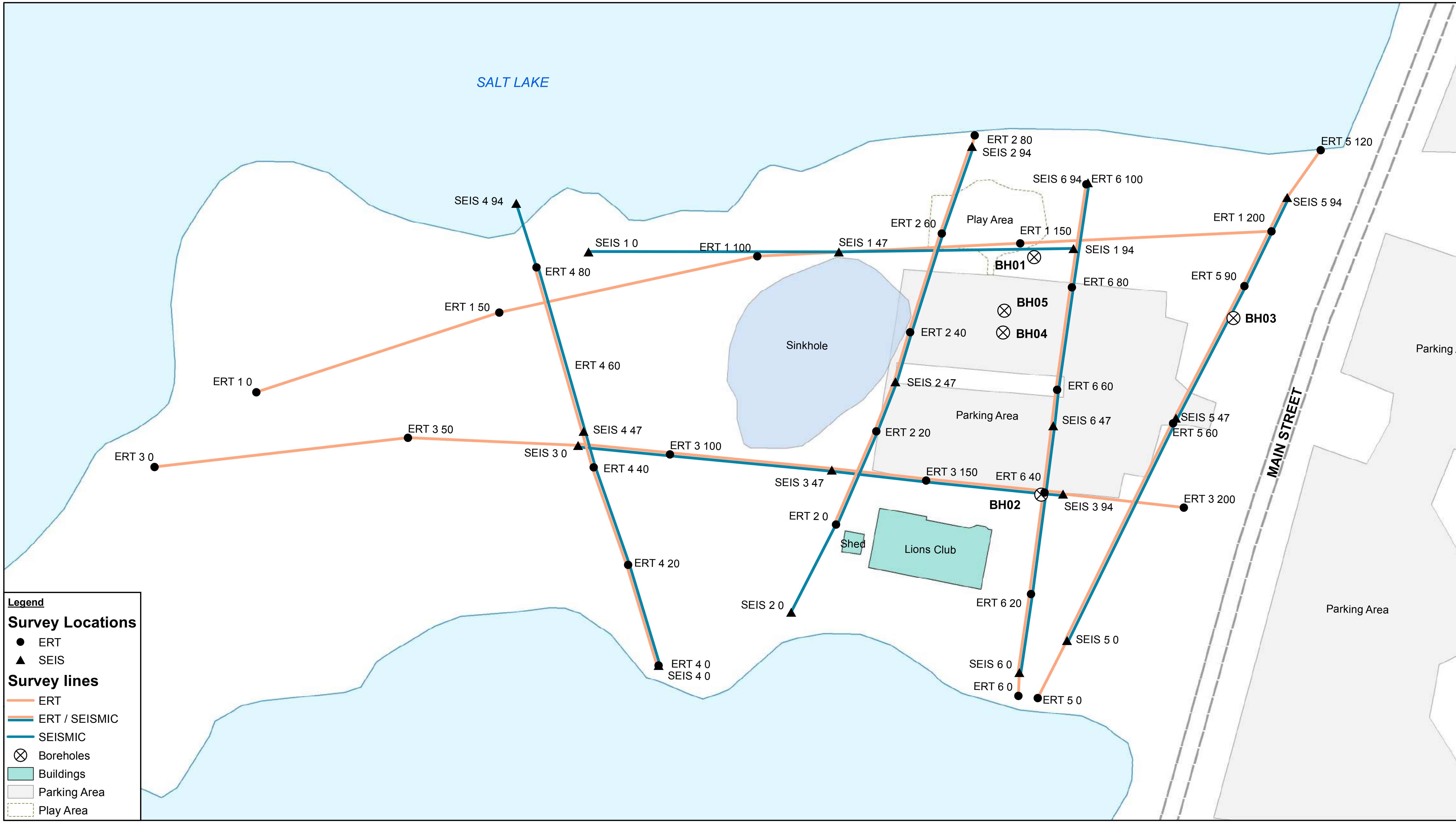
TOWN OF OXFORD
MAIN ST, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181 (001)
Jun 20, 2019

SITE LOCATION

FIGURE 1

GIS File: I:\GIS_DATA\Projects\8-chars\1119----\11195181 Oxford\11195181-RPT\11195181(001)\11195181(001)_GIS-HX001.mxd



Source: Insert source text here.

0 7 14 21
Metres

Coordinate System:
NAD 1983 CSRS UTM Zone 20N

N

TOWN OF OXFORD
MAIN ST, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

SITE PLAN

11195181 (001)
Aug 8, 2019

FIGURE 2

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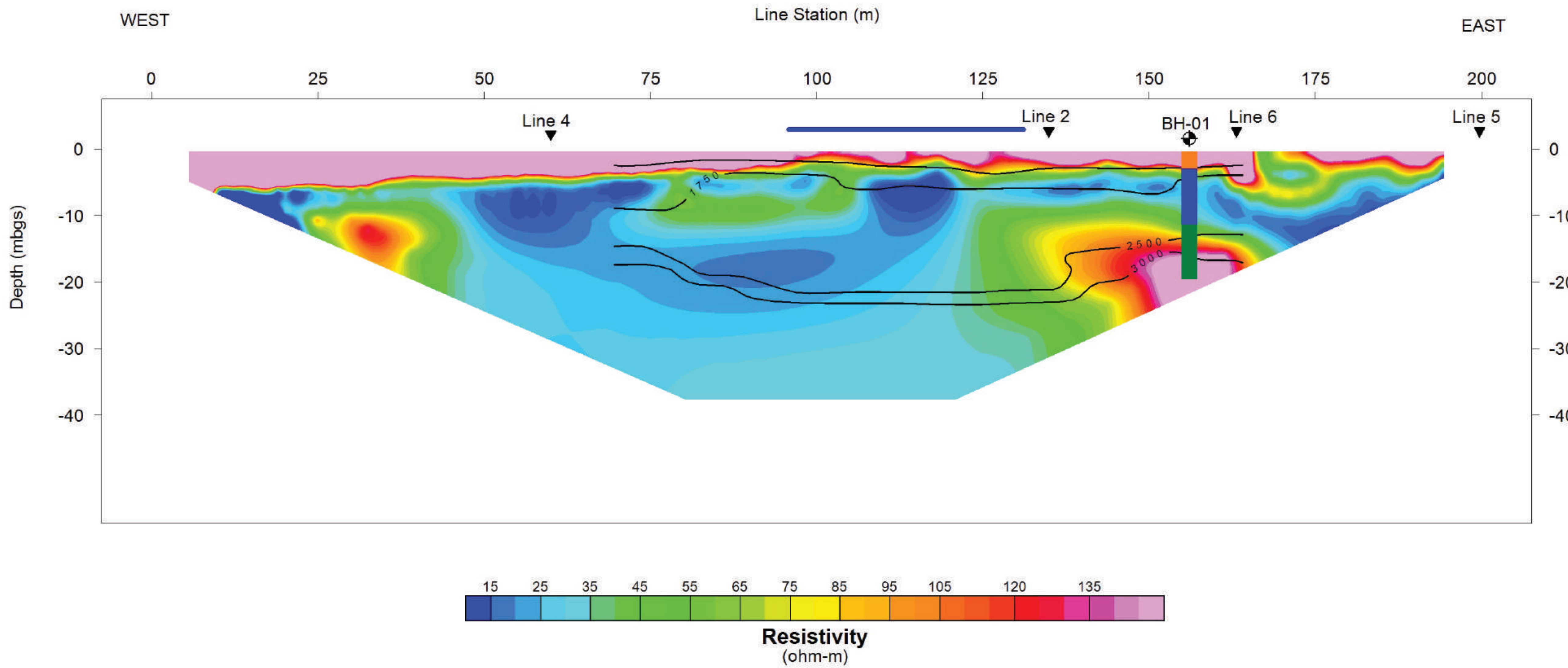
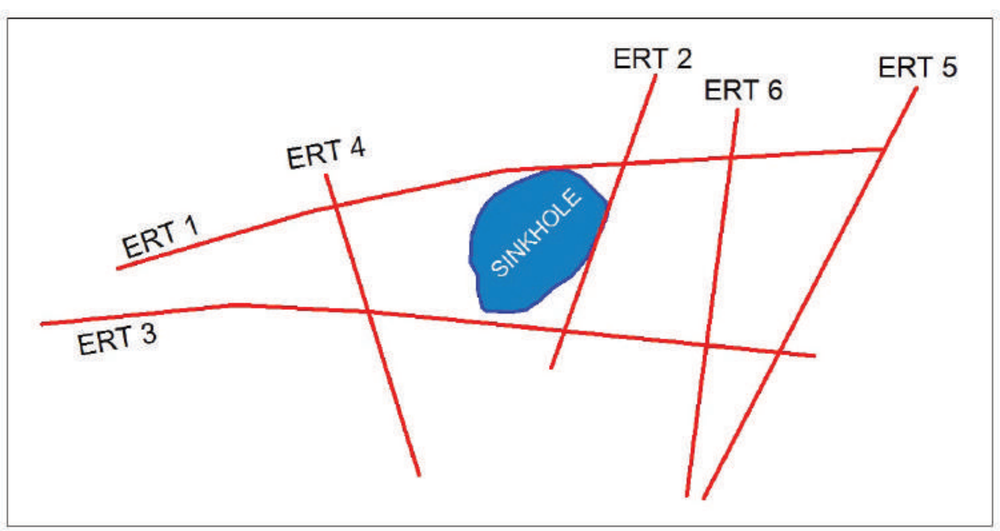




LEGEND

BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
—2500—	P-wave Velocity Contour (1000, 1750, 2500, and 3000 m/s)		Sandstone / Siltstone / Mudstone

10 0 10 20 30 40

(meters)

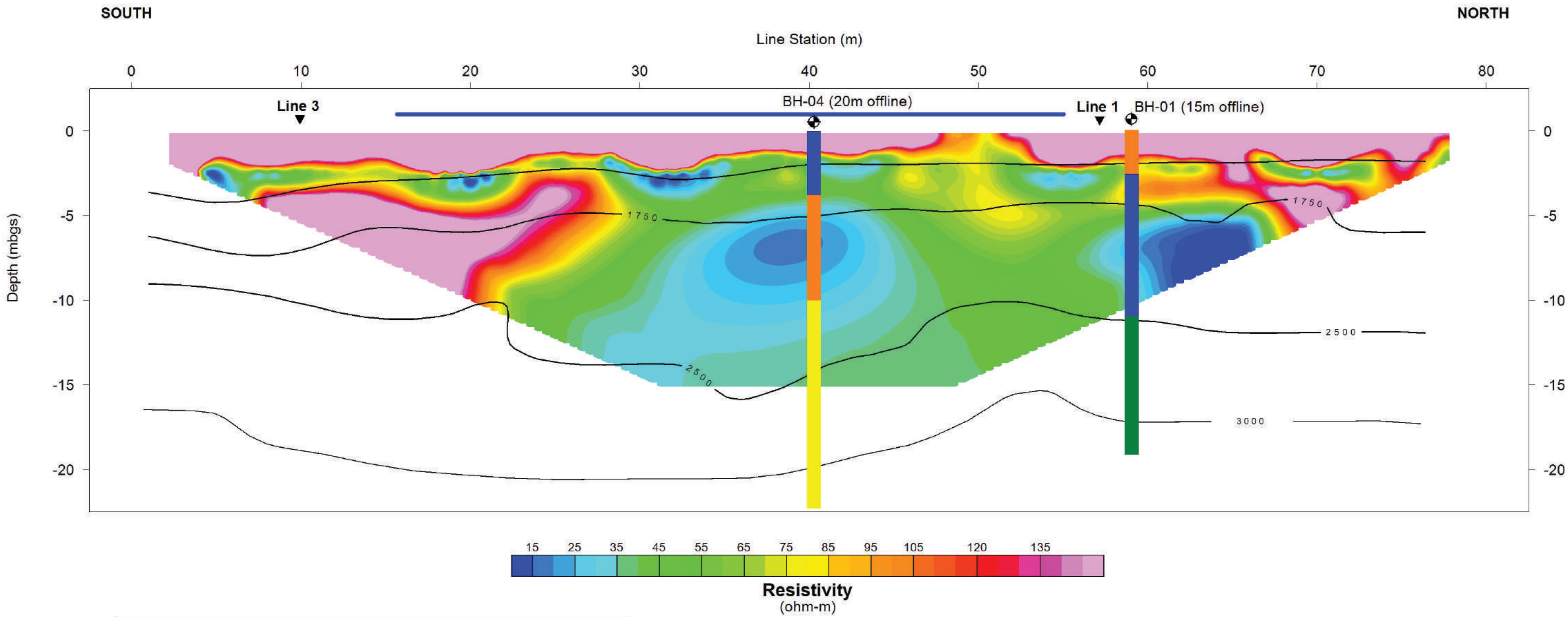
ERT FIELD PARAMETERS:
Date Collected: May 9, 2019
Electrode Configuration: GradientPlus Array
Minimum Electrode Spacing: 2.5 m

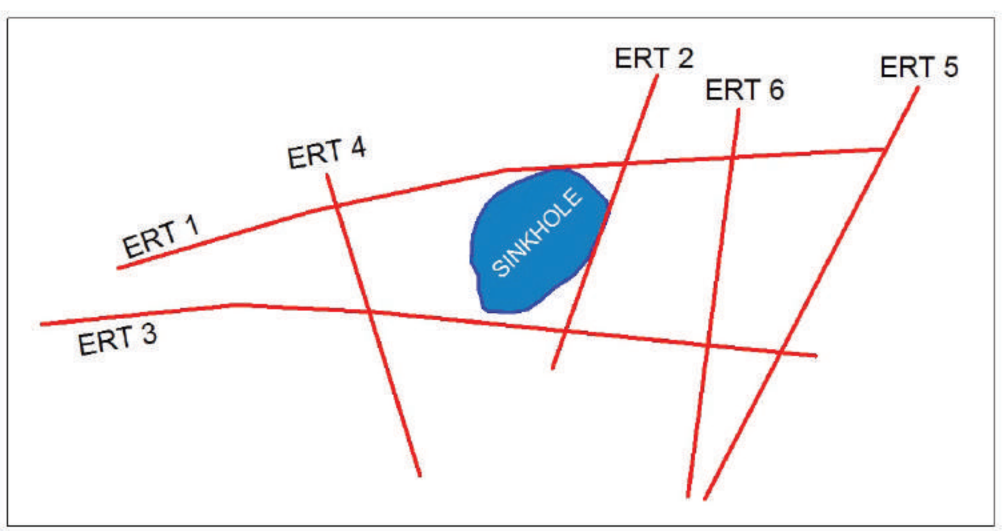
N:\CA\Halifax\Legacy\working\11190000s\11195181 Town of Oxford\Oasis\Maps

TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

LINE 1
ERT RESULTS

Date: June 14, 2019 | Drawn by: dparker
Project No. 11195181
Figure No: 3 | REV 001





LEGEND

BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
—2500—	P-wave Velocity Contour (1000, 1750, 2500, and 3000 m/s)		Sandstone / Siltstone / Mudstone

2.5 0 2.5 5 7.5 10 12.5 15
(meters)

FIELD PARAMETERS:
Date Collected: May 9, 2019
Electrode Configuration: GradientPlus Array
Minimum Electrode Spacing: 1.0 m

TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

GHD

LINE 2
ERT RESULTS

Date: June 14, 2019 | Drawn by: dparker
Project No. 11195181
Figure No. 4 | REV 001

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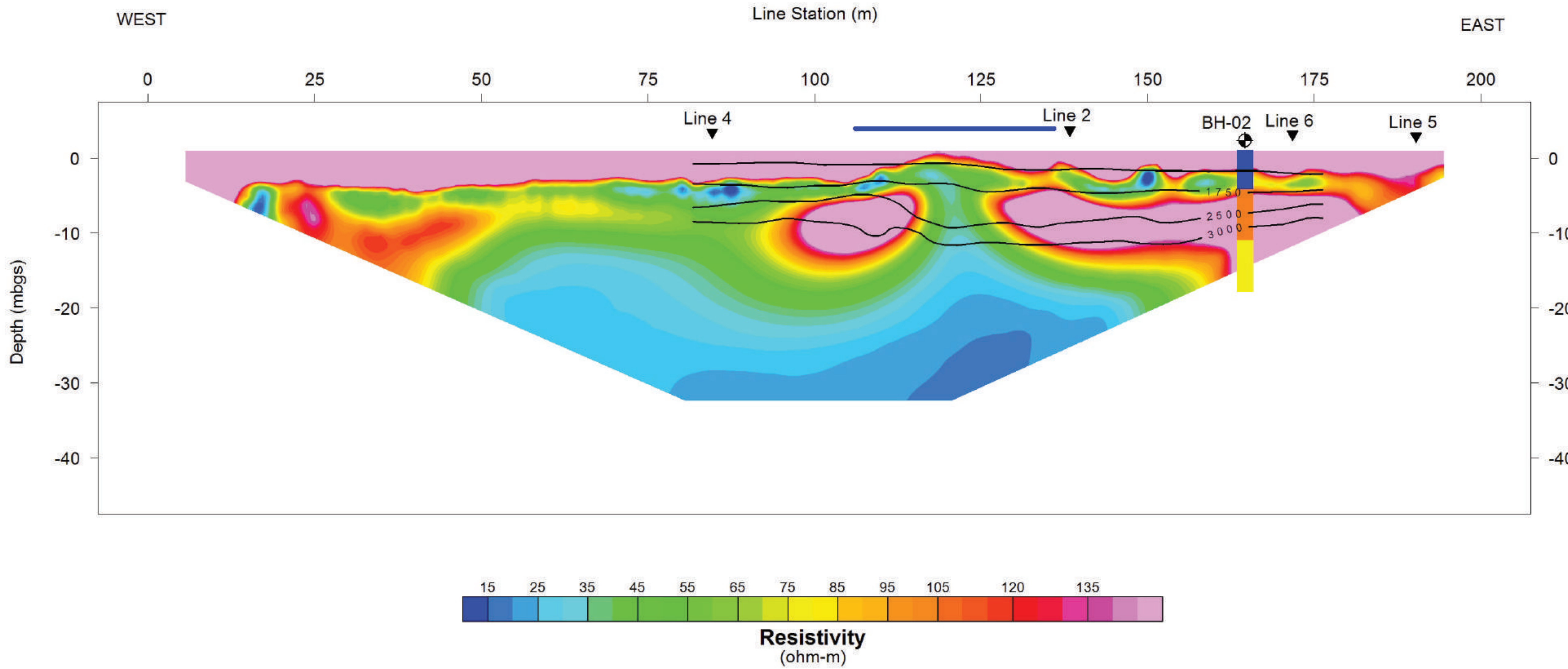
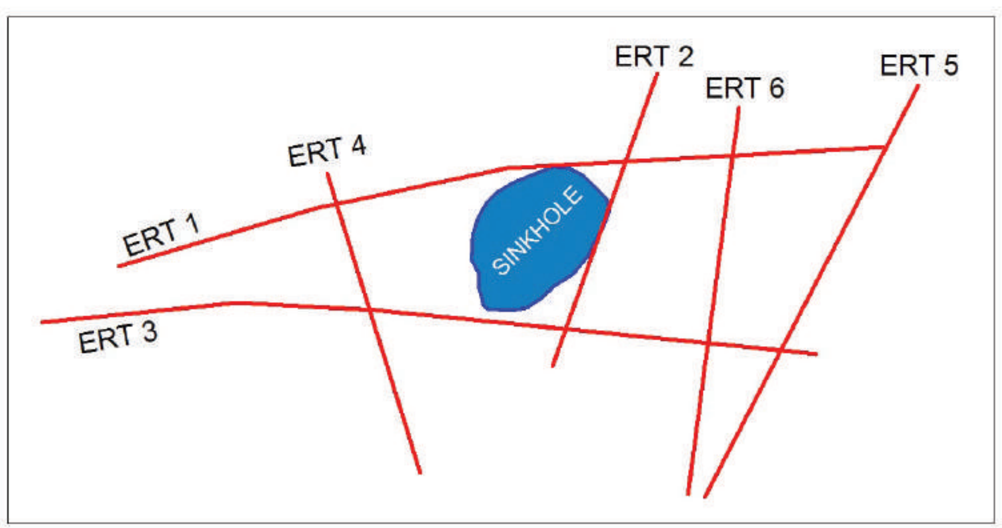
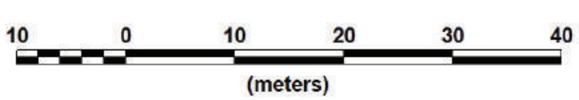




LEGEND

BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
—2500—	P-wave Velocity Contour (1000, 1750, 2500, and 3000 m/s)		Sandstone / Siltstone / Mudstone



FIELD PARAMETERS:
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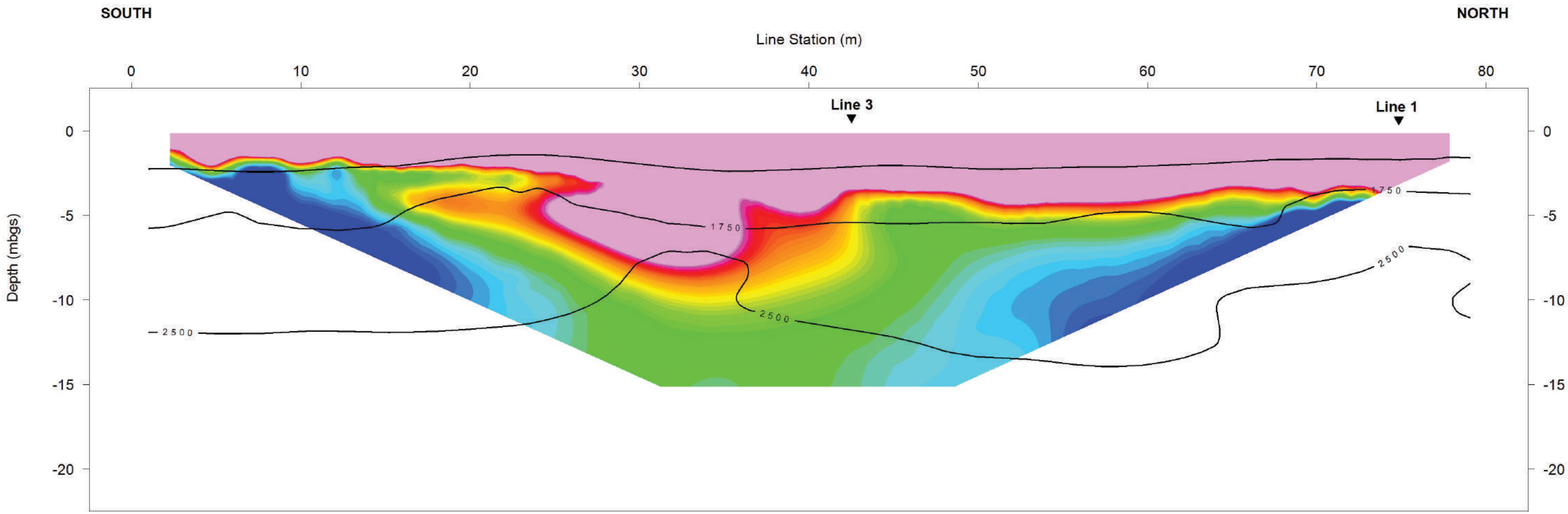
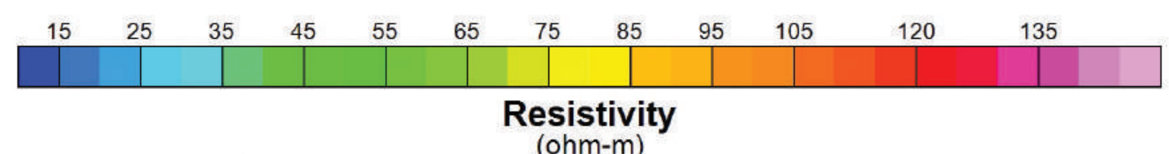
Electrode Configuration: GradientPlus Array
Minimum Electrode Spacing: 2.5 m

