Site Survey Report on Geophysical Survey Works at Otford Chalk Pit, Otford, Kent

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1. INTRODUCTION

Sevenoaks District Council (Council) commissioned Callias Professional Services Ltd (CPS) to undertake a site condition survey and assessment of a publicly accessed amenity, specifically a former Chalk Pit (Pit), located near Otford Railway Station, as shown in the Figure 1 below. The approximate National Grid reference of the center for the site is TQ5336559431, and the nearest post code is TM14 5QX.

Figure 1 Location of the Site, Otford Chalk Pit

Out of consideration towards public safety, the site was temporarily closed by the Council so that appropriate surveys could be carried out, aimed at help devise remedial measures for this site in order for it to be returned back to safe public use.

The scope of this assessment is to determine the frequency and the locations of the observed geohazards, namely sinkholes. One of such sinkholes, relatively large in size, was initially noted by the Council's personnel in this former Pit area and it was pointed out to CPS during the inaugural site visit on 26th June 2024.

To determine the extent and locations of the sinkholes at this site, a 2D Electrical Resistivity Tomography (ERT) geophysical survey was chosen to be appropriate due to its capability to identify areas of high resistivity attributed to probable low density ground. The geophysical (ERT related) survey works were conducted on site in the period from 4th October to 7th of October 2024 (inclusive).

2. DATA ACQUISITION

2D ERT profiles were carried out using “state of the art” geophysical surveying equipment ABEM Terrameter LS2 (resistivity meter) system with four (4No) multielectrode cables (21No electrodes on each), used to transfer current and potential signals from the resistivity meter to the ground. The precise coordinates of each electrode were measured using the Leica GNSS system GS18 T.

The electrode configurations applied for acquiring measurements for each profile were both for Schlumberger and Dipole-Dipole.

The Schlumberger array is less sensitive to noise (better signal-to-noise ratio), and is more sensitive to vertical variations in resistivity, thus depicting layering better.

In contrast, the Dipole-Dipole configuration is more sensitive to noise (lower signal-to-noise ratio), but also more sensitive to horizontal resistivity variations, hence better for revealing finite-dimensional anomalies.

In total, four (4No) ERT profiles were developed. The total length of the longer two profiles (“profiles 1 & 2”) were 120 m and the other two (“profiles 3 & 4”), 80 m each. The electrode spacing was set at 1.5m for “profiles 1 & 2”, and 1m for “profiles 3 & 4”, to ensure sufficient resolution for detecting the anticipated resistivity anomalies.

One of the 120-meter ERT profiles (“profile 1”) was aligned in such way so that it passed next to the known, relatively large (approximately 3m in diameter, 1m depth), existing sinkhole such that it passed tangentially at the profile's approximate midpoint. This was done to allow the sinkhole's influence on the ERT’s response on “profile 1” to serve as benchmark for identifying potential similar anomalies at this site. The second 120-meter ERT profile (“profile 2”) was positioned / aligned nearly perpendicular to the “profile 1” and in parallel with the remainder 80-meter ERT profiles (“profiles 3 & 4”), as depicted in Figure 2. During data acquisition, a relatively small size sinkhole was encountered (approximately 0.4m diameter, 0.7m depth), which is located at the start of ”profile 3”. (See Figure 2 below, and Photo 10 in Appendix B).

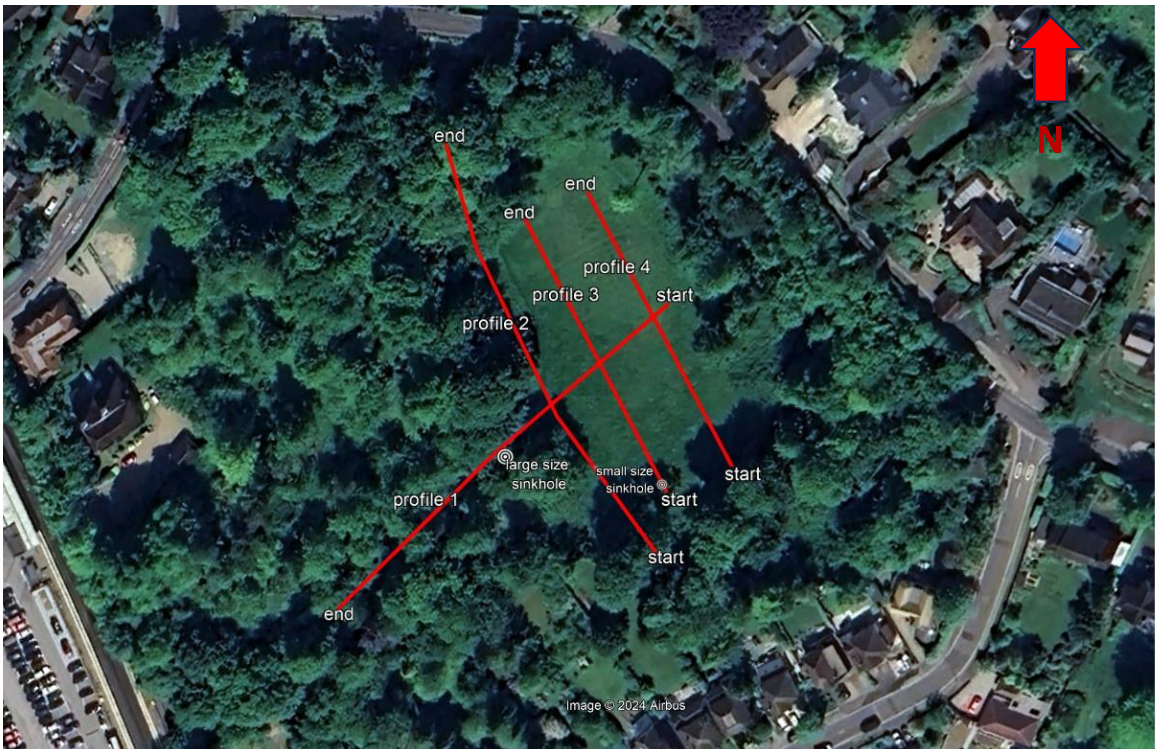

Figure 2 Extract of Google Maps with the positions of ERT “profiles 1 to 4” (red lines) and the existing sinkholes (white circles) as observed on site.

3. DATA PROCESSING AND INVERSION

Geotomo Res2DInv package (Aarhus Geosoftware) was utilized for data processing and inversion. Raw