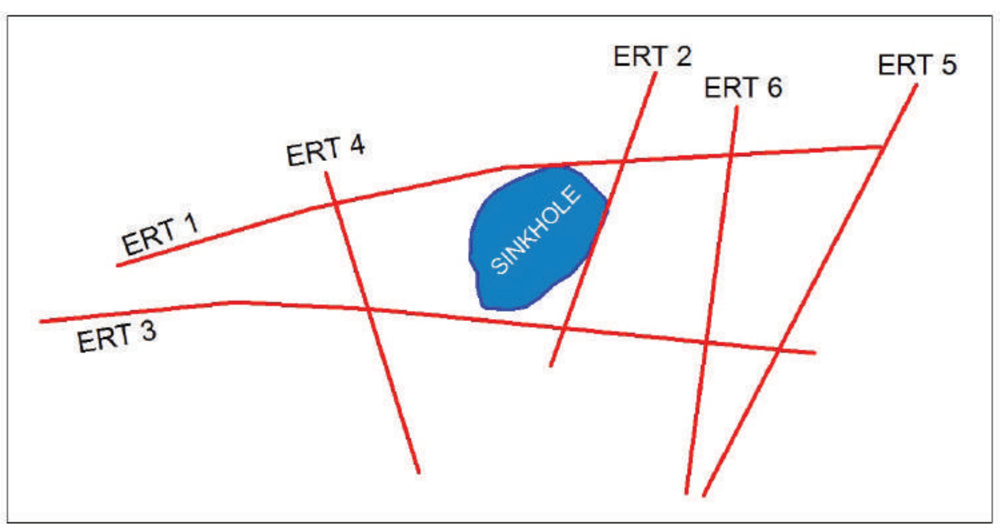
TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

LINE 3
ERT RESULTS

Date	June 14, 2019
Drawn by	dparker
Project No.	11195181
Figure No.	5
REV	001







LEGEND

BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
—2500—	P-wave Velocity Contour (1000, 1750, 2500, and 3000 m/s)		Sandstone / Siltstone / Mudstone

2.5 0 2.5 5 7.5 10 12.5 15
(meters)

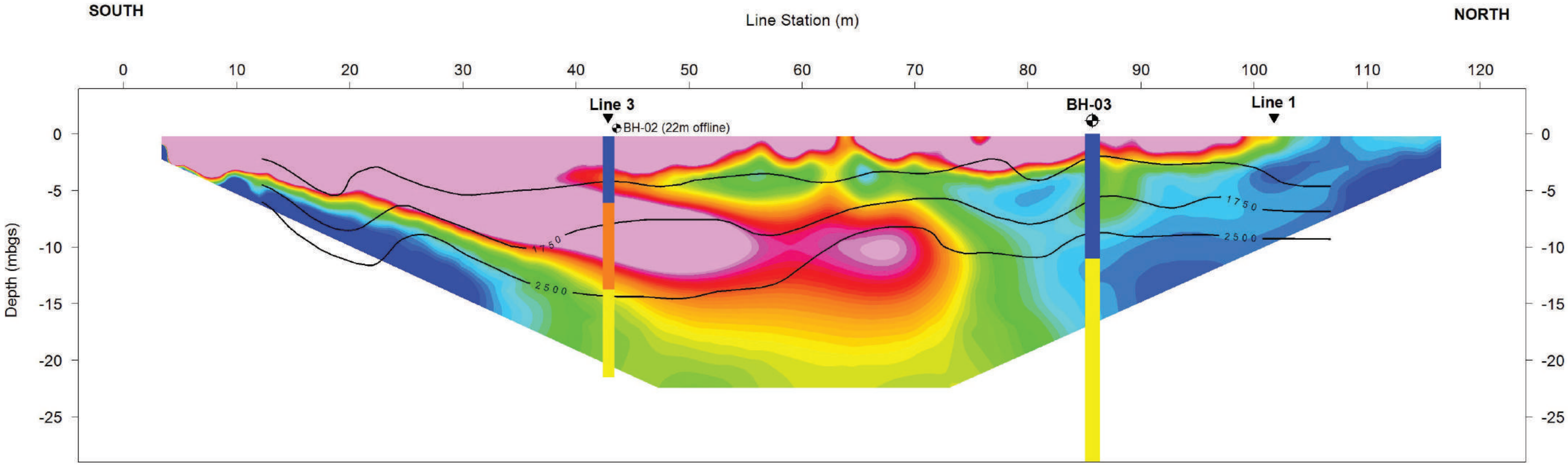
FIELD PARAMETERS:
Date Collected: May 10, 2019
Electrode Configuration: GradientPlus Array
Minimum Electrode Spacing: 1.0 m

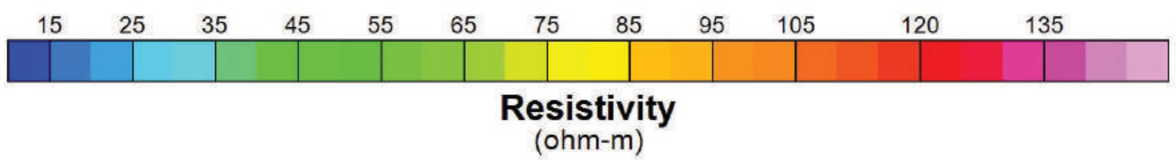
FILE: N:CA\Halifax\11195181\Oasis\ERT Line 4.map

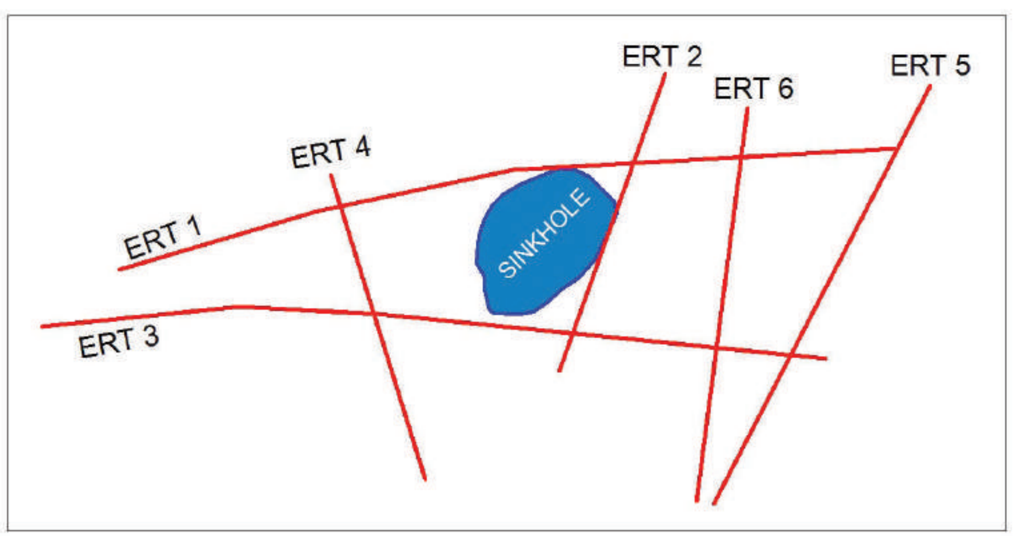
TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

LINE 4
ERT RESULTS

Date: June 14, 2019	Drawn by: dparker
Project No. 11195181	
Figure No. 6	REV 001

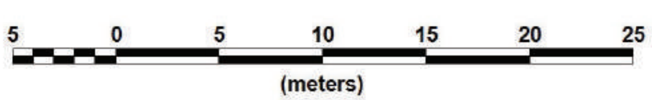






LEGEND

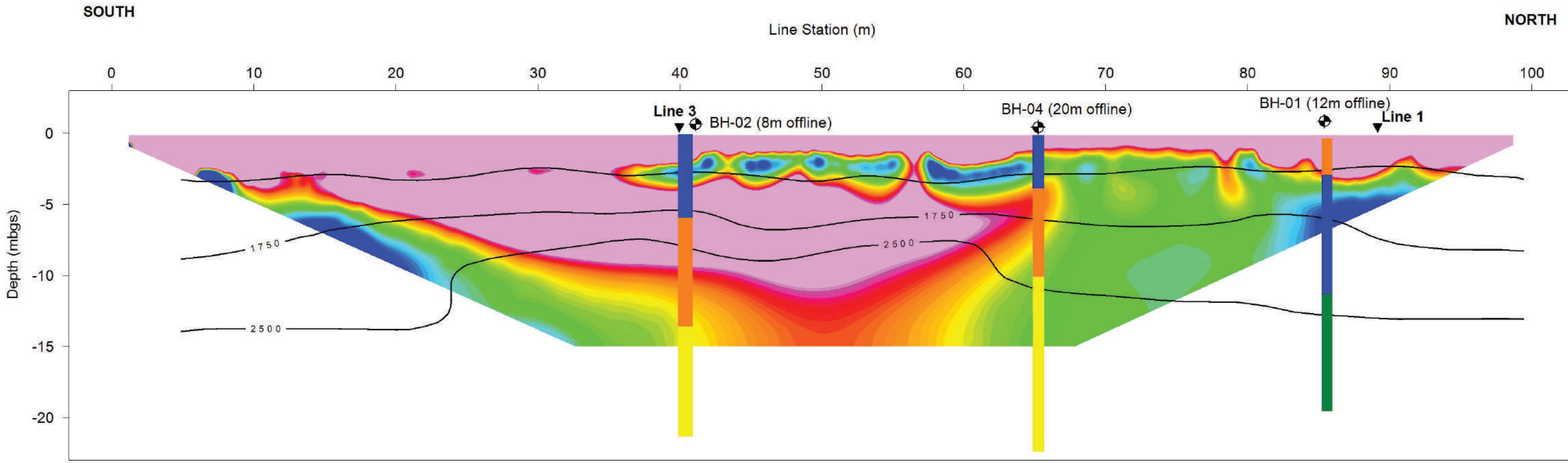
BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
—2500—	P-wave Velocity Contour (1000, 1750, 2500, and 3000 m/s)		Sandstone / Siltstone / Mudstone

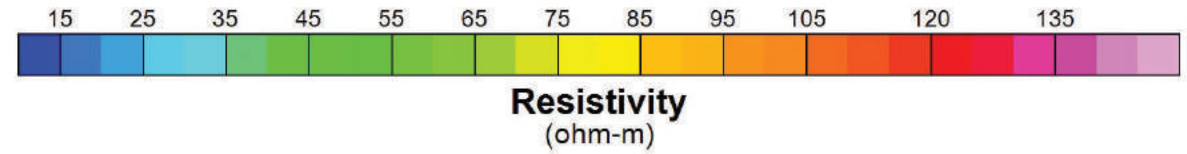


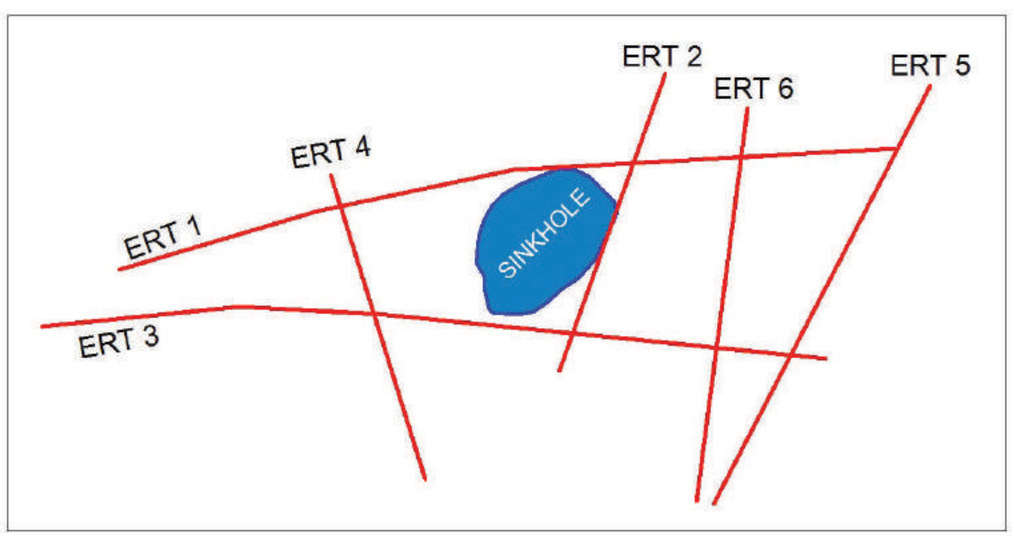
FIELD PARAMETERS:
Date Collected: May 10, 2019
Electrode Configuration: GradientPlus Array
Minimum Electrode Spacing: 1.5 m

TOWN OF OXFORD OXFORD SINKHOLE INVESTIGATION			
GHD	LINE 5 ERT RESULTS	Date: June 14, 2019	Drawn by: dparker
		Project No. 11195181	
		Figure No: 7	REV 001

FILE: N:CA\Halifax\11195181\Oasis\ERT Line 5.map

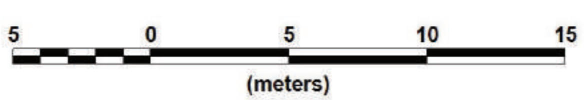






LEGEND

BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
2500	P-wave Velocity Contour (1000, 1750, 2500, and 3000 m/s)		Sandstone / Siltstone / Mudstone



FIELD PARAMETERS:
Date Collected: May 10, 2019
Electrode Configuration: GradientPlus Array
Minimum Electrode Spacing: 1.0 m

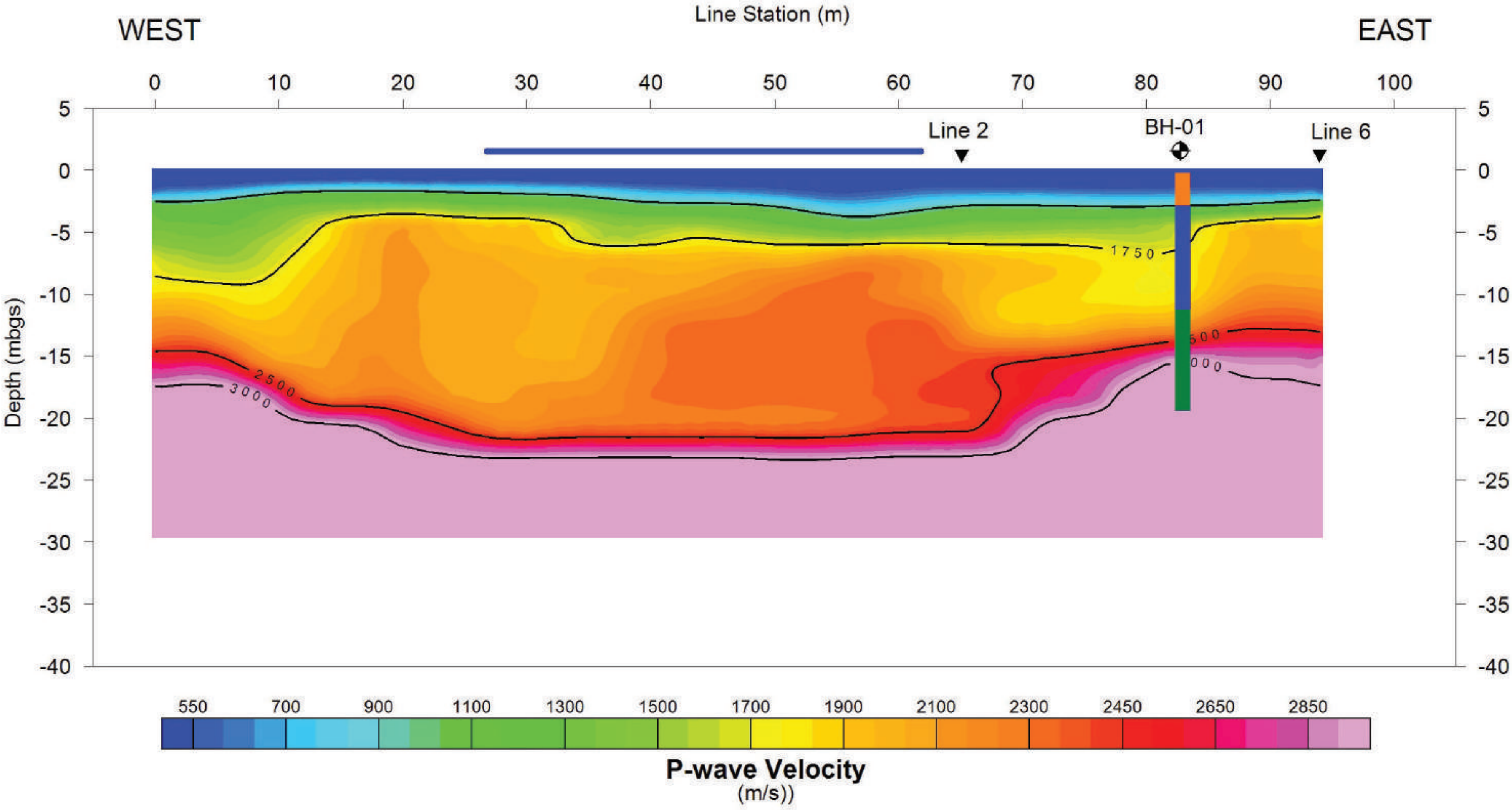
TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

LINE 6
ERT RESULTS

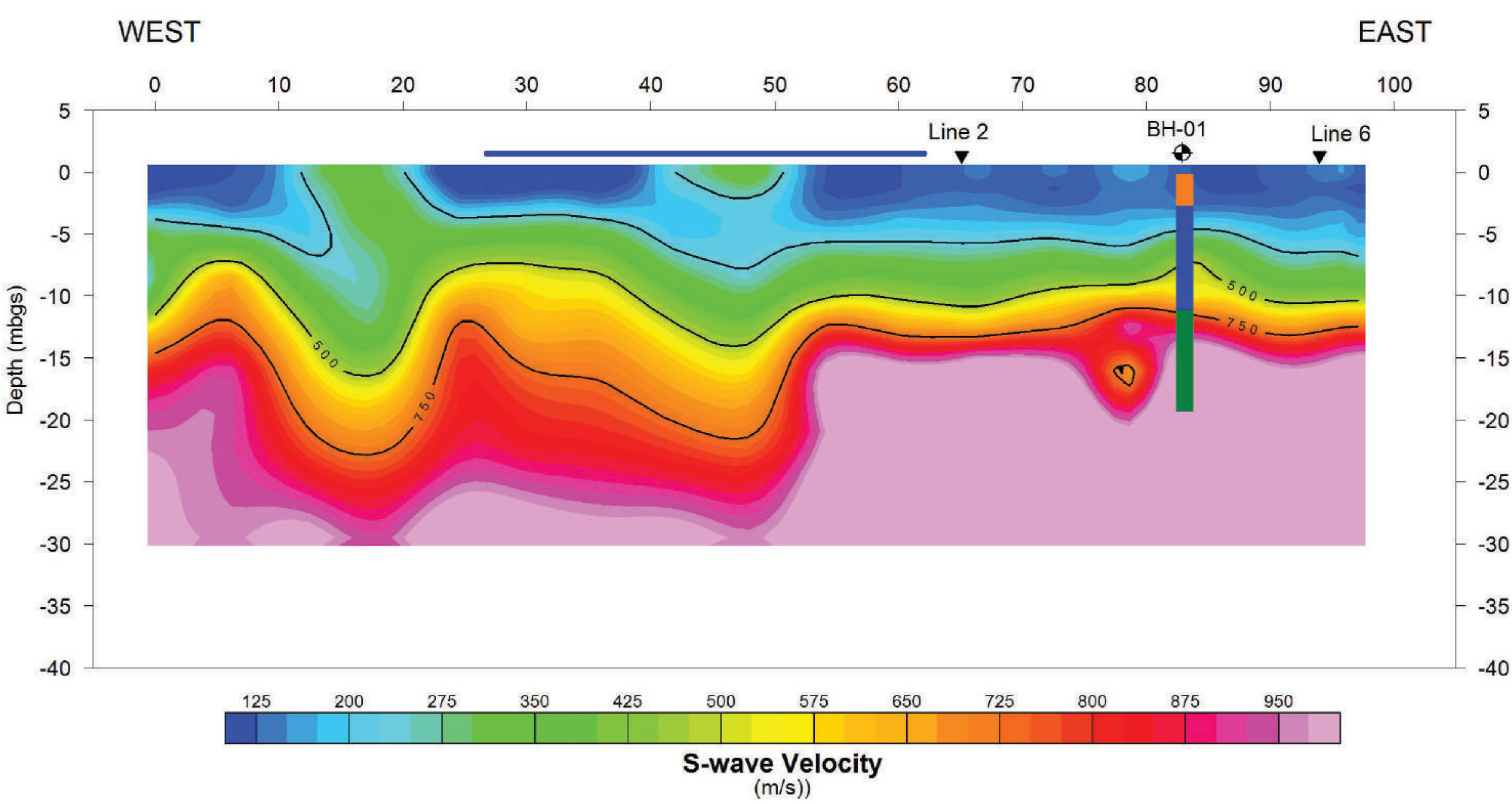
Date: June 14, 2019 | Drawn by: dparker
Project No. 11195181
Figure No: 8 | REV 001

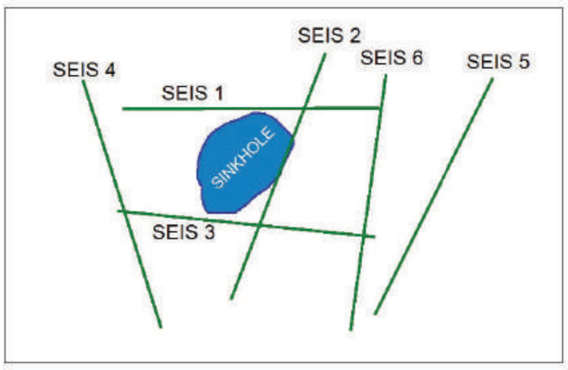
FILE: N:CAHalifax \working\11195181\Oasis\maps

SEISMIC REFRACTION



MASW





LEGEND

BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
—2500—	Seismic Velocity Contour (m/s)		Sandstone / Siltstone / Mudstone

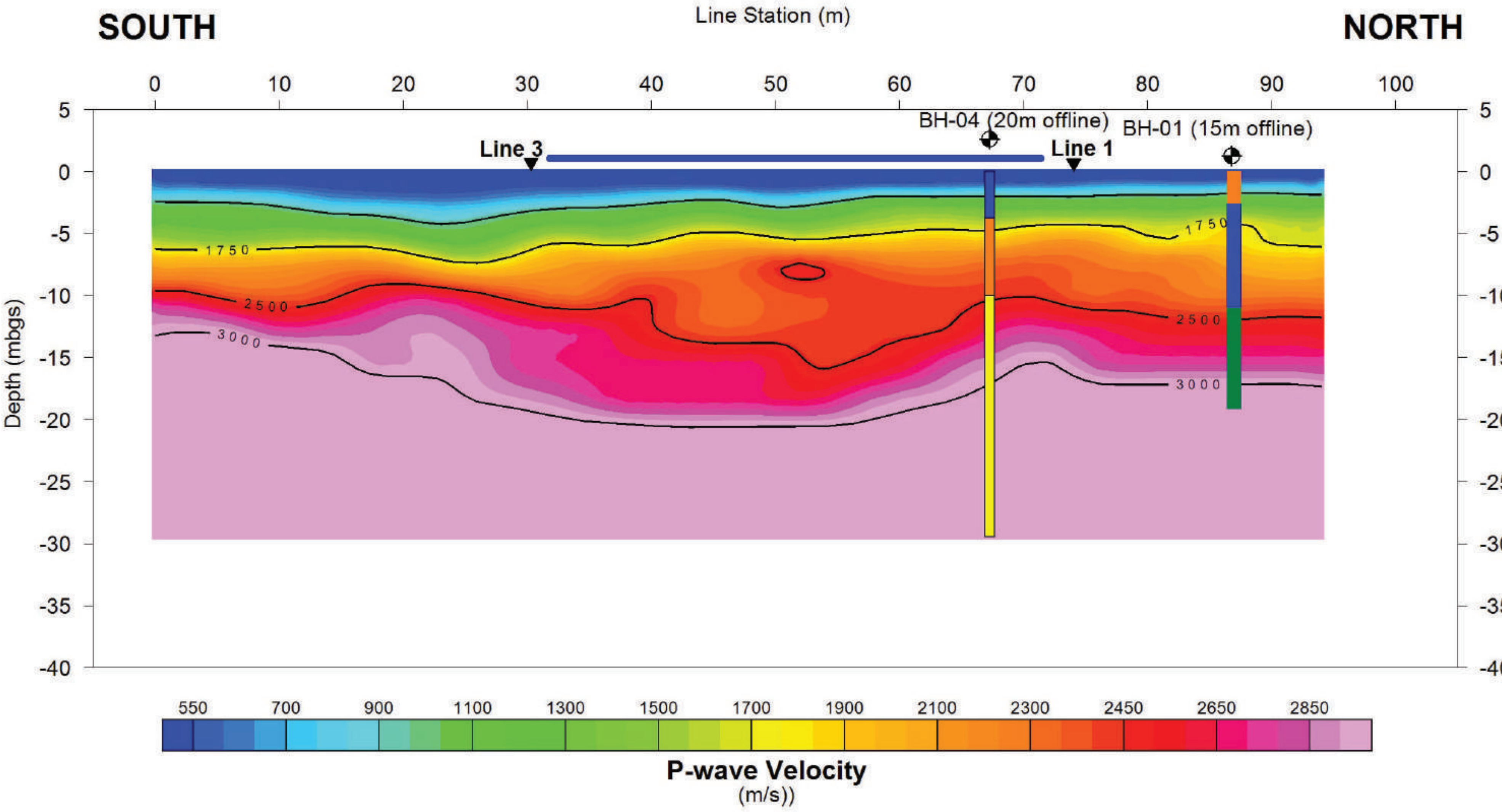
5 0 5 10 15 20
(meters)

FIELD PARAMETERS:
Date Collected: May 15, 2019
Geophone Spacing: 2 m
Seismic Source: Plate and Hammer

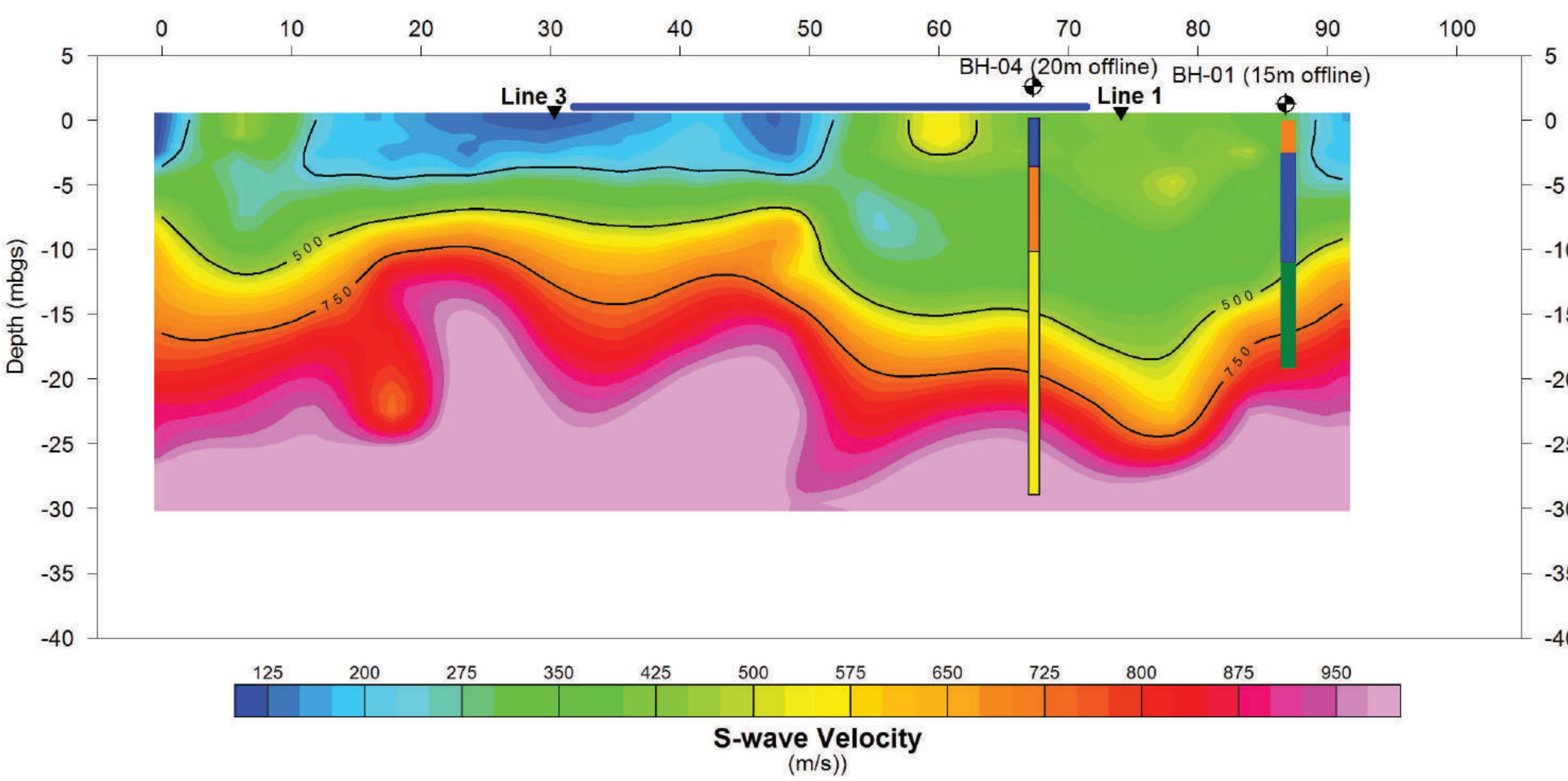
TOWN OF OXFORD OXFORD SINKHOLE INVESTIGATION			
GHD	LINE 1 SEISMIC RESULTS	Date: June 14, 2019	Drawn by: dparker
		Project No. 11195181	
		Figure No. 9	REV 001

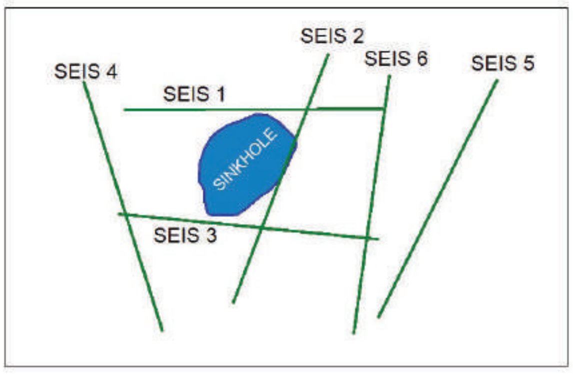
FILE: N:CA\Halifax\11195181\Oasis\Seismic Line 1.map

SEISMIC REFRACTION



MASW





LEGEND

BH-01	Borehole Location
Line 4	Survey Line Intersection
	Approximate Sinkhole Location (at surface, extrapolated)
—2500—	Seismic Velocity Contour (m/s)

- Clay
- Sand / Gravel
- Conglomerate
- Sandstone / Siltstone / Mudstone

5 0 5 10 15 20
(meters)

FIELD PARAMETERS:
Date Collected: May 16, 2019
Geophone Spacing: 2 m
Seismic Source: Plate and Hammer

TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

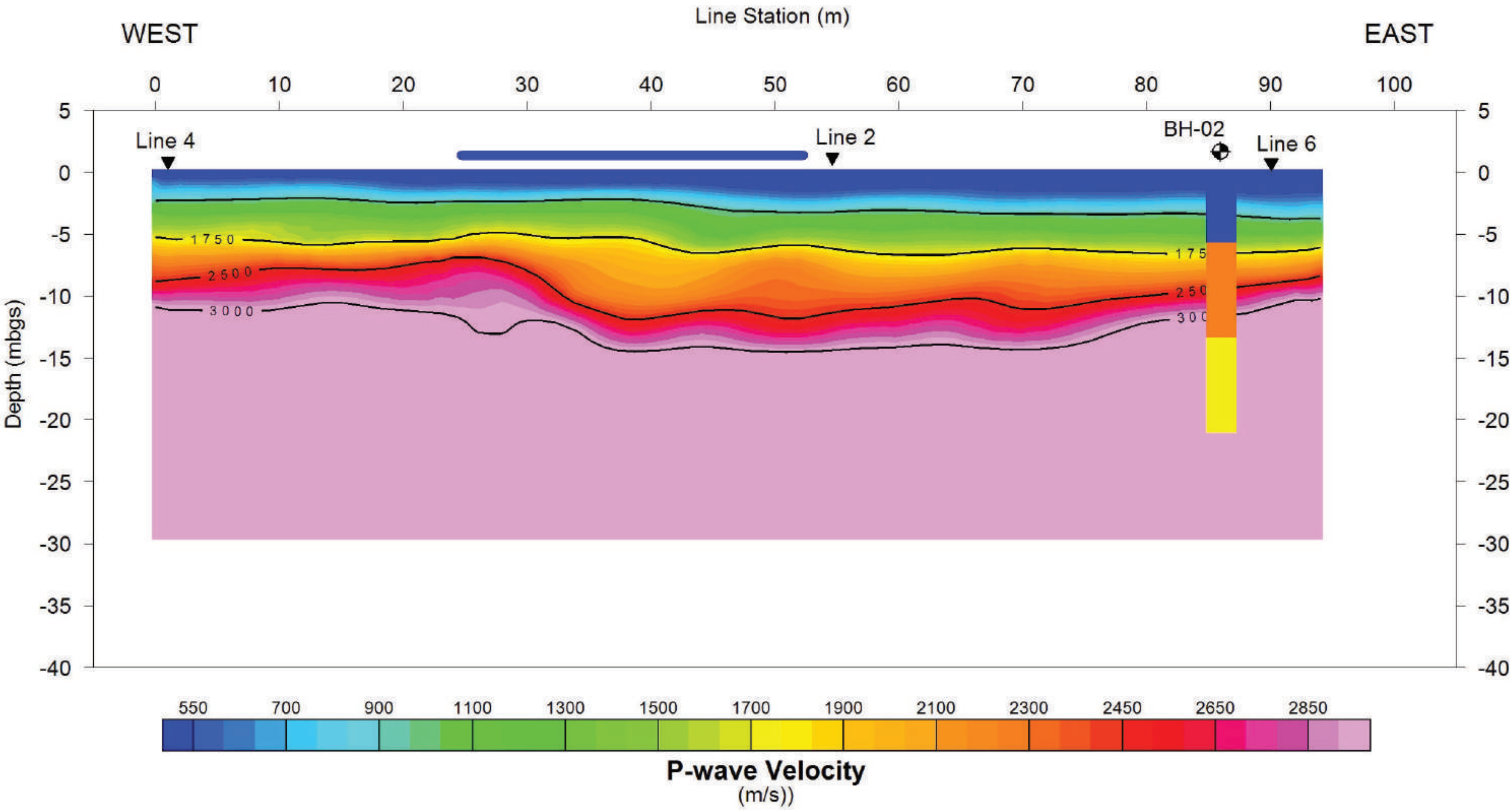
GHD

LINE 2
SEISMIC RESULTS

Date	June 14, 2019	Drawn by	dparker
Project No	11195181		
Figure No	10	REV	001

FILE: N:CA\Halifax\11195181\Oasis\Seismic Line 2.map

SEISMIC REFRACTION



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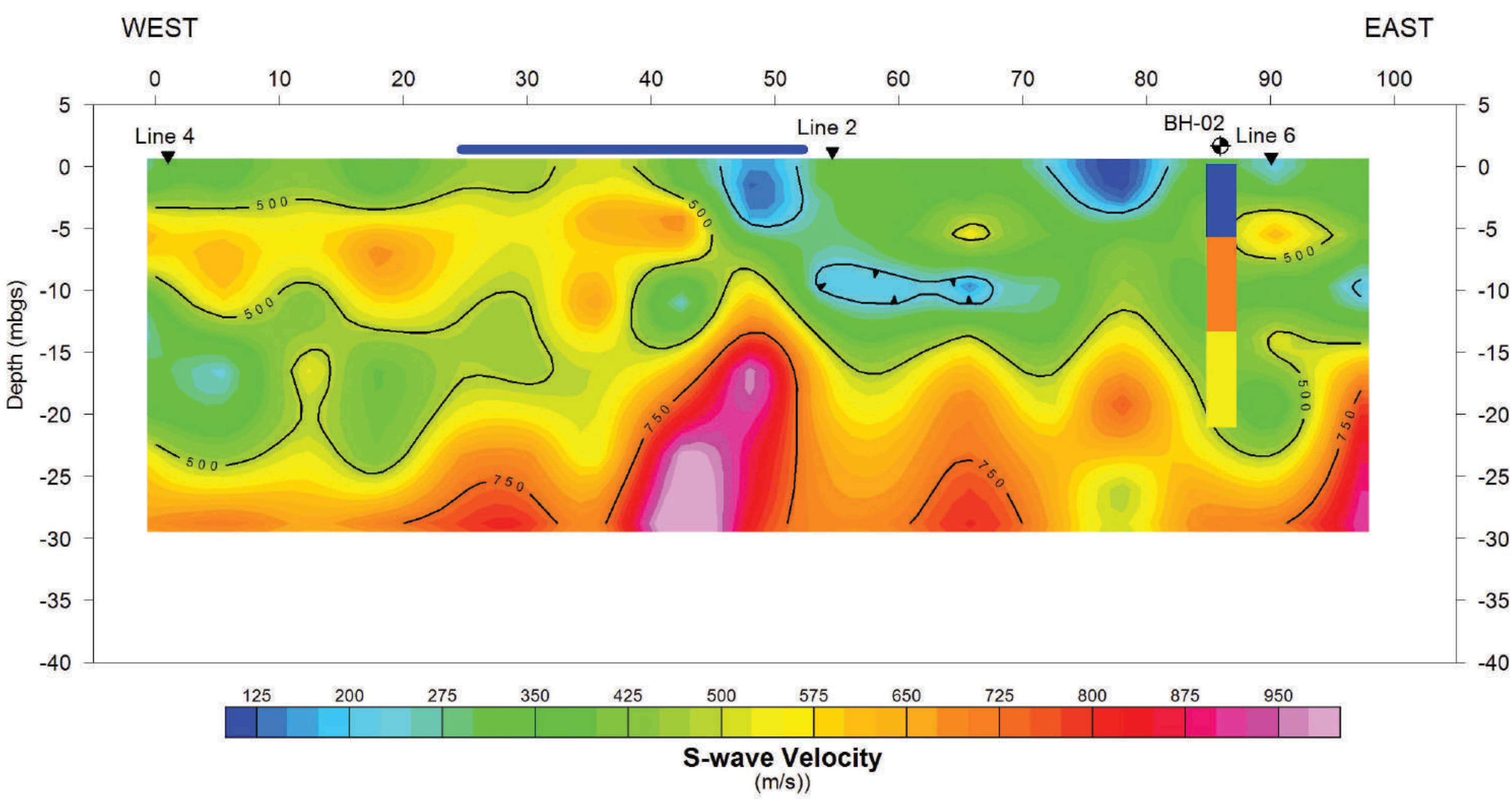
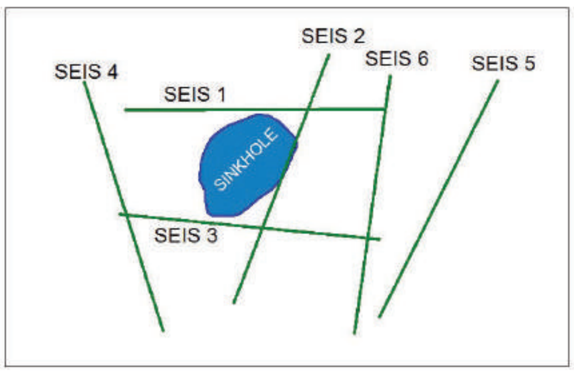
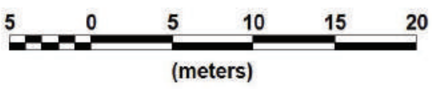




LEGEND

BH-01	Borehole Location
Line 4	Survey Line Intersection
	Approximate Sinkhole Location (at surface, extrapolated)
—2500—	Seismic Velocity Contour (m/s)

- Clay
- Sand / Gravel
- Conglomerate
- Sandstone / Siltstone / Mudstone



FIELD PARAMETERS:
Date Collected: May 15, 2019
Geophone Spacing: 2 m
Seismic Source: Plate and Hammer

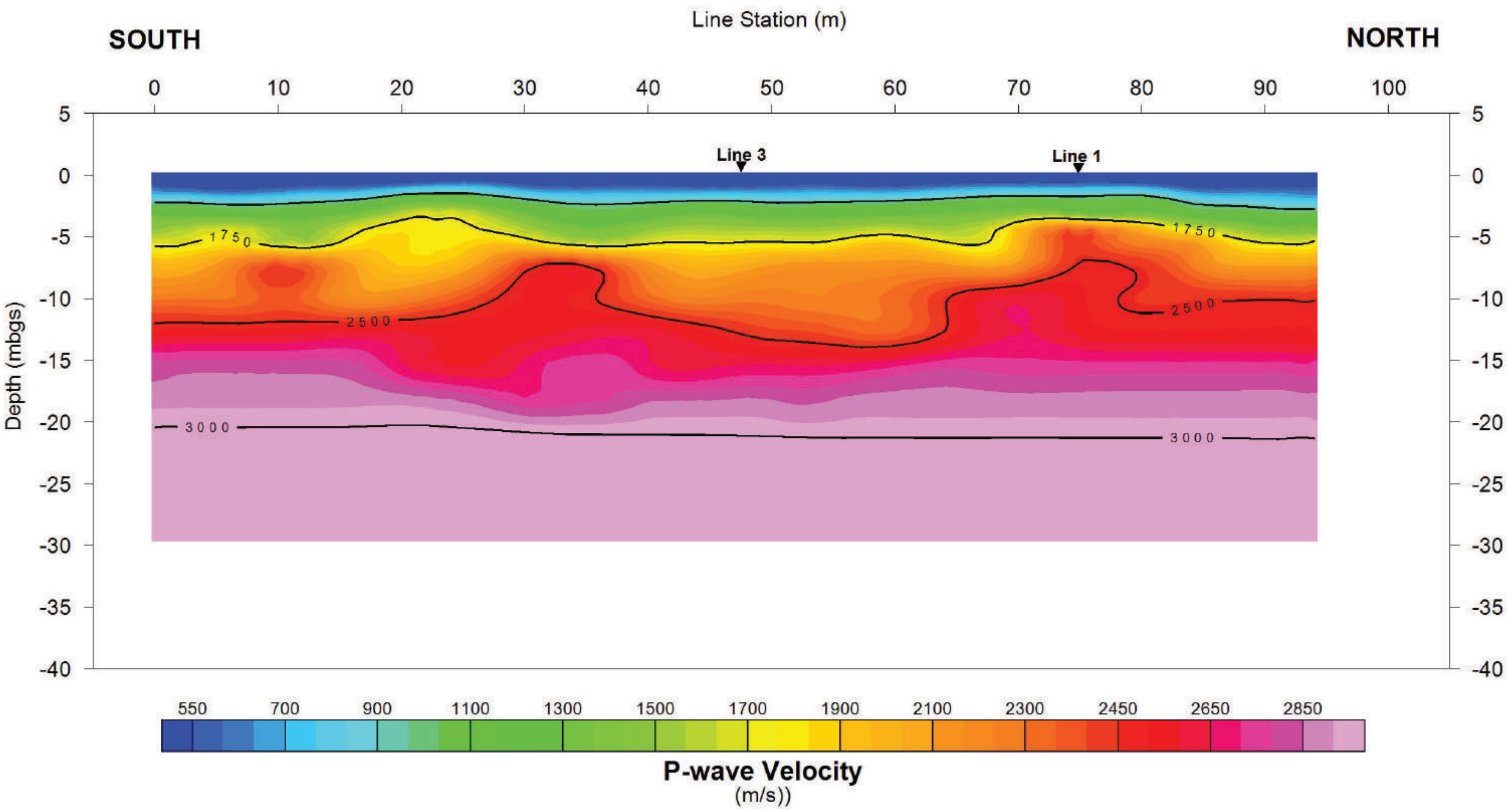
FILE: N:CA\Halifax\11195181\Oasis\Seismic Line 3.map

TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

LINE 3
SEISMIC RESULTS

Date	June 14, 2019
Drawn by	dparker
Project No	11195181
Figure No	11
REV	001

SEISMIC REFRACTION



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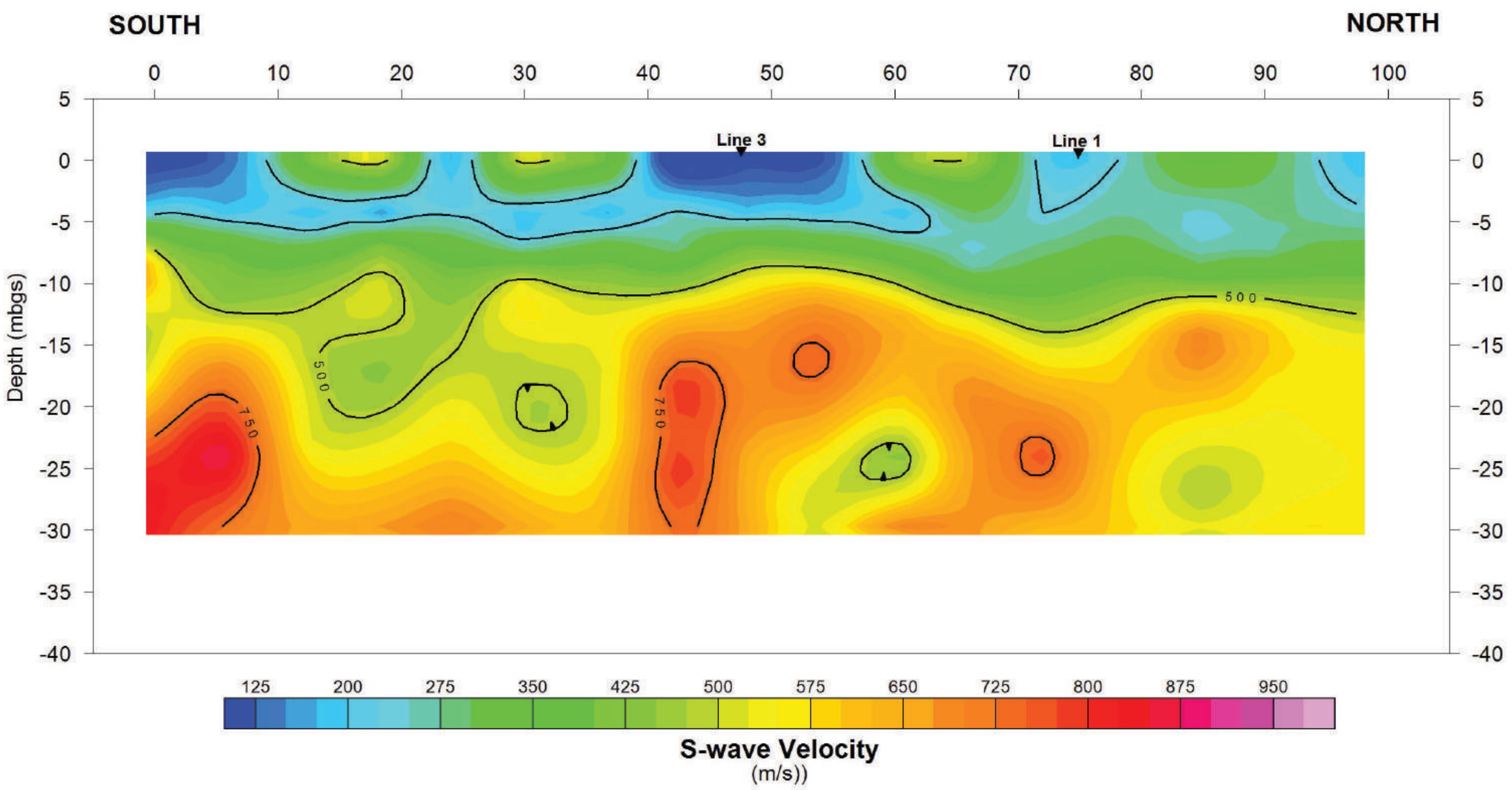
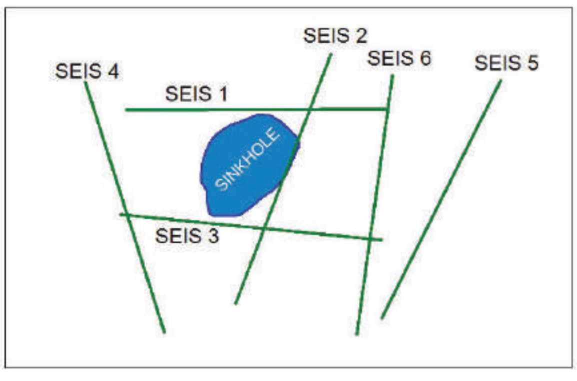
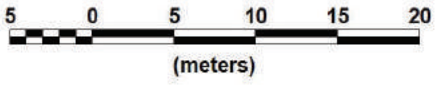




LEGEND

BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
—2500—	Seismic Velocity Contour (m/s)		Sandstone / Siltstone / Mudstone



FIELD PARAMETERS:
Date Collected: May 17, 2019
Geophone Spacing: 2 m
Seismic Source: Plate and Hammer

TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

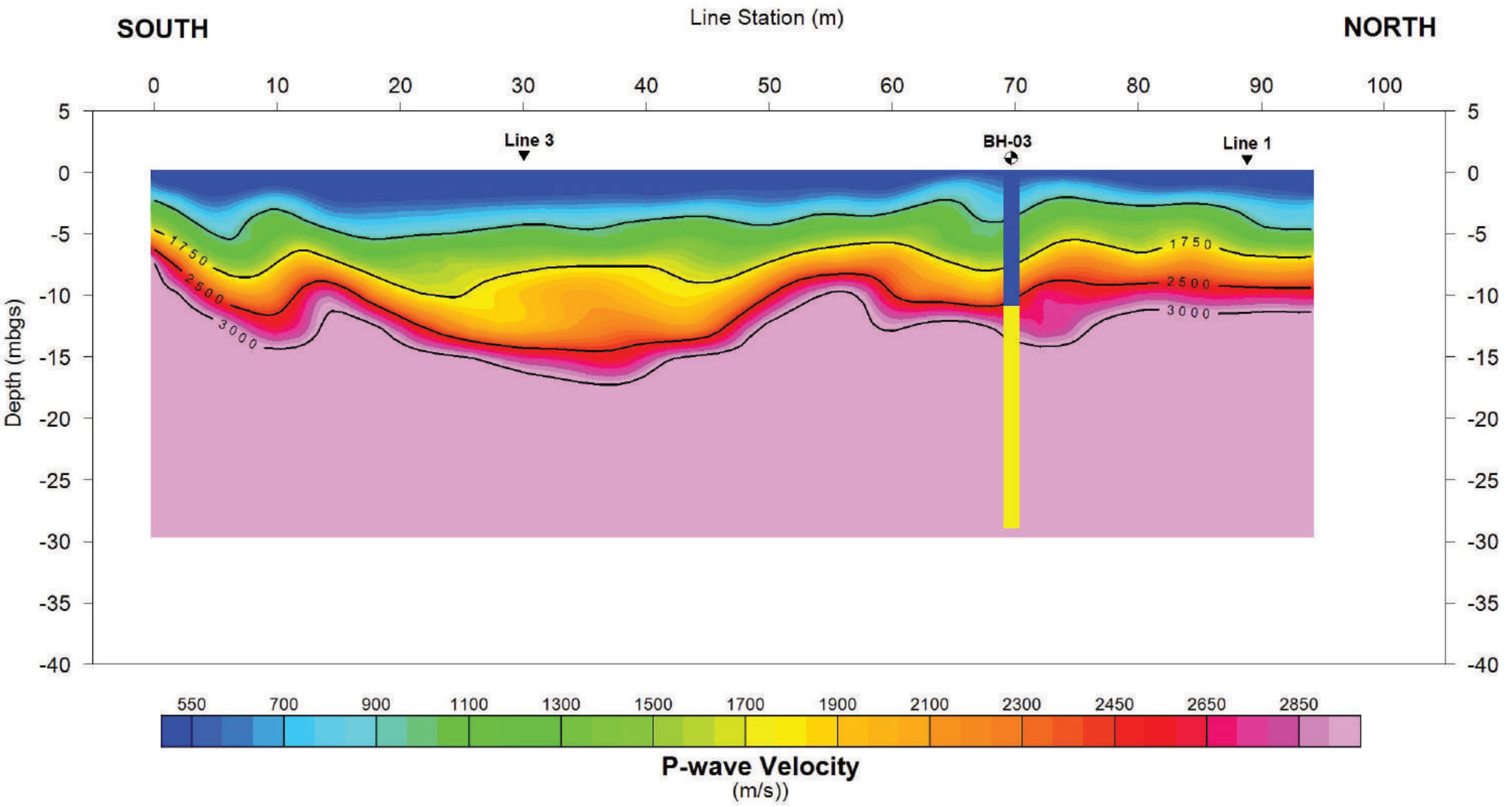
GHD

LINE 4
SEISMIC RESULTS

Date: June 14, 2019 | Drawn by: dparker
Project No. 11195181
Figure No: 12 | REV 001

FILE: N:\CA\Halifax\11195181\Oasis\Seismic Line 4.map

SEISMIC REFRACTION



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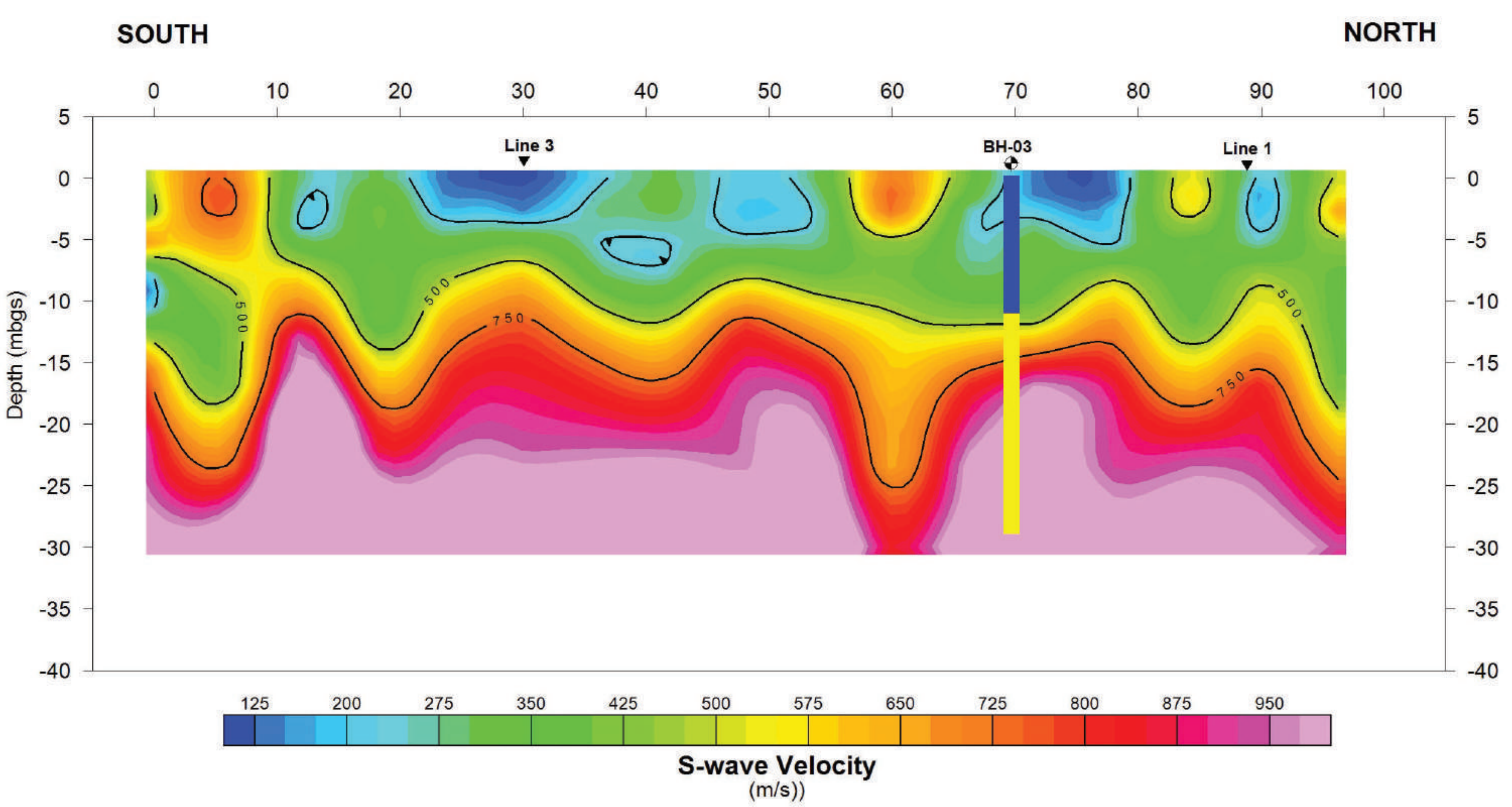
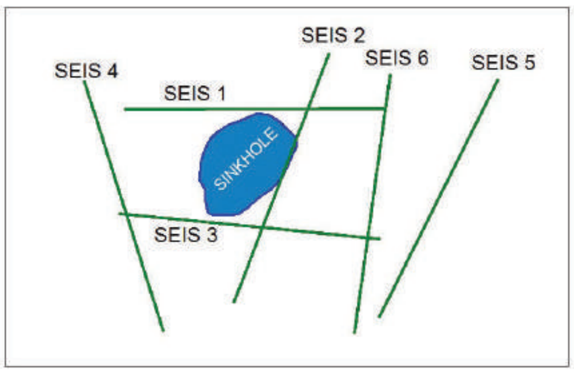
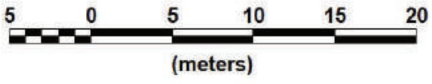




LEGEND

BH-01	Borehole Location		Clay
Line 4	Survey Line Intersection		Sand / Gravel
	Approximate Sinkhole Location (at surface, extrapolated)		Conglomerate
—2500—	Seismic Velocity Contour (m/s)		Sandstone / Siltstone / Mudstone



FIELD PARAMETERS:
Date Collected: May 16, 2019
Geophone Spacing: 2 m
Seismic Source: Plate and Hammer

TOWN OF OXFORD
OXFORD SINKHOLE INVESTIGATION

LINE 5
SEISMIC RESULTS

Date: June 14, 2019	Drawn by: dparker		
Project No. 11195181			
Figure No. 13		REV 001	

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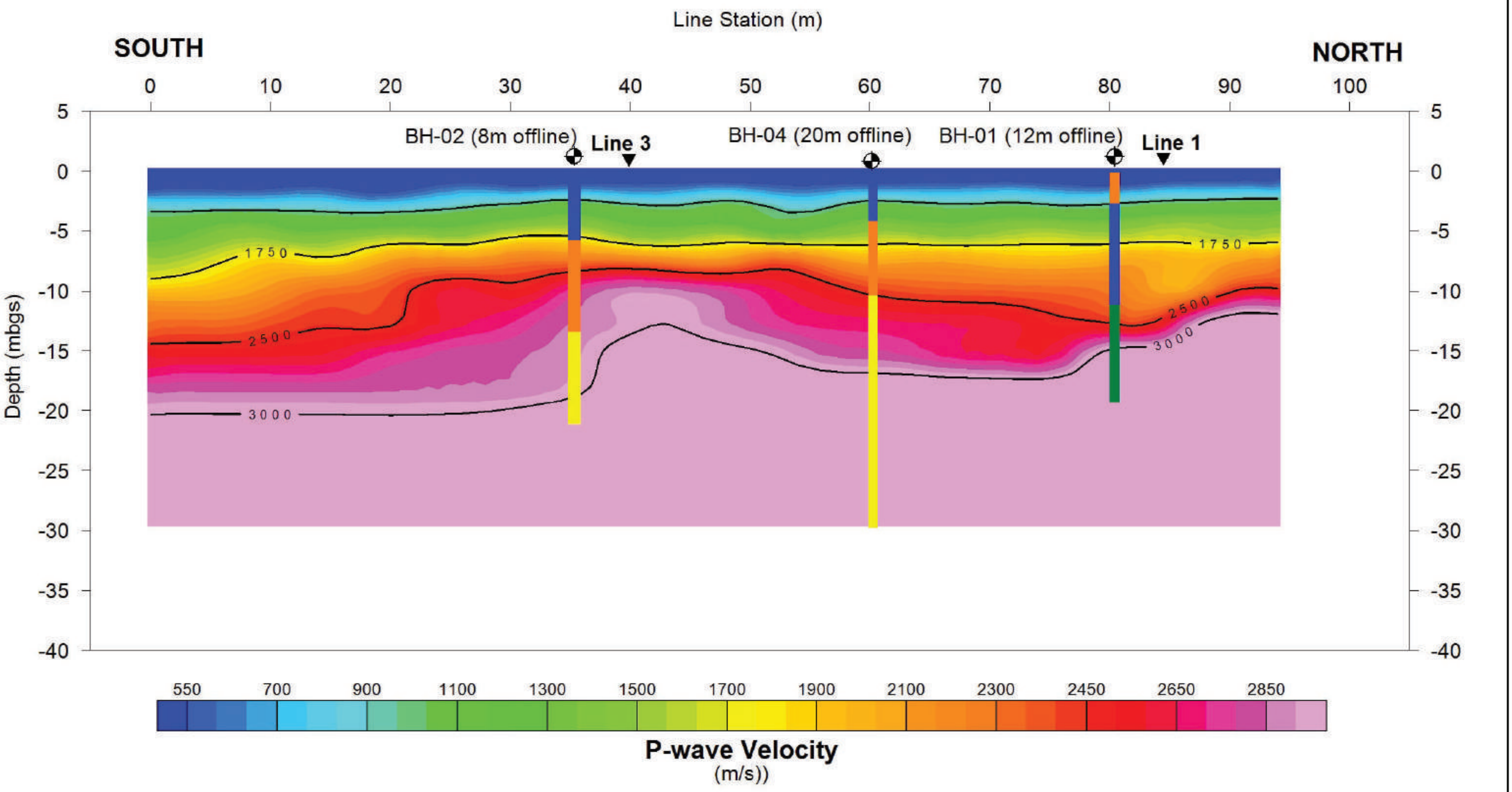
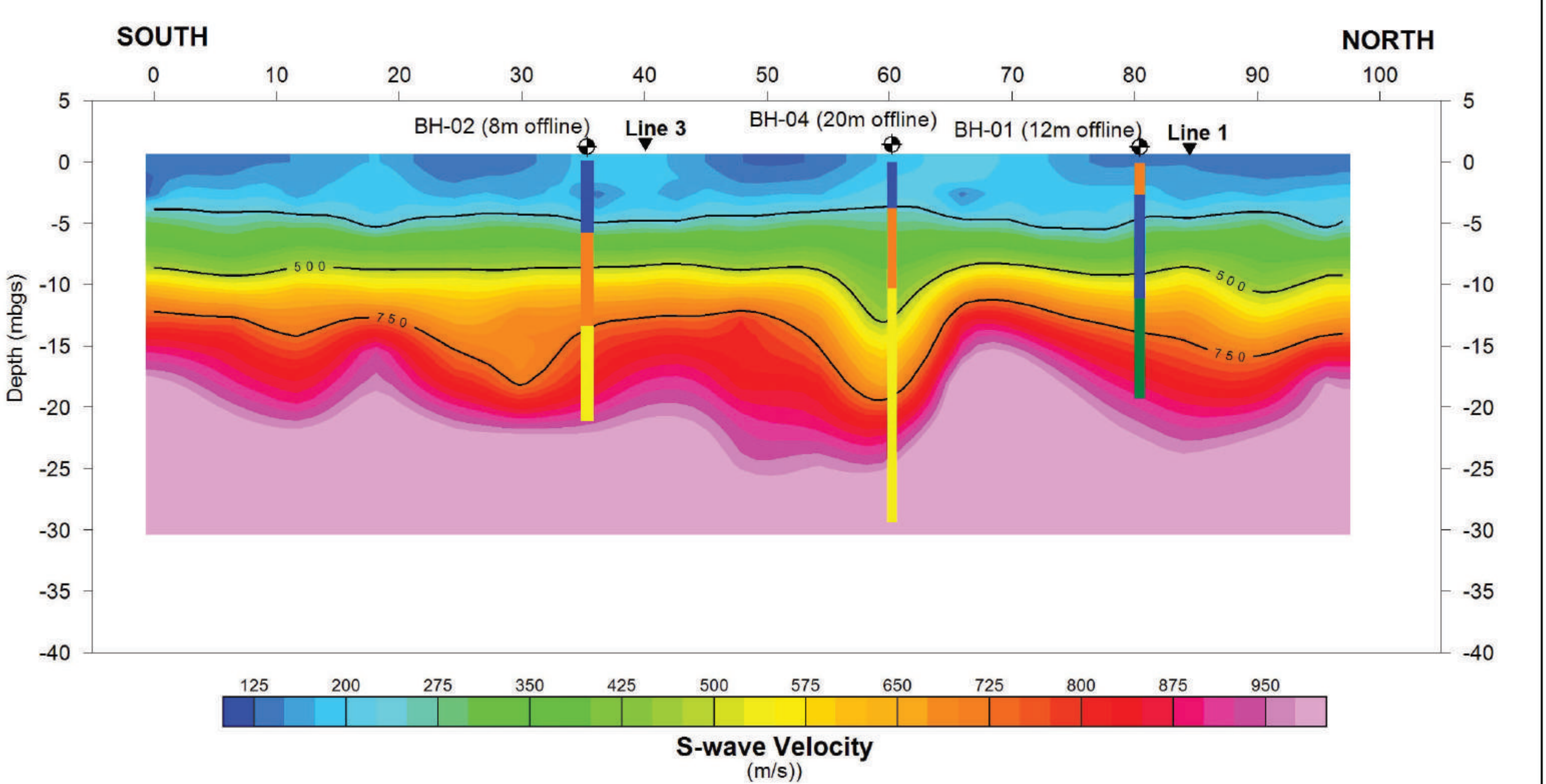
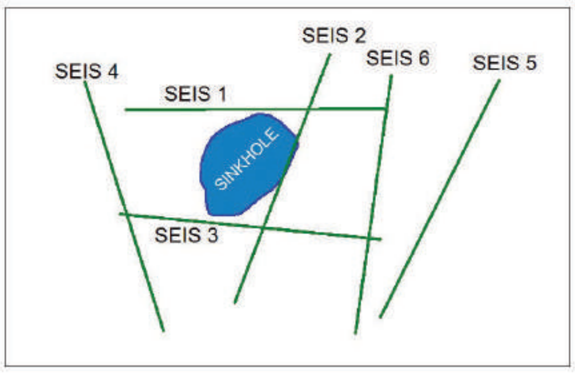
FILE: N:CA\Halifax\11195181\Oasis\Seismic Line 5.map

SEISMIC REFRACTION



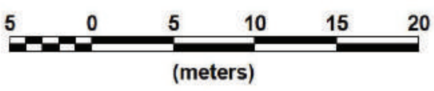
MASW





LEGEND

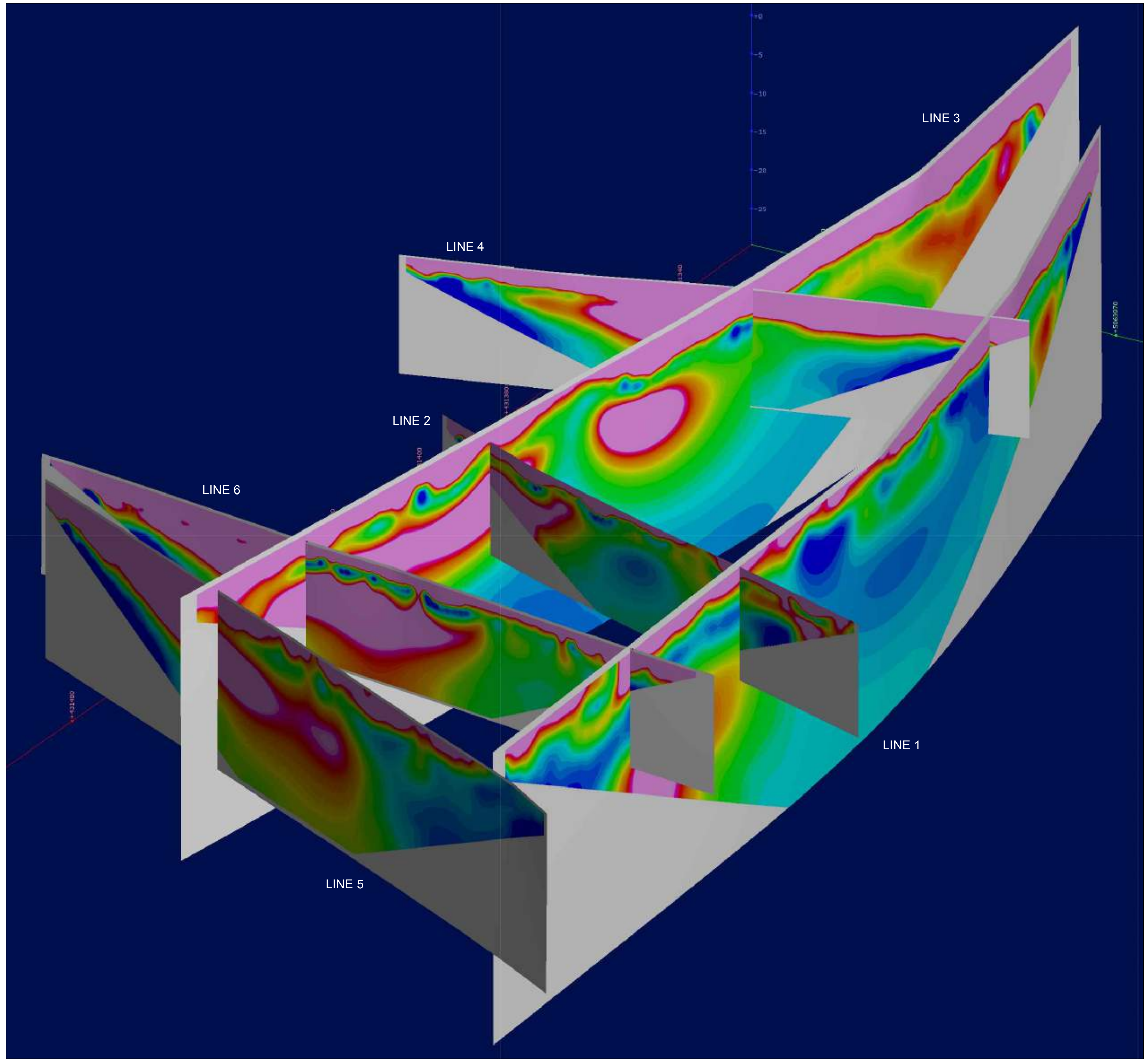
- **BH-01** — Borehole Location
- **Line 4** — Survey Line Intersection
- Approximate Sinkhole Location (at surface, extrapolated)
- —2500— Seismic Velocity Contour (m/s)
- Clay
- Sand / Gravel
- Conglomerate
- Sandstone / Siltstone / Mudstone



FIELD PARAMETERS:
Date Collected: May 16, 2019
Geophone Spacing: 2 m
Seismic Source: Plate and Hammer

TOWN OF OXFORD OXFORD SINKHOLE INVESTIGATION		
GHD	LINE 6 SEISMIC RESULTS	Date: June 14, 2019 — Drawn by: dparker Project No. 11195181 Figure No. 14 — REV 001

FILE: N:CA\Halifax\11195181\Oasis\Seismic Line 6.map



SCALE = NTS
3D FENCE DIAGRAMS ARE INTENDED FOR VISUALIZATION PURPOSES ONLY. ANY MEASUREMENTS, GRID VALUES, ETC. SHOULD BE TAKEN FROM THE INDIVIDUAL 2D CROSS SECTIONS

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01
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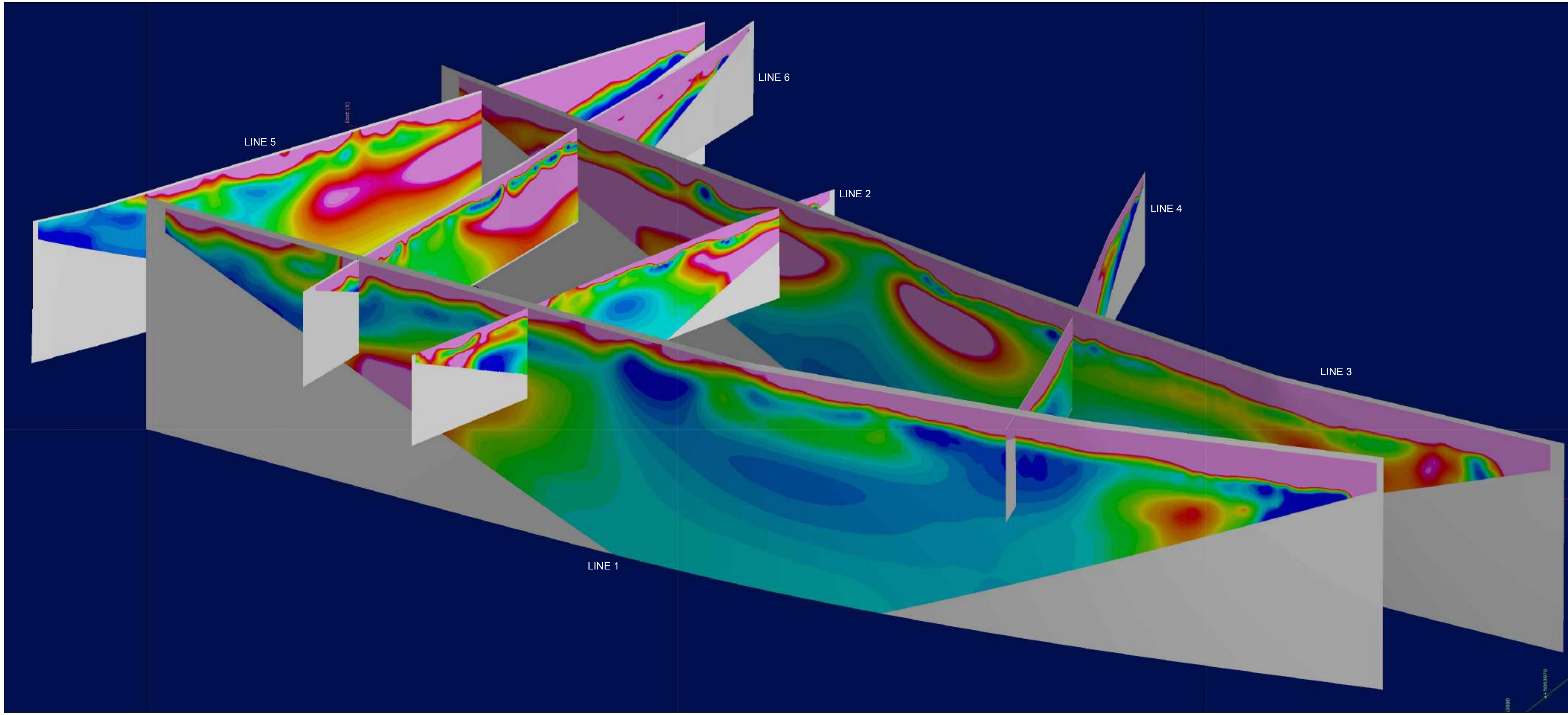
3D ERT VISUALIZATION (VIEW 1)

FIGURE 15

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX001.dwg



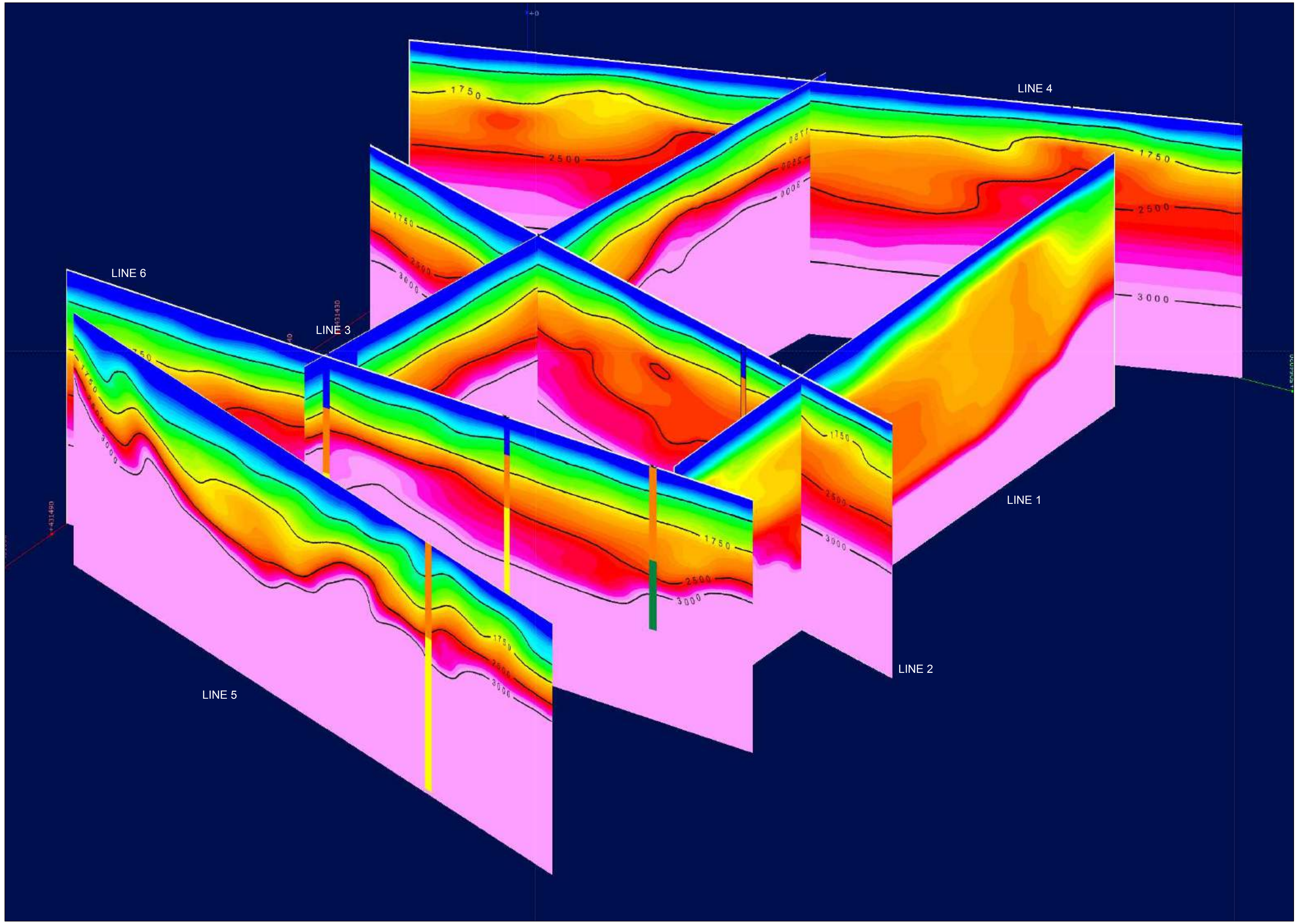
SCALE = NTS
3D FENCE DIAGRAMS ARE INTENDED FOR VISUALIZATION PURPOSES ONLY. ANY MEASUREMENTS, GRID VALUES, ETC. SHOULD BE TAKEN FROM THE INDIVIDUAL 2D CROSS SECTIONS

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01
Jun 21, 2019

3D ERT VISUALIZATION (VIEW 2)

FIGURE 16



SCALE = NTS
3D FENCE DIAGRAMS ARE INTENDED FOR VISUALIZATION PURPOSES ONLY. ANY MEASUREMENTS, GRID VALUES, ETC. SHOULD BE TAKEN FROM THE INDIVIDUAL 2D CROSS SECTIONS

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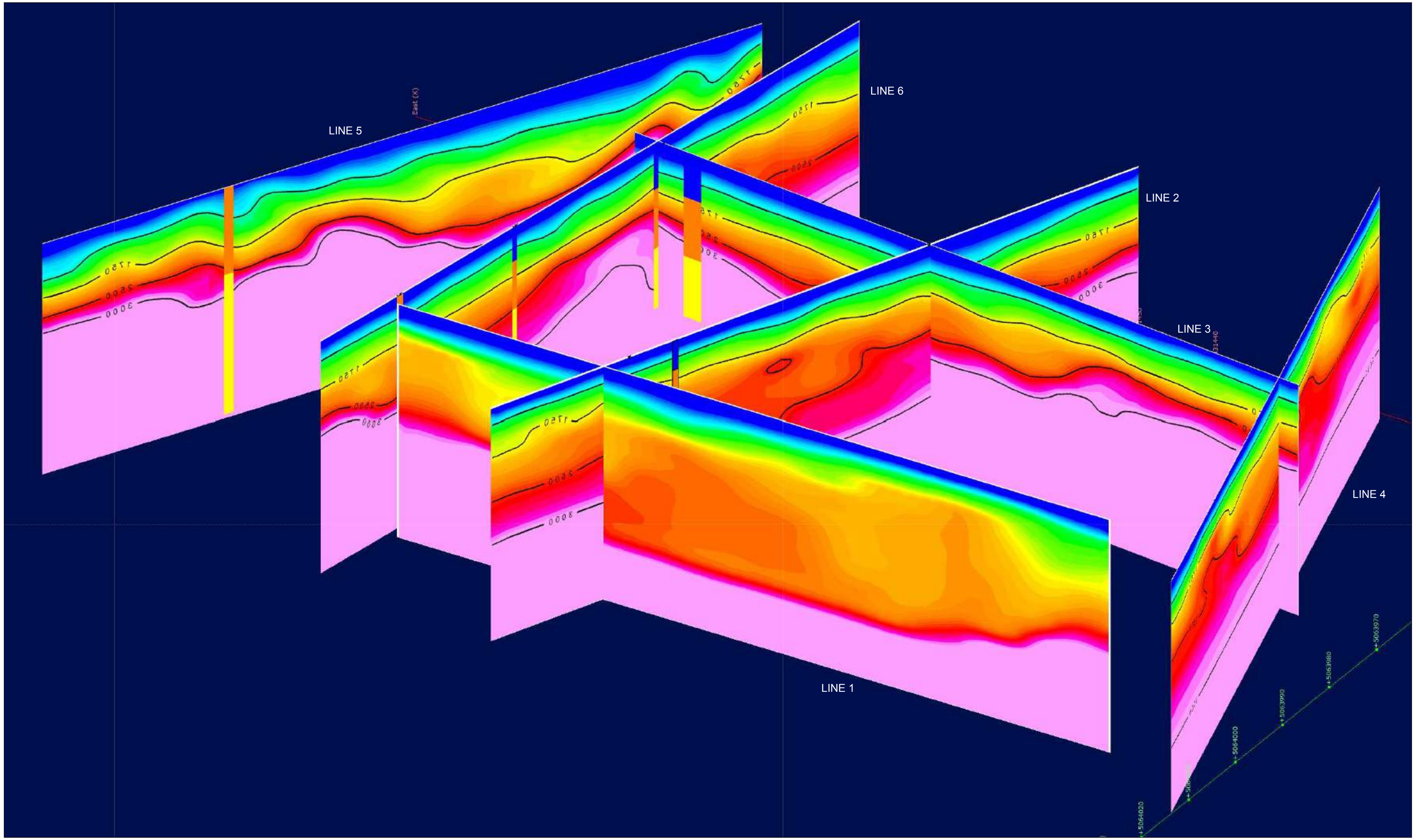
TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01
Jun 21, 2019

3D SEISMIC REFRACTION VISUALIZATION (VIEW 1)

FIGURE 17

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX003.dwg



SCALE = NTS
3D FENCE DIAGRAMS ARE INTENDED FOR VISUALIZATION PURPOSES ONLY. ANY MEASUREMENTS, GRID VALUES, ETC. SHOULD BE TAKEN FROM THE INDIVIDUAL 2D CROSS SECTIONS

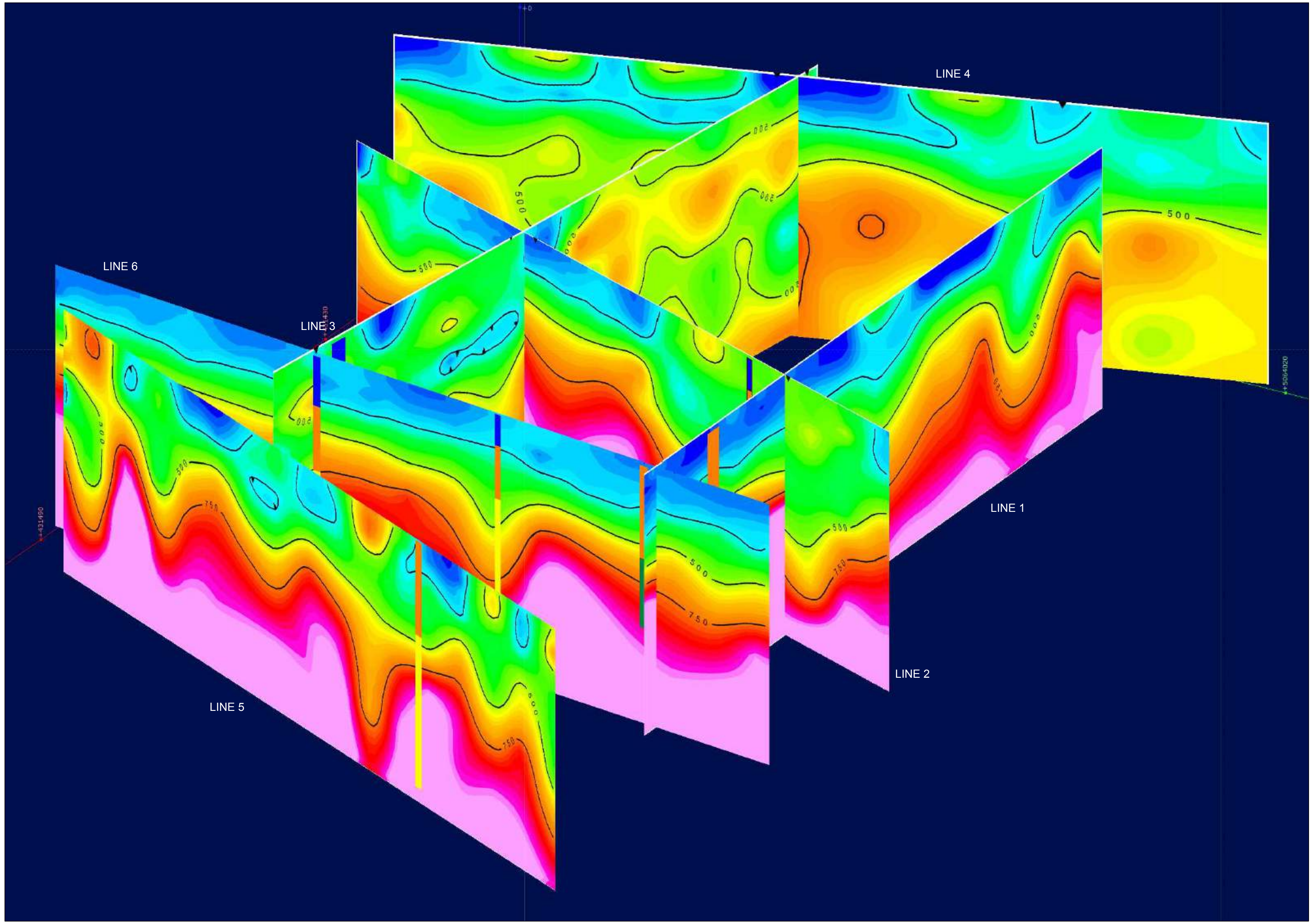
TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01
Jun 21, 2019

3D SEISMIC REFRACTION VISUALIZATION (VIEW 2)

FIGURE 18

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX004.dwg



SCALE = NTS
3D FENCE DIAGRAMS ARE INTENDED FOR VISUALIZATION PURPOSES ONLY. ANY MEASUREMENTS, GRID VALUES, ETC. SHOULD BE TAKEN FROM THE INDIVIDUAL 2D CROSS SECTIONS

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TOWN OF OXFORD
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OXFORD SINKHOLE INVESTIGATION

11195181-01
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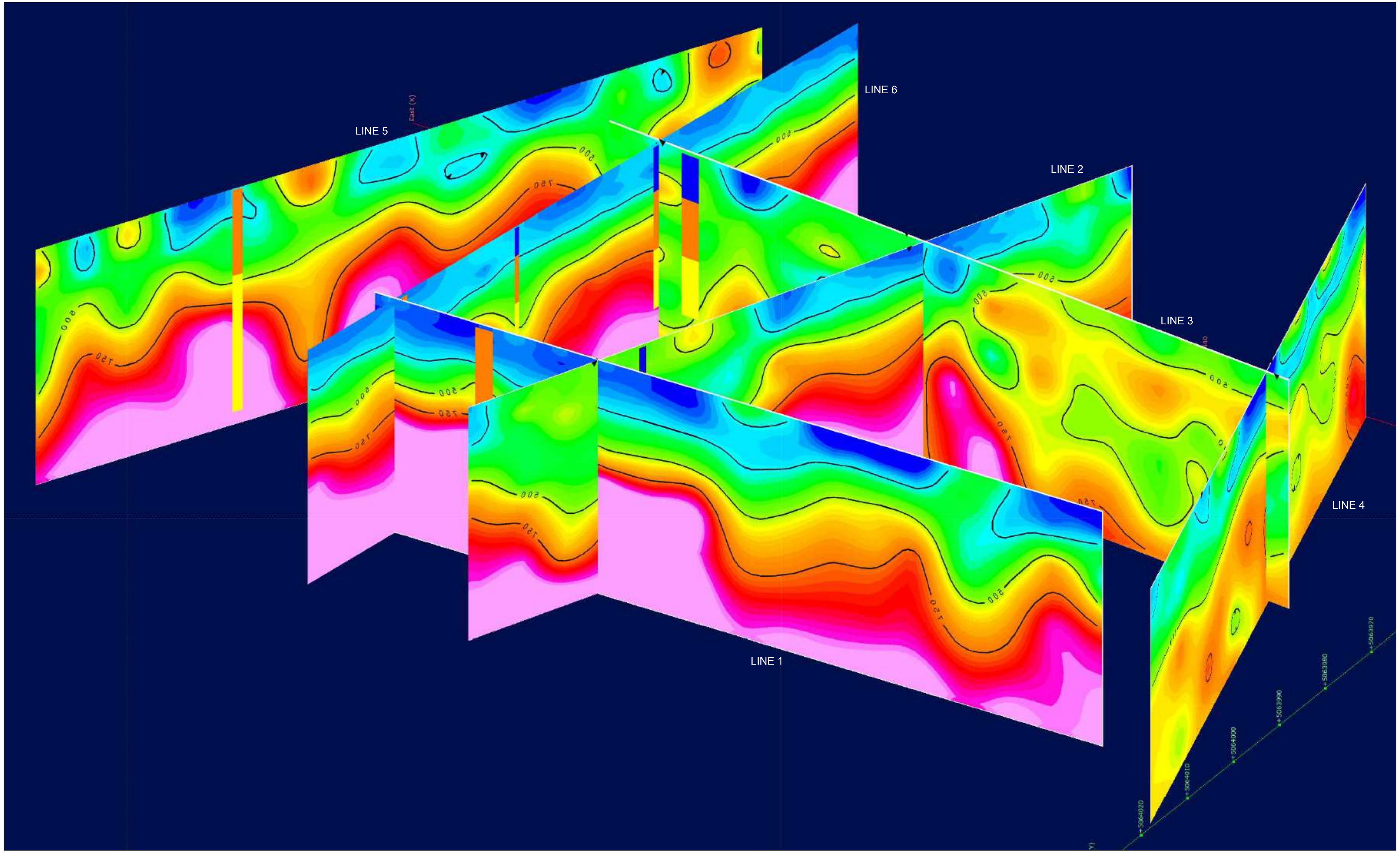
3D MASW VISUALIZATION (VIEW 1)

FIGURE 19

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX005.dwg



SCALE = NTS
3D FENCE DIAGRAMS ARE INTENDED FOR VISUALIZATION PURPOSES ONLY. ANY MEASUREMENTS, GRID VALUES, ETC. SHOULD BE TAKEN FROM THE INDIVIDUAL 2D CROSS SECTIONS

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01
Jun 21, 2019

3D MASW VISUALIZATION (VIEW 2)

FIGURE 20

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX006.dwg

Appendices

Appendix A
Site Photographs

PHOTO 1 - PANORAMIC VIEW OF SINKHOLE, LOOKING WEST FROM PARKING LOT

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

PHOTOGRAPHIC LOG

11195181-01

Jun 24, 2019

FIGURE P1

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX007.dwg

PHOTO 2 - LOOKING EAST FROM WEST SIDE OF SINKHOLE

PHOTO 3 - WESTERN EDGE OF SINKHOLE

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

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PHOTOGRAPHIC LOG

FIGURE P2

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX008.dwg

PHOTO 4 - TREED AREA WEST OF SINKHOLE

PHOTO 5 - ERT LINE 2; ADJACENT TO SINKHOLE LOOKING SOUTH

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01
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PHOTOGRAPHIC LOG

FIGURE P3

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX009.dwg

PHOTO 6 - ERT LINE 2; LOOKING NORTH

PHOTO 7 - SETTING UP AN ERT LINE

PHOTO 8 - DATA ACQUISITION OF AN ERT LINE

PHOTO 9 - SEISMIC LINE 6, LOOKING NORTH

PHOTO 10 - SEISMIC LINE 1, LOOKING SOUTHEAST

PHOTO 11 - SEISMIC DATA COLLECTION- LINE 2

PHOTO 12 - GEOETCHNICAL DRILLING EQUIPMENT

PHOTO 13 - DRILLING BH01

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01

Jun 24, 2019

PHOTOGRAPHIC LOG

FIGURE P7

PHOTO 14 - DRILLING BH02

PHOTO 15 - DRILLING BH04

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01

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PHOTOGRAPHIC LOG

FIGURE P8

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX014.dwg

PHOTO 16 - WORN DRILLING BIT DUE TO DIFFICULT CONDITIONS

PHOTO 17 - SANDSTONE IN BH01

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01

Jun 24, 2019

PHOTOGRAPHIC LOG

FIGURE P9

CAD File: I:\Drafting\8-chars\11------\1119----\111951--\11195181\11195181-REPORTS\11195181-Rpt-1\11195181-01(001)GN-HX015.dwg

PHOTO 18 - CONGLOMERATE IN BH03

TOWN OF OXFORD
MAIN STREET, OXFORD, NOVA SCOTIA
OXFORD SINKHOLE INVESTIGATION

11195181-01

Jun 24, 2019

PHOTOGRAPHIC LOG

FIGURE P10

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Appendix B
Geophysical Methodologies

GEOPHYSICAL METHODOLOGIES

ELECTRICAL RESISTIVITY TOMOGRAPHY

Electrical resistivity tomography (ERT) is a technique for mapping the distribution of subsurface electrical resistivity (or its inverse, conductivity) in a cross-sectional format. Resistivity data are collected through a linear array of electrodes coupled to a direct current (DC) resistivity transmitter and receiver, and an electronic switching box. The spacing between electrodes controls the horizontal and vertical resolution of the data (smaller spacing results in higher resolutions). Similarly, the length of the array controls the depth of investigation (longer arrays yield greater investigation depths). Data collection is carried out in a sequential and automated fashion that takes advantage of all possible combinations of current injection and potential measurement electrodes. The data are downloaded to a computer for processing and analysis, which includes the application of a two-dimensional (2-D) finite difference or finite element inversion routine. The final product is a 2-D cross-section plotting resistivity (in ohm-m), or conductivity (in millisiemens per metre [mS/m]), versus depth.

The electrical resistivity or electrical conductivity of a formation is dependent on the mineral content of the grains and the concentration of salts in any pore water. Fine-grained materials like clays and silts typically have relatively low resistivities, whereas dry granular material like sands and gravels will exhibit relatively high resistivities. Similarly, fresh water has a relatively high resistivity and saline water has a relatively low resistivity.

SEISMIC REFRACTION

The seismic refraction method uses the propagation of compressional waves in the subsurface to determine the velocity structure of the ground. Seismic energy is produced by a source (e.g., sledge hammer, weight drop, or explosive), and spreads downwards and laterally through the earth. An array of receivers (geophones) measures the arrival of that energy at points on a line. Increasing vertical velocity gradients with depth will cause seismic energy to refract back to the surface. Decreasing vertical velocity gradients are rare but, where present, will bend rays away from the surface and create shadow zones that cannot be imaged. The travel path that the energy takes from each shot to each receiver can be represented by a curved ray path. Typically, seismic energy that has propagated through bedrock material will arrive with faster apparent velocities along the seismic array than seismic energy that has travelled through overburden.

The picked travel times of the first-arriving energy can be used as input to seismic inversion software (e.g., Plotrefa, Rayfract, etc.), which solves for the velocity model of the subsurface that best fits the observed travel times. The accuracy of each travel-time pick is determined by the frequency of the first-arriving energy and the signal-to-noise (S/N) ratio. Factors that can reduce the frequency and/or S/N ratios include soft or spongy soils, wind noise, traffic noise, and the distance between the shot and the receiver (signal strength will reduce proportionally with increasing length of the ray path). The maximum depth of investigation of a velocity model is determined by the deepest refracted ray path. As a general rule, the longer the horizontal offset between a shot and a receiver, the greater the depth of penetration.

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

When seismic waves are generated from an active seismic source (i.e. a weight drop or sledge hammer), both surface and body waves (including compressional and shear waves) are generated, propagating in all directions. In conventional seismic methods, it is the measurement of the body wave arrival (reflection / refraction) that is of interest, whereas the surface wave arrival is generally considered to be a source of noise. A Rayleigh wave is a particular type of surface wave that travels along or near the ground surface and is characterized by relatively low velocities, low frequencies, and high amplitudes. Surface wave velocity is dispersive, or frequency-dependent (i.e., the sampling depth of a particular frequency component of a surface wave is directly proportional to its wavelength). Therefore, information on the shallow subsurface can be derived from measurements of low frequency components of Rayleigh waves.

The process for acquiring multichannel shot records is similar to that of acquiring seismic reflection shot records, utilizing an active seismic source and a linear receiver array, and collecting data in a roll along common-midpoint (CMP) acquisition mode. Dispersion curves are extracted from each shot record using a wavefield-transformation method. From these dispersion curves, the fundamental mode of the surface wave is extracted, removing all other reflected or scattered waves and ambient noise (Kansas Geological Survey 2006, internet site). The extracted dispersion curves are then inverted to obtain one-dimensional (1-D) shear wave velocity (Vs) profiles (i.e., a single 1-D profile for each shot record). Multiple profiles are then combined, resulting in a 2-D cross-section of Vs versus depth. As Vs is also described as ‘stiffness’, sharp contrasts in Vs may indicate voids, fractures, subsidence-prone areas, or bedrock surface.

Advantages to surface-wave imaging are the ease with which the high-amplitude waves are generated (i.e., utilizing a truck-mounted weight drop or sledgehammer), and the relative insensitivity to ambient, mechanical, or electrical noise.

Appendix C
Borehole Logs

GHD

BOREHOLE REPORT

Borehole No. BH-1

CLIENT: TOWN OF OXFORD

PROJECT: 2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE

LOCATION: 627 MAIN STREET, OXFORD, NOVA SCOTIA

DESCRIBED BY: O. GALVIER VERIFIED BY: D. BEAUSEIGLE

GEODETIC COORDINATES (UTM, NAD-83) (m)
X : 431489.8
Y : 5064004.0
Z : 8.13

▼ - WATER LEVEL
Date :
Depth (m) :

Location plan :

Borehole type :
Core bit size : NQ
Hammer type : Automatique
Energy ratio :
Date (start) : 2019-06-05
Date (finish) : 2019-06-05

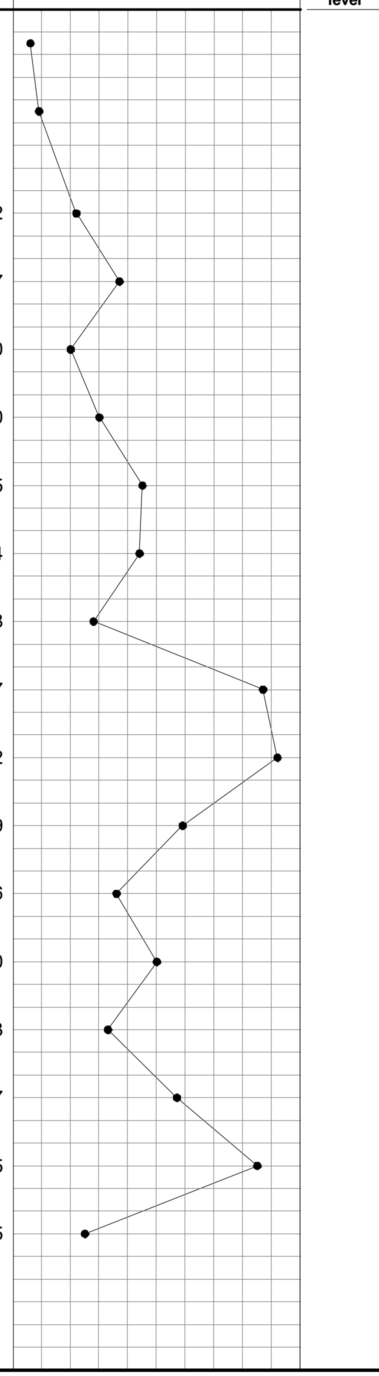
SAMPLE TYPE
SS(E) - Split Spoon (Environment)
RC(E) - Rock diamond core
AU(E) - Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E) - Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

TESTS RESULTS
○ Water content (%)
△ C_u (Field, kPa)
W_P W_L Atterberg limits (%)
□ C_u (Lab, kPa)
● "N" Standard penetration test value
▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD
0.00	8.13	Ground surface							
0.10	8.03	Top soil, some sand, brown, soft, presence of matter of plastic and vegetables	Remoulded	CF-1	100			1-1-5-5	6
		Native soil: Gravelly SAND, brown, moist, loose, medium-coarse grained GSD:21% Clay/Silt; 56% Sand; 24% Gravel	Remoulded	CF-2	100			2-3-6-4	9
			Lost						
1.50	6.63	becoming red-brown, medium dense	Remoulded	CF-3	100			7-9-13-16	22
			Remoulded	CF-4	87			13-21-16-14	37
2.70	5.43	Sandy CLAY, red-brown, stiff, low plasticity, fine grained GSD: 62% Clay/Silt; 33% Sand; 6% Gravel	Remoulded	CF-5	68			10-8-12-18	20
			Remoulded	CF-6	56			10-12-18-31	30
			Remoulded	CF-7	42			17-23-12-19	45
4.30	3.83	becoming with some gravel, grey, coarse grained GSD: 13% Clay/Silt; 29% Sand; 58% Gravel	Remoulded	CF-8	100			11-20-24-19	44
			Remoulded	CF-9	88			10-13-15-34	28
5.50	2.63	becoming with some gravel, medium-coarse grained, angular GSD: 42% Clay/Silt; 39% Sand; 19% Gravel	Remoulded	CF-10	72			3-35-52-46	87
			Remoulded	CF-11	95			33-45-47-39	92
			Remoulded	CF-12	100			17-24-35-31	59
			Remoulded	CF-13	19			10-13-23-29	36
8.10	0.03	GSD: 52% Clay/Silt; 33% Sand; 15% Gravel	Remoulded	CF-14	100			13-20-30-41	50
			Remoulded	CF-15	100			8-15-18-21	33
			Remoulded	CF-16	100			20-32-25-40	57
			Remoulded	CF-17	100			27-35-50-44	85
			Remoulded	CF-18	64			9-10-15-17	25
11.00	-2.87	becoming with some gravel, medium-coarse grained, angular GSD: 69% Clay/Silt; 15% Sand; 16% Gravel	Remoulded	CF-19	71			55-100/8cm	R
			Lost						



See the attached explicative note for the complete list of symbols and abbreviations

BOREHOLE REPORT

Borehole No. BH-1

CLIENT:	TOWN OF OXFORD	GEODETIC COORDINATES (UTM, NAD-83) (m)	▼ - WATER LEVEL
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE	X : 431489.8	Date :
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA	Y : 5064004.0	Depth (m) :
DESCRIBED BY:	O. GALVIER VERIFIED BY: D. BEAUSEIGLE	Z : 8.13	Location plan :

Borehole type :
Core bit size : NQ
Hammer type : Automatique
Energy ratio :
Date (start) : 2019-06-05
Date (finish) : 2019-06-05

SAMPLE TYPE
SS(E) - Split Spoon (Environment)
RC(E) - Rock diamond core
AU(E) - Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E) - Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

TESTS RESULTS:
○ Water content (%) △ C_u (Field, kPa)
W_P W_L Atterberg limits (%) □ C_u (Lab, kPa)
● "N" Standard penetration test value
▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Symbol	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	Water level
12.00	-3.87		Ground surface								
11.90	-3.77		**Bedrock:** SANDSTONE interbedded with mudstone, red-brown, loose (SW)	Diamond drilling						92	
13.20	-5.07		SANDSTONE, red-brown, intact (SW)	Diamond drilling						81	
				Diamond drilling						77	
				Diamond drilling						63	
				Diamond drilling						86	
19.00	-10.87		End of borehole								

GHD

BOREHOLE REPORT

Borehole No. BH-2

CLIENT:	TOWN OF OXFORD
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA
DESCRIBED BY:	O. GALVIER
VERIFIED BY:	D. BEAUSEIGLE

GEODETIC COORDINATES (UTM, NAD-83) (m)
X : 431491.1
Y : 5063958.9
Z : 8.30

- WATER LEVEL
Date :
Depth (m) :

Location plan :

Borehole type :	
Core bit size :	NQ
Hammer type :	Automatique
Energy ratio :	
Date (start) :	2019-06-05
Date (finish) :	2019-06-05

SAMPLE TYPE
- SS(E) - Split Spoon (Environment)
- RC(E) - Rock diamond core
- AU(E) - Auger
- TEE - Sampling Tube Environment
- ST - Shelby tube
- GS(E) - Grab sample

SAMPLE STATE
- Remoulded
- Intact
- Diamond drilling
- Lost

TEST SYMBOL
- GSA: grain size analysis
- CA: chemical analysis
- W_L: liquid limit
- W_P: plastic limit
- w : water content
- C_u: undrained shear strength
- S_T: sensitivity
- Dup: duplicate sample

TESTS RESULTS
- ○ Water content (%)
- W_P W_L Atterberg limits (%)
- ● "N" Standard penetration test value
- ▲ "N_C" Dynamic penetration test value
- △ C_u (Field, kPa)
- □ C_u (Lab, kPa)

Depth (m)	Elevation (m)	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	Water level
0.00	8.30	Ground surface								
		Native soil: Clayey SAND/ sandy CLAY, brown, slightly moist, medium plasticity, fine grained, angular, presence of vegetation at surface GSD: 32% Clay/Silt; 58% Sand; 10% Gravel		CF-1	52			1-3-4-5	7	
				CF-2	83			1-3-4-5	7	
1.70	6.60	becoming wet GSD: 38% Clay/Silt; 45% Sand; 17% Gravel		CF-3	100			3-6-7-6	13	
				CF-4	100			7-5-5-7	10	
				CF-5	89			8-10-11-14	21	
4.50	3.80	GSD: 70% Clay/Silt; 21% Sand; 10% Gravel		CF-6	100			6-13-12-14	25	
6.00	2.30	becoming with some gravel, medium coarse grained, subangular		CF-7	62			5-5-17-26	22	
7.50	0.80	Sandy GRAVEL, brown, very dense, fine to coarse, subangular, sand coarse grained GSD: 21% Clay/Silt; 53% Sand; 26% Gravel		CF-8	83			8-38-51-43	89	
				CF-9	18			17-56-50/15cm	R	
9.60	-1.30	GRAVEL, brown-yellow-grey, subangular								
11.30	-3.00	Gravelly SAND, fine-medium grained, subangular GSD: 15% Clay/Silt; 51% Sand; 35%		CF-10	9			4-15-26-50/13cm	R	

BOREHOLE REPORT

Borehole No. **BH-2**

CLIENT:	TOWN OF OXFORD	GEODETIC COORDINATES (UTM, NAD-83) (m)	▼ - WATER LEVEL
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE	X : 431491.1	Date :
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA	Y : 5063958.9	Depth (m) :
DESCRIBED BY:	O. GALVIER VERIFIED BY: D. BEAUSEIGLE	Z : 8.30	Location plan :

Borehole type :
Core bit size : NQ
Hammer type : Automatique
Energy ratio :
Date (start) : 2019-06-05
Date (finish) : 2019-06-05

SAMPLE TYPE
SS(E) - Split Spoon (Environment)
RC(E) - Rock diamond core
AU(E) - Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E) - Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

TESTS RESULTS
○ Water content (%) △ C_u (Field, kPa)
W_P W_L Atterberg limits (%) □ C_u (Lab, kPa)
● "N" Standard penetration test value
▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Symbol	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	10 20 30 40 50 60 70 80 90	Water level
12.00	-3.70		Ground surface									
			Gravel	Lost								
13.70	-5.40		**Bedrock:** CONGLOMERATE, red-brown, low strength, coarse grained	Lost						0		
				Lost						6		
				Lost						7		
				Lost						0		
				Lost						71		
				Lost						0		
				Lost						0		
21.60	-13.30		End of borehole Note: Drill bit completely worn - pulled out to change the bit - Hole collapse									

BOREHOLE REPORT

Borehole No. BH-3

CLIENT:	TOWN OF OXFORD
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA
DESCRIBED BY:	O. GALVIER
VERIFIED BY:	D. BEAUSEIGLE

GEODETIC COORDINATES (UTM, NAD-83) (m)
X : 431528.2
Y : 5063992.9
Z : 7.85

- WATER LEVEL
Date :
Depth (m) :

Location plan :

Borehole type :	
Core bit size :	NQ
Hammer type :	Automatique
Energy ratio :	
Date (start) :	2019-06-05
Date (finish) :	2019-06-05

SAMPLE TYPE
- SS(E)- Split Spoon (Environment)
- RC(E)- Rock diamond core
- AU(E)- Auger
- TEE - Sampling Tube Environment
- ST - Shelby tube
- GS(E)- Grab sample

SAMPLE STATE
- Remoulded
- Intact
- Diamond drilling
- Lost

TEST SYMBOL
- GSA: grain size analysis
- CA: chemical analysis
- W_L: liquid limit
- W_P: plastic limit
- w : water content
- C_u: undrained shear strength
- S_T: sensitivity
- Dup: duplicate sample

TESTS RESULTS legend:
- ○ Water content (%)
- W_P W_L Atterberg limits (%)
- ● "N" Standard penetration test value
- ▲ "N_C" Dynamic penetration test value
- △ C_u (Field, kPa)
- □ C_u (Lab, kPa)

Depth (m)	Elevation (m)	Symbol	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	10 20 30 40 50 60 70 80 90	Water level
0.00	7.85		Ground surface									
			Casing; no drill core recovered from surface to 10.8 m depth.									
10.80	-2.95		**Bedrock:** CONGLOMERATE, red-brown, low strength, coarse grained							0		

Depth scale (m): 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0

BOREHOLE REPORT

Borehole No. **BH-3**

CLIENT:	TOWN OF OXFORD	GEODETIC COORDINATES (UTM, NAD-83) (m)	- WATER LEVEL
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE	X : 431528.2	Date :
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA	Y : 5063992.9	Depth (m) :
DESCRIBED BY: O. GALVIER	VERIFIED BY: D. BEAUSEIGLE	Z : 7.85	Location plan :

Borehole type :
Core bit size : NQ
Hammer type : Automatique
Energy ratio :
Date (start) : 2019-06-05
Date (finish) : 2019-06-05

SAMPLE TYPE
SS(E) - Split Spoon (Environment)
RC(E) - Rock diamond core
AU(E) - Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E) - Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

STRATIGRAPHY | **SAMPLE** | **TESTS RESULTS**

Legend: ○ Water content (%) △ C_u (Field, kPa) ⊢⊣ W_P W_L Atterberg limits (%) □ C_u (Lab, kPa) ● "N" Standard penetration test value ▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Symbol	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	10 20 30 40 50 60 70 80 90	Water level
12.00	-4.15		Ground surface									
			Continues from above									
12.8										19		
14.1										21		
15.4										0		
16.8										26		
18.1										0		
19.4										32		
20.7										0		
22.1										27		
23.4										84		

Depth scale: 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0

See the attached explicative note for the complete list of symbols and abbreviations

BOREHOLE REPORT

Borehole No. **BH-3**

CLIENT: TOWN OF OXFORD
PROJECT: 2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE
LOCATION: 627 MAIN STREET, OXFORD, NOVA SCOTIA
DESCRIBED BY: O. GALVIER VERIFIED BY: D. BEAUSEIGLE

GEODETIC COORDINATES (UTM, NAD-83) (m)
X : 431528.2
Y : 5063992.9
Z : 7.85

- WATER LEVEL
Date :
Depth (m) :

Location plan :

Borehole type :
Core bit size : NQ
Hammer type : Automatique
Energy ratio :
Date (start) : 2019-06-05
Date (finish) : 2019-06-05

SAMPLE TYPE
SS(E)- Split Spoon (Environment)
RC(E)- Rock diamond core
AU(E)- Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E)- Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

TESTS RESULTS
○ Water content (%) △ C_u (Field, kPa)
W_P W_L Atterberg limits (%) □ C_u (Lab, kPa)
● "N" Standard penetration test value
▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Symbol	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	10 20 30 40 50 60 70 80 90	Water level
24.00	-16.15		Ground surface									
			Continues from above	Lost								
										56		
25.0												
26.0										0		
27.0										0		
28.0												
29.0										63		
30.0										19		
30.80	-22.95		End of borehole									
31.0												
32.0												
33.0												
34.0												
35.0												

BOREHOLE REPORT

Borehole No. **BH-4**

CLIENT:	TOWN OF OXFORD		
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE		
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA		
DESCRIBED BY:	O. GALVIER	VERIFIED BY:	D. BEAUSEIGLE

GEODETIC COORDINATES (UTM, NAD-83) (m)
X : 431483.8
Y : 5063990.1
Z : 8.13

▼ - WATER LEVEL
Date :
Depth (m) :

Location plan :

Borehole type :	
Core bit size :	NQ
Hammer type :	Automatique
Energy ratio :	
Date (start) :	2019-06-08
Date (finish) :	2019-06-08

SAMPLE TYPE
- SS(E) - Split Spoon (Environment)
- RC(E) - Rock diamond core
- AU(E) - Auger
- TEE - Sampling Tube Environment
- ST - Shelby tube
- GS(E) - Grab sample

SAMPLE STATE
- Remoulded
- Intact
- Diamond drilling
- Lost

TEST SYMBOL
- GSA: grain size analysis
- CA: chemical analysis
- W_L: liquid limit
- W_P: plastic limit
- w : water content
- C_u: undrained shear strength
- S_T: sensitivity
- Dup: duplicate sample

TESTS RESULTS legend:
- ○ Water content (%)
- W_P W_L Atterberg limits (%)
- ● "N" Standard penetration test value
- ▲ "N_C" Dynamic penetration test value
- △ C_u (Field, kPa)
- □ C_u (Lab, kPa)

STRATIGRAPHY				SAMPLE						TESTS RESULTS		
Depth (m)	Elevation (m)	Symbol	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	10 20 30 40 50 60 70 80 90	Water level
0.00	8.13		Ground surface									
0.10	8.03		Asphalt									
			Casing; no drill core recovered from surface to 10.0 m depth.									
10.00	-1.87		**Bedrock:** CONGLOMERATE, red-brown, low strength, coarse grained							0		

Depth scale (m): 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0

BOREHOLE REPORT

Borehole No. **BH-4**

CLIENT:	TOWN OF OXFORD	GEODETIC COORDINATES (UTM, NAD-83) (m)	- WATER LEVEL
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE	X : 431483.8	Date :
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA	Y : 5063990.1	Depth (m) :
DESCRIBED BY:	O. GALVIER VERIFIED BY: D. BEAUSEIGLE	Z : 8.13	Location plan :

Borehole type :
Core bit size : NQ
Hammer type : Automatique
Energy ratio :
Date (start) : 2019-06-08
Date (finish) : 2019-06-08

SAMPLE TYPE
SS(E) - Split Spoon (Environment)
RC(E) - Rock diamond core
AU(E) - Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E) - Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

TESTS RESULTS legend:
○ Water content (%) △ C_u (Field, kPa)
W_P W_L Atterberg limits (%) □ C_u (Lab, kPa)
● "N" Standard penetration test value
▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Symbol	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	10 20 30 40 50 60 70 80 90	Water level
12.00	-3.87		Ground surface									
			Continues from above									
										0		
13.0												
14.0										11		
15.0										0		
16.0												
17.0										0		
18.0										0		
19.0												
20.0										0		
21.0												
22.0										0		
23.0										0		

See the attached explicative note for the complete list of symbols and abbreviations

BOREHOLE REPORT

Borehole No. **BH-4**

CLIENT: TOWN OF OXFORD

PROJECT: 2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE

LOCATION: 627 MAIN STREET, OXFORD, NOVA SCOTIA

DESCRIBED BY: O. GALVIER VERIFIED BY: D. BEAUSEIGLE

GEODETIC COORDINATES (UTM, NAD-83) (m)
X : 431483.8
Y : 5063990.1
Z : 8.13

- WATER LEVEL
Date :
Depth (m) :

Location plan :

Borehole type :
Core bit size : NQ
Hammer type : Automatique
Energy ratio :
Date (start) : 2019-06-08
Date (finish) : 2019-06-08

SAMPLE TYPE
SS(E)- Split Spoon (Environment)
RC(E)- Rock diamond core
AU(E)- Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E)- Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

STRATIGRAPHY | **SAMPLE** | **TESTS RESULTS**

○ Water content (%) △ C_u (Field, kPa)
W_P W_L Atterberg limits (%) □ C_u (Lab, kPa)
● "N" Standard penetration test value
▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Symbol	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	10 20 30 40 50 60 70 80 90	Water level
24.00	-15.87		Ground surface									
			Continues from above	Lost						0		
				Lost						0		
				Lost						0		
29.00	-20.87		End of borehole									

Depth scale: 25.0, 26.0, 27.0, 28.0, 29.0, 30.0, 31.0, 32.0, 33.0, 34.0, 35.0

BOREHOLE REPORT

Borehole No. **BH-5**

CLIENT:	TOWN OF OXFORD	GEODETIC COORDINATES (UTM, NAD-83) (m)	- WATER LEVEL
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE	X : 431484.1	Date :
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA	Y : 5063994.4	Depth (m) :
DESCRIBED BY:	O. GALVIER VERIFIED BY: D.PARKER	Z : 8.13	Location plan :

Borehole type :	
Core bit size :	
Hammer type :	
Energy ratio :	
Date (start) :	2019-07-26
Date (finish) :	2019-07-27

SAMPLE TYPE
- SS(E) - Split Spoon (Environment)
- RC(E) - Rock diamond core
- AU(E) - Auger
- TEE - Sampling Tube Environment
- ST - Shelby tube
- GS(E) - Grab sample

SAMPLE STATE
- Remoulded
- Intact
- Diamond drilling
- Lost

TEST SYMBOL
- GSA: grain size analysis
- CA: chemical analysis
- W_L: liquid limit
- W_P: plastic limit
- w : water content
- C_u: undrained shear strength
- S_T: sensitivity
- Dup: duplicate sample

TESTS RESULTS legend: ○ Water content (%); △ C_u (Field, kPa); W_P W_L Atterberg limits (%); □ C_u (Lab, kPa); ● "N" Standard penetration test value; ▲ "N_C" Dynamic penetration test value

Scale: 10 20 30 40 50 60 70 80 90

Depth (m)	Elevation (m)	Symbol	Description (STRATIGRAPHY)	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	Water level
0.00	8.13		Ground surface								
			Casing; no drill core recovered from surface to 10.67 m depth.								
10.67	-2.54		**Native soil:** GRAVEL, red-brown, very dense, medium-coarse grained, poorly graded, conglomerate	Diamond drilling		67					
10.87	-2.74										
11.18	-3.05										
11.28	-3.15		Clayey SAND, traces of medium gravel, brown-black with slight red,								

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0

BOREHOLE REPORT

Borehole No. **BH-5**

CLIENT:	TOWN OF OXFORD	GEODETIC COORDINATES (UTM, NAD-83) (m)	- WATER LEVEL
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE	X : 431484.1	Date :
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA	Y : 5063994.4	Depth (m) :
DESCRIBED BY:	O. GALVIER — VERIFIED BY: D.PARKER	Z : 8.13	Location plan :

Borehole type :
Core bit size :
Hammer type :
Energy ratio :
Date (start) : 2019-07-26
Date (finish) : 2019-07-27

SAMPLE TYPE
SS(E)- Split Spoon (Environment)
RC(E)- Rock diamond core
AU(E)- Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E)- Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

TESTS RESULTS legend: ○ Water content (%); △ C_u (Field, kPa); W_P W_L Atterberg limits (%); □ C_u (Lab, kPa); ● "N" Standard penetration test value; ▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Description	Recovery %	N, N_C or RQD
12.00	-3.87	Ground surface		
		loose, medium-fine grained, subangular grains		
		GRAVEL, grey with light brown-red, medium grained, poorly graded, iron staining		
12.65	-4.52	Destructive drilling		
		GRAVEL, traces of red-brown clay (potential conglomerate), brown-grey with some light colour seams	47	
14.48	-6.35	**Bedrock:** CONGLOMERATE, matrix of clayey SAND, some coarse gravel, dark red-brown with lightly colored grey on cobbles and some yellow-brown areas, good grading, medium strength, joints are 20 to 300 mm apart		
16.21	-8.08	SANDSTONE, dark brown-red, fine-medium grain size, sangular, weakly cemented, medium strength joints are 100-300 mm apart	100	0
17.37	-9.24	GRAVEL, traces of sand (coarse), light-dark grey, loose, moderately graded	40	
			38	
20.27	-12.14	SANDSTONE, traces of gravel, dark red-brown, coarse grained, angular, low strength, joints are 0 to 20 mm apart		
20.45	-12.32	CONGLOMERATE, matrix of red-brown clayey SAND, dark red-brown and light-dark grey and red grains, low strength, joints are 0 to 300 mm	51	0
			83	0
23.32	-15.19	becoming grey with iron staining		

Depth scale (m): 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0

Tests results scale: 10 20 30 40 50 60 70 80 90; Water level

See the attached explicative note for the complete list of symbols and abbreviations

BOREHOLE REPORT

Borehole No. BH-5

CLIENT:	TOWN OF OXFORD
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA
DESCRIBED BY:	O. GALVIER
VERIFIED BY:	D.PARKER

GEODETIC COORDINATES (UTM, NAD-83) (m)
X : 431484.1
Y : 5063994.4
Z : 8.13

- WATER LEVEL
Date :
Depth (m) :

Location plan :

Borehole type :
Core bit size :
Hammer type :
Energy ratio :
Date (start) : 2019-07-26
Date (finish) : 2019-07-27

SAMPLE TYPE
SS(E)- Split Spoon (Environment)
RC(E)- Rock diamond core
AU(E)- Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E)- Grab sample

SAMPLE STATE
Remoulded
Intact
Diamond drilling
Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

TESTS RESULTS
○ Water content (%) △ C_u (Field, kPa)
W_P W_L Atterberg limits (%) □ C_u (Lab, kPa)
● "N" Standard penetration test value
▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Description	Recovery %	N, N_C or RQD
24.00	-15.87	Ground surface		
		Continues from above	100	0
			100	0
			37	0
			17	0
			100	0
			28	0
32.16	-24.03	GRAVEL, light dark grey-brown, coarse grained (possible conglomerate)	37	
			26	
			47	
			40	
			53	
			58	

Columns: State, Type and Number, Other tests, PID (ppm), 6 in / 15 cm Blow counts (sampler size), Water level — no entries. Depth scale: 25.0, 26.0, 27.0, 28.0, 29.0, 30.0, 31.0, 32.0, 33.0, 34.0, 35.0. Test results scale: 10 20 30 40 50 60 70 80 90.

BOREHOLE REPORT

Borehole No. BH-5

CLIENT:	TOWN OF OXFORD	GEODETIC COORDINATES (UTM, NAD-83) (m)	▼ - WATER LEVEL
PROJECT:	2019 GEOTECHNICAL INVESTIGATION - OXFORD SINKHOLE	X : 431484.1	Date :
LOCATION:	627 MAIN STREET, OXFORD, NOVA SCOTIA	Y : 5063994.4	Depth (m) :
DESCRIBED BY:	O. GALVIER VERIFIED BY: D.PARKER	Z : 8.13	Location plan :

Borehole type :
Core bit size :
Hammer type :
Energy ratio :
Date (start) : 2019-07-26
Date (finish) : 2019-07-27

SAMPLE TYPE
SS(E) - Split Spoon (Environment)
RC(E) - Rock diamond core
AU(E) - Auger
TEE - Sampling Tube Environment
ST - Shelby tube
GS(E) - Grab sample

SAMPLE STATE
☒ Remoulded
▨ Intact
◫ Diamond drilling
■ Lost

TEST SYMBOL
GSA: grain size analysis
CA: chemical analysis
W_L: liquid limit
W_P: plastic limit
w : water content
C_u: undrained shear strength
S_T: sensitivity
Dup: duplicate sample

TESTS RESULTS
○ Water content (%) △ C_u (Field, kPa)
W_P W_L Atterberg limits (%) □ C_u (Lab, kPa)
● "N" Standard penetration test value
▲ "N_C" Dynamic penetration test value

Depth (m)	Elevation (m)	Description	State	Type and Number	Recovery %	Other tests	PID (ppm)	6 in / 15 cm Blow counts (sampler size)	N, N_C or RQD	Water level
36.00	-27.87	Ground surface								
		Continues from above	■		66					
37.19	-29.06	CONGLOMERATE with a karst-related matrix, some fine gravel, dark red-brown with grey and orange stains slightly weathered, medium strength, 300 to 1000 mm	■		83				86	
38.56	-30.43	becoming grey with patches of brown-orange slightly weathered	■		100				87	
40.08	-31.95	GRAVEL, traces of coarse sand, light grey, loose, moderately graded	■		70				66	
41.61	-33.48	CONGLOMERATE with a karst-related matrix, some brown-grey gravel, dark grey, fine to coarse grained	■		100				26	
			■		100				16	
44.04	-35.91	End of borehole								

Depth scale: 37.0, 38.0, 39.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0

Test results scale: 10 20 30 40 50 60 70 80 90

Appendix D
Laboratory Results

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-1 SPT 2

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Gravelly SAND with some clay

Location: Oxford's Lions Club

Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	100	100	86	83	76	66	58	51	44	31	20.5
Limits	min.																
	max.																

Other Tests	Results	Limits	
		min.	max.

	Results
Maximum Dry Density	(kg/m³)
Optimum Moisture	(%)

Granulometry Analysis Results

Clay or Silt	Sand	Gravel
21	56	24

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

GHD Consultants Ltée. 2385 rue Charbonneau Trois-Rivières Qc G9A 5C9

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-1 SPT 5

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Sandy CLAY/SILT with gravel

Location: Oxford's Lions Club

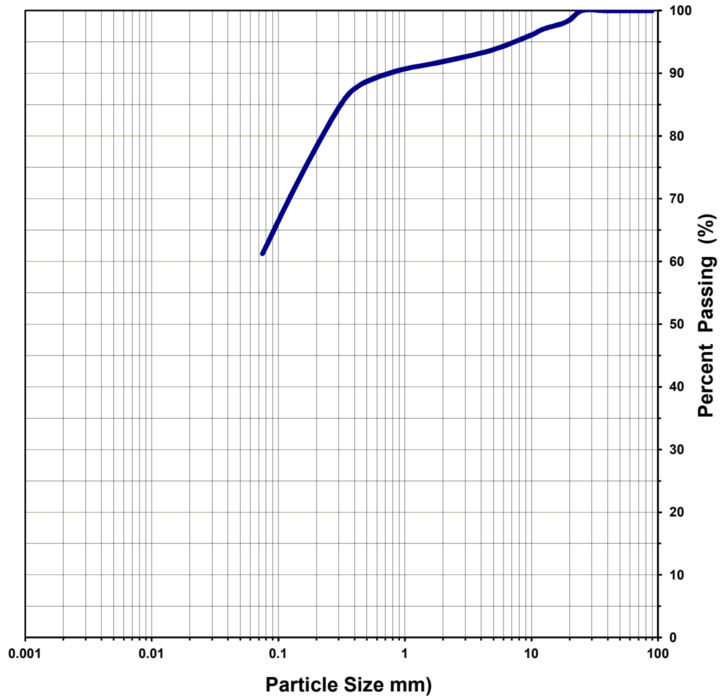
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	100	98	97	96	94	92	90	88	84	74	61.2
Limits	min.																
	max.																

Other Tests	Results	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
61	33	6

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-1 SPT 8

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Sandy GRAVEL with some clay/silt

Location: Oxford's Lions Club

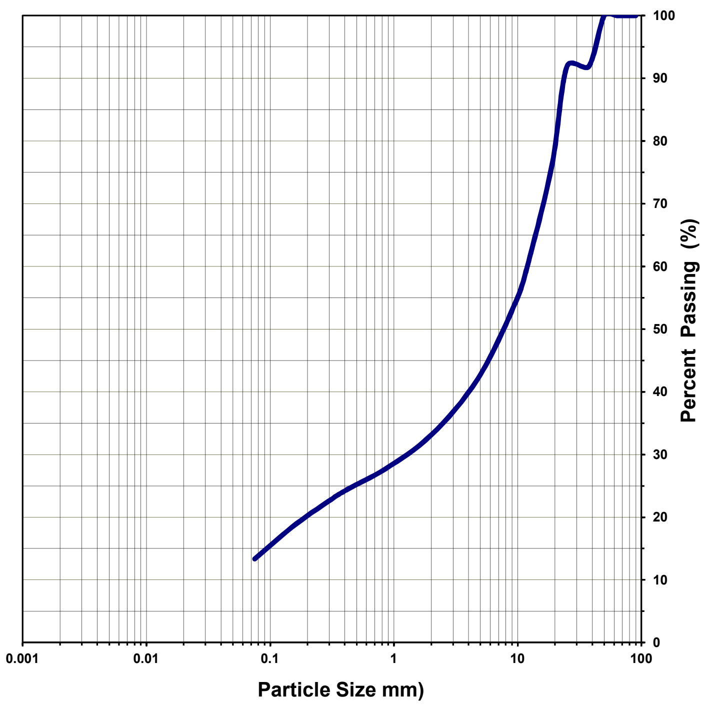
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	92	76	61	54	42	33	28	24	23	18	13.3
Limits	min.																
	max.																

Other Tests	Results	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
13	29	58

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-1 SPT 10

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Sandy CLAY/SILT with some gravel

Location: Oxford's Lions Club

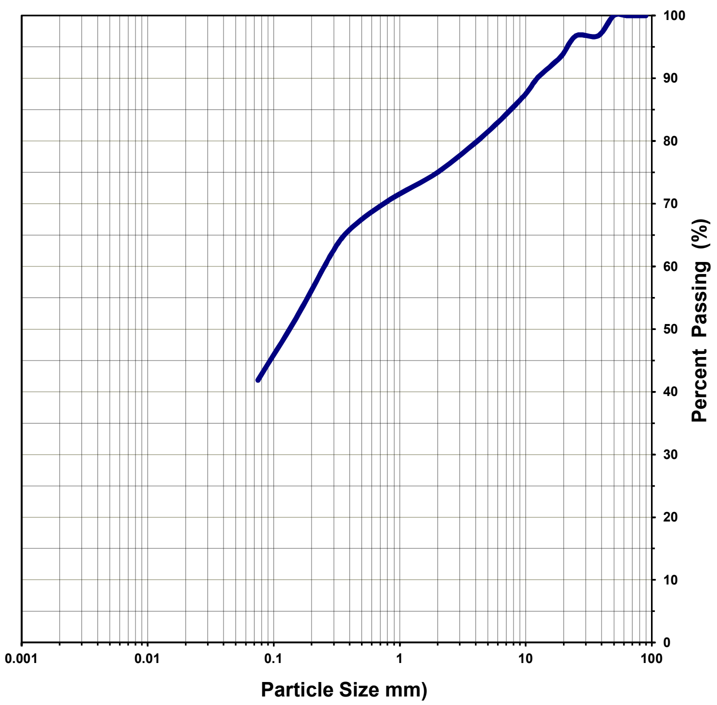
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	97	93	90	87	81	75	71	66	63	52	41.9
Limits	min.																
	max.																

Other Tests	Results	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
42	39	19

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-1 SPT 14

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Sandy CLAY/SILT with some gravel

Location: Oxford's Lions Club

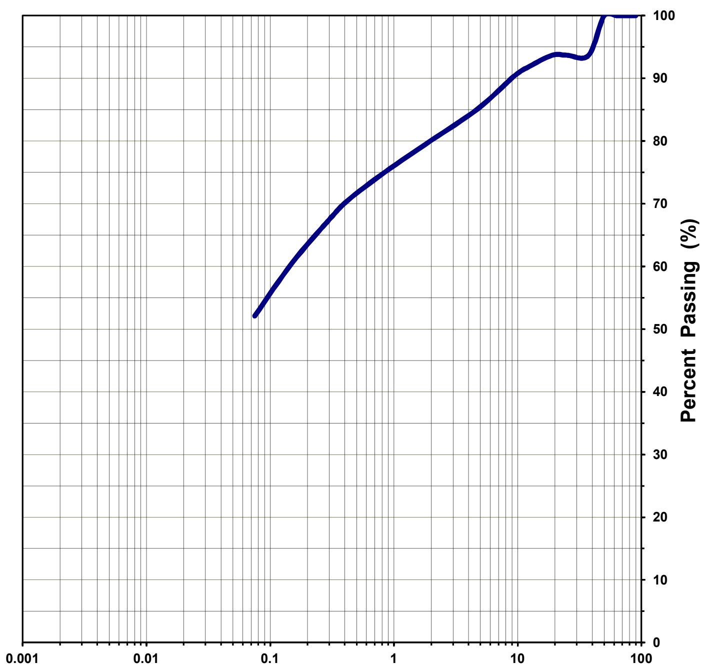
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	94	94	92	90	85	80	75	71	67	61	52.1
Limits	min.																
	max.																

Other Tests	Prepared	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
52	33	15

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-1 SPT 19

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type:

Location: Oxford's Lions Club

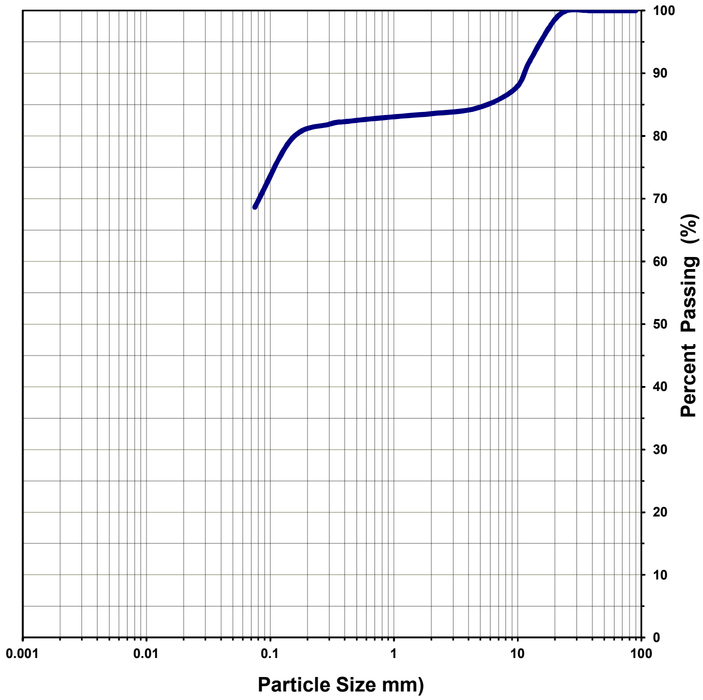
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	100	98	92	88	84	84	83	82	82	80	68.6
Limits	min.																
	max.																

Other Tests	Results	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
69	15	16

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH2 - SPT 2

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Clayey SAND with some gravel

Location: Oxford's Lions Club

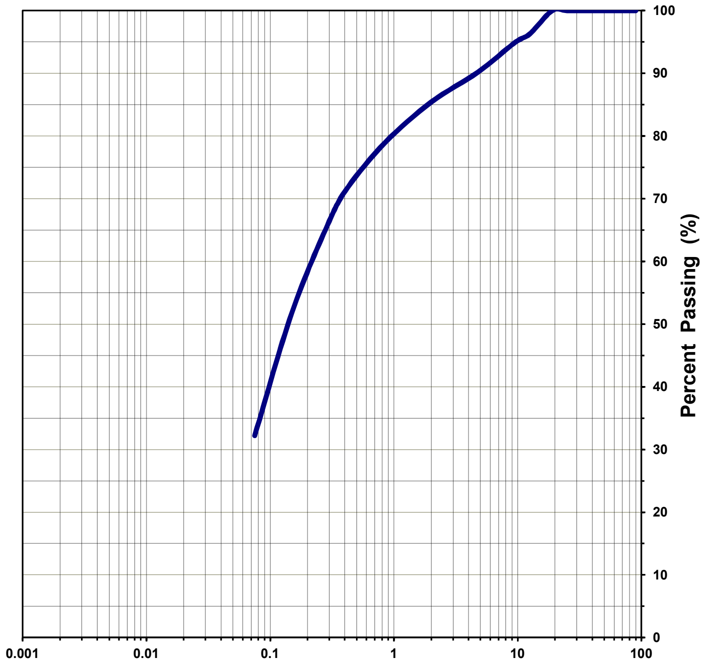
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	100	100	96	95	90	85	79	72	66	52	32.2
Limits	min.																
	max.																

Other Tests	Results	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
32	58	10

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-2 SPT 4

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Clayey/silt SAND with some gravel

Location: Oxford's Lions Club

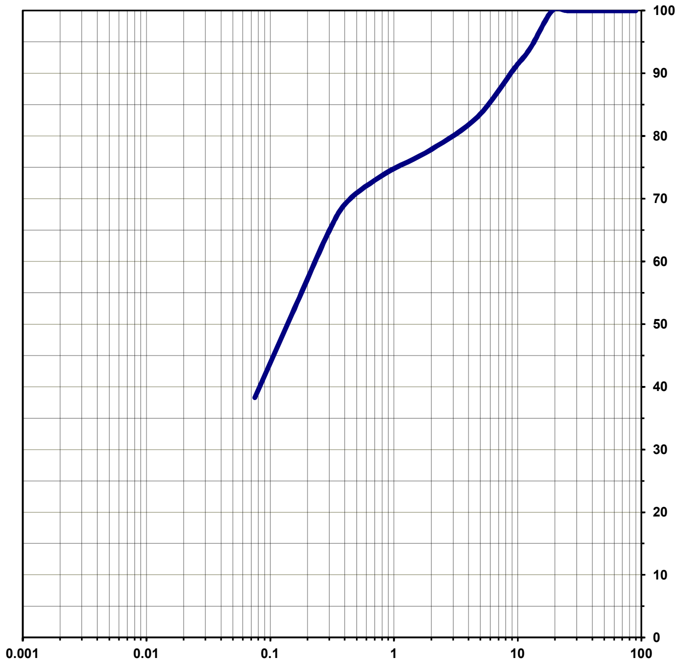
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	100	100	94	91	83	78	74	70	65	52	38.3
Limits	min.																
	max.																

Other Tests	Results	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
38	45	17

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-2 SPT 6

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Sandy CLAY/SILT with some gravel

Location: Oxford's Lions Club

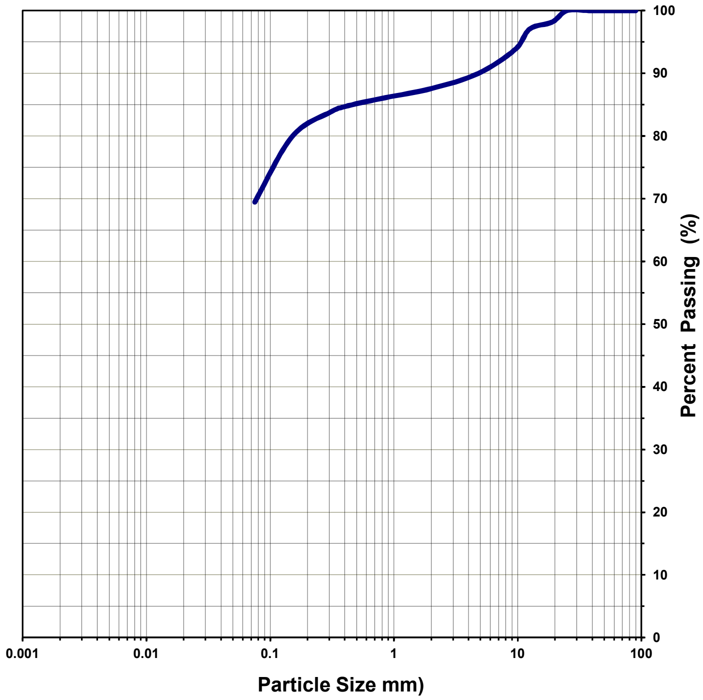
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	100	98	97	94	90	88	86	85	84	80	69.5
Limits	min.																
	max.																

Other Tests	Results	Limits	
		min.	max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
70	21	10

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-2 SPT 9

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Gravelly SAND with some clay/silt

Location: Oxford's Lions Club

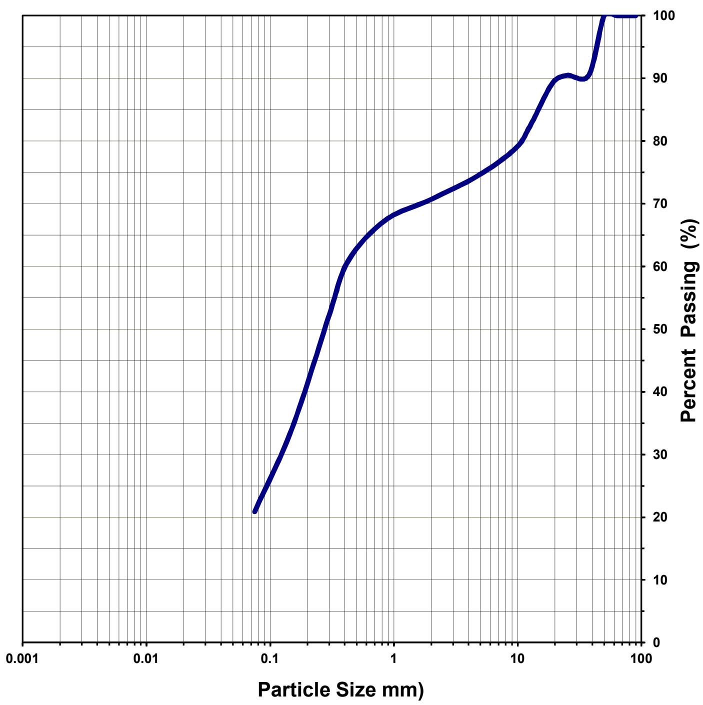
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	90	89	82	79	74	71	67	61	52	34	20.9
Limits	min.																
	max.																

Other Tests	Results	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
21	53	26

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

Report - Soil and Aggregate Grain Size Analysis

Client: Town of Oxford

Project No: 11195181

Sample Number: BH-2 SPT 10

Project: Oxford Sinkhole Geotechnical Investigation

Date of Sampling: 5-Jun-19

Sampled By: Oliver Galvier

Material Type: Gravelly SAND with some clay/silt

Location: Oxford's Lions Club

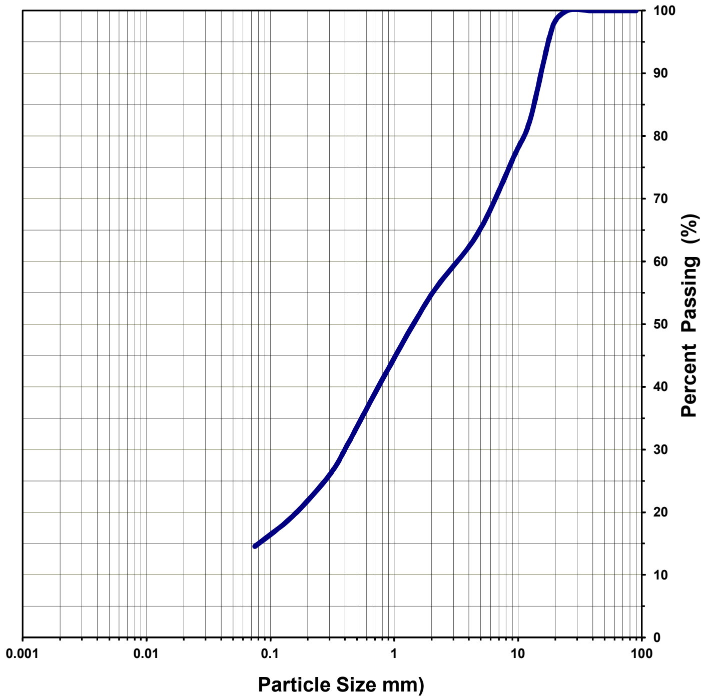
Proposed Usage:

Sieve Sizes		90 mm	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.00 mm	0.850 mm	425 µm	300 µm	150 µm	75 µm
Cummlative Results		100	100	100	100	100	100	97	83	77	65	55	42	31	26	19	14.5
Limits	min.																
	max.																

Other Tests	Results	Limits min.	Limits max.

	Results
Maximum Dry Density	(kg/m^3)
Optimum Moisture	(%)

Granulometry Analysis Results



Clay or Silt	Sand	Gravel
15	51	35

Remarks

Prepared by: Michael Gaines

Verified by: Oliver Galvier

Date: 2019-06-15

120 Western Parkway Bedford NS B4B 0v2 Canada

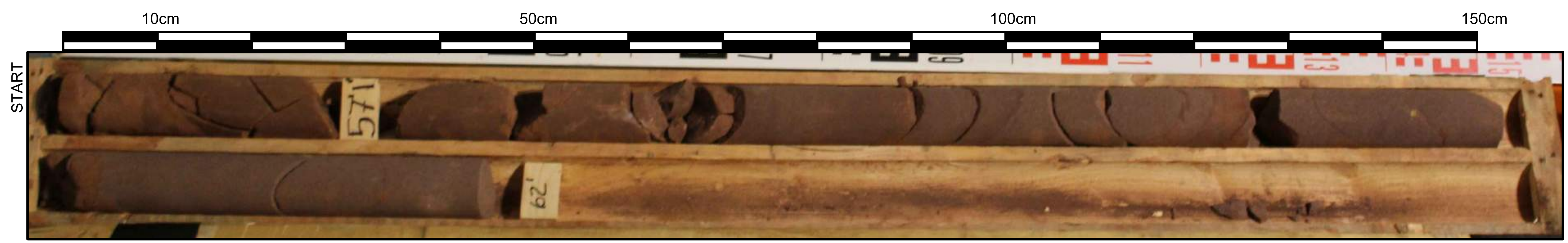
Appendix E
Drill Core Photos

BOREHOLE ID: BH-1 | DEPTH RANGE: FROM 11.353m TO 14.091m | DATE: 06-05-2019

CORE BOX: BOX 1 OF 3 | LOGGED BY: O. GALVIER

BOREHOLE ID: BH-1 | DEPTH RANGE: FROM 14.091m TO 17.145m | DATE: 06-05-2019

CORE BOX: BOX 2 OF 3 | LOGGED BY: O. GALVIER



BOREHOLE ID: BH-1 | DEPTH RANGE: FROM 17.145m TO 18.897m | DATE: 06-05-2019

CORE BOX: BOX 3 OF 3 | LOGGED BY: O. GALVIER

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GEOTECHNICAL INVESTIGATION

ROCK CORE LOG

085586-06
Jul 3, 2019

BH1

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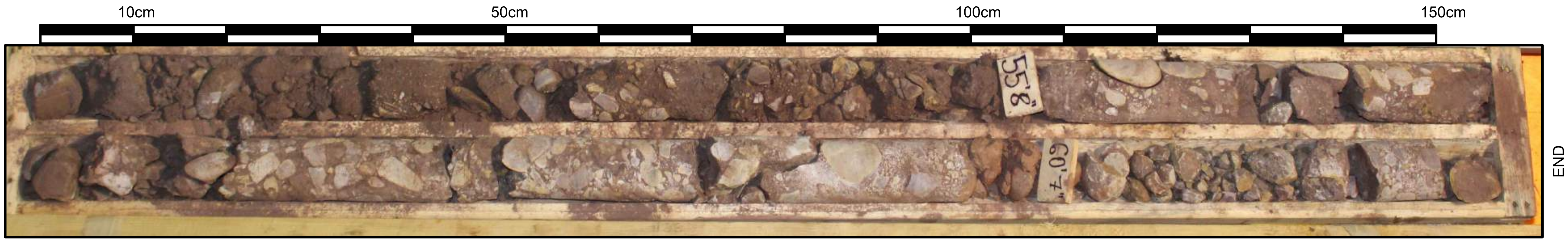
BOREHOLE ID: BH-2 DEPTH RANGE: FROM 10.058m TO 15.773m DATE: 06-05-2019

CORE BOX: BOX 1 OF 3 LOGGED BY: O. GALVIER



BOREHOLE ID: BH-2 DEPTH RANGE: FROM 15.773m TO 18.821m DATE: 06-05-2019

CORE BOX: BOX 2 OF 3 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-2 DEPTH RANGE: FROM 18.821m TO 19.355m DATE: 06-05-2019

CORE BOX: BOX 3 OF 3 LOGGED BY: O. GALVIER

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BH2

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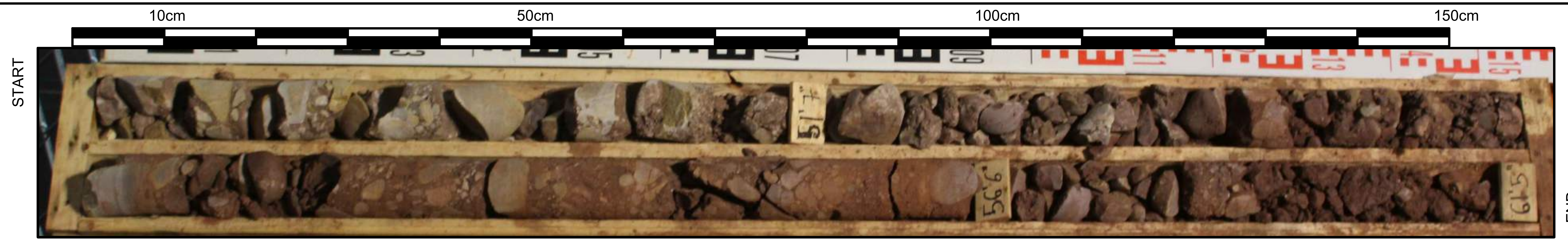
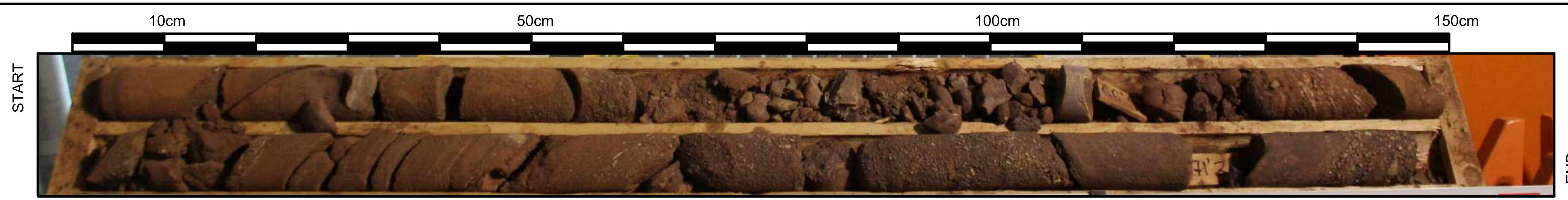
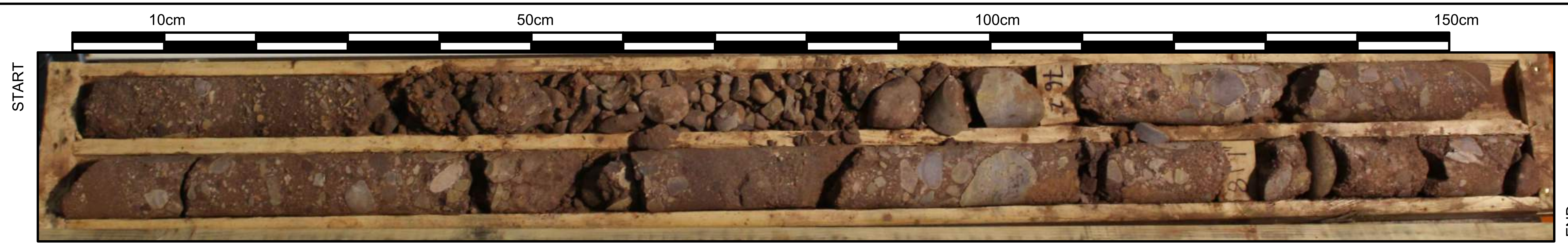
BOREHOLE ID: BH-3 CORE BOX: BOX 1 OF 7 DEPTH RANGE: FROM 10.668m TO 14.630m DATE: 06-05-2019 LOGGED BY: O. GALVIER



BOREHOLE ID: BH-3 CORE BOX: BOX 2 OF 7 DEPTH RANGE: FROM 14.630m TO 18.719m DATE: 06-05-2019 LOGGED BY: O. GALVIER



BOREHOLE ID: BH-3 CORE BOX: BOX 3 OF 7 DEPTH RANGE: FROM 18.719m TO 21.946m DATE: 06-05-2019 LOGGED BY: O. GALVIER



BOREHOLE ID: BH-3 CORE BOX: BOX 4 OF 7 DEPTH RANGE: FROM 21.946m TO 24.714m DATE: 06-05-2019 LOGGED BY: O. GALVIER

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BH3 1 OF 2

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10cm 50cm 100cm 150cm

START

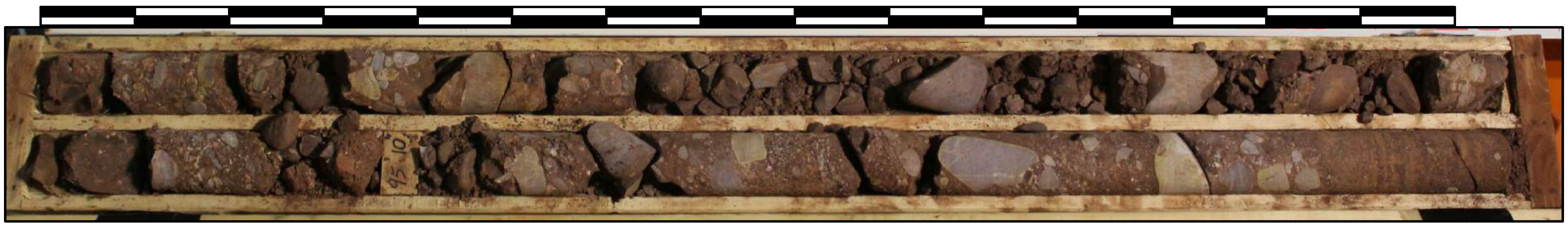
END

BOREHOLE ID: BH-3 DEPTH RANGE: FROM 24.714m TO 27.711m DATE: 06-05-2019

CORE BOX: BOX 5 OF 7 LOGGED BY: O. GALVIER

10cm 50cm 100cm 150cm

START



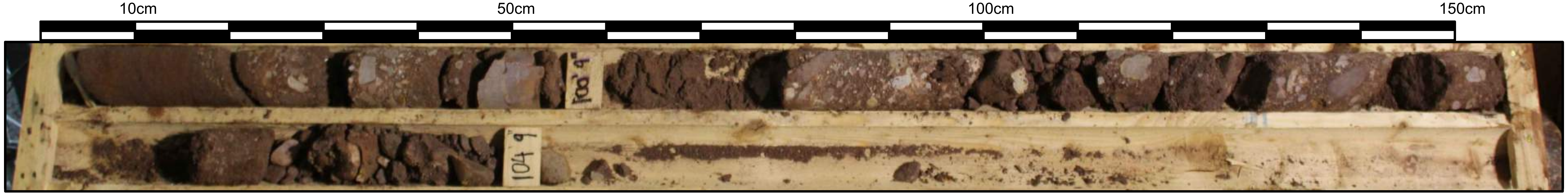
END

BOREHOLE ID: BH-3 DEPTH RANGE: FROM 27.711m TO 30.150m DATE: 06-05-2019

CORE BOX: BOX 6 OF 7 LOGGED BY: O. GALVIER

10cm 50cm 100cm 150cm

START



END

BOREHOLE ID: BH-3 DEPTH RANGE: FROM 30.150m TO 31.928m DATE: 06-05-2019

CORE BOX: BOX 7 OF 7 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-4 CORE BOX: BOX 1 OF 4 DEPTH RANGE: FROM 10.363m TO 15.469m DATE: 06-08-2019 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-4 CORE BOX: BOX 2 OF 4 DEPTH RANGE: FROM 15.469m TO 20.422m DATE: 06-08-2019 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-4 CORE BOX: BOX 3 OF 4 DEPTH RANGE: FROM 20.422m TO 26.469m DATE: 06-08-2019 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-4 CORE BOX: BOX 3 OF 4 DEPTH RANGE: FROM 25.603m TO 27.457m DATE: 06-08-2019 LOGGED BY: O. GALVIER

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BH4

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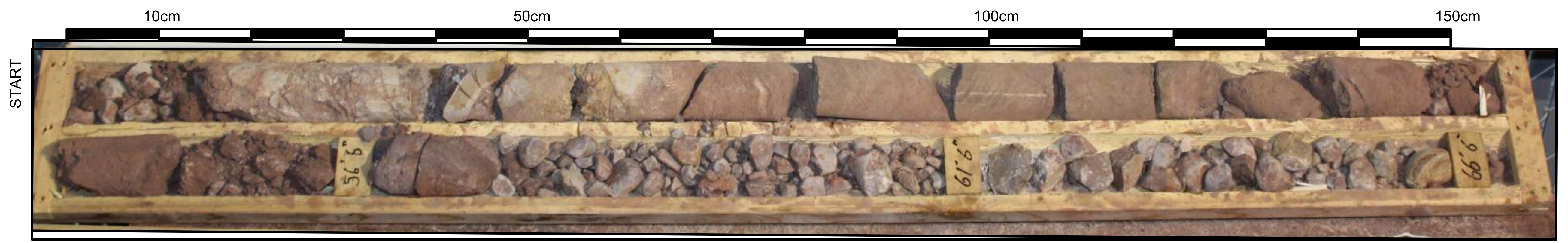
BOREHOLE ID: BH-5 DEPTH RANGE: FROM 10.668m TO 15.545m DATE: 07-26-2019

CORE BOX: BOX 1 OF 8 LOGGED BY: O. GALVIER



BOREHOLE ID: BH-5 DEPTH RANGE: FROM 15.545m TO 20.269m DATE: 07-26-2019

CORE BOX: BOX 2 OF 8 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-5 DEPTH RANGE: FROM 20.269m TO 24.232m DATE: 07-26-2019

CORE BOX: BOX 3 OF 8 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-5 DEPTH RANGE: FROM 24.232m TO 27.889m DATE: 07-26-2019

CORE BOX: BOX 4 OF 8 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-5 DEPTH RANGE: FROM 27.889m TO 32.156m DATE: 07-26-2019

CORE BOX: BOX 5 OF 8 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-5 DEPTH RANGE: FROM 32.156m TO 37.033m DATE: 07-26-2019

CORE BOX: BOX 6 OF 8 LOGGED BY: O. GALVIER

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BOREHOLE ID: BH-5 DEPTH RANGE: FROM 37.033m TO 40.081m DATE: 07-26-2019

CORE BOX: BOX 7 OF 8 LOGGED BY: O. GALVIER

BOREHOLE ID: BH-5 DEPTH RANGE: FROM 40.081m TO 44.043m DATE: 07-26-2019

CORE BOX: BOX 8 OF 8 LOGGED BY: O. GALVIER

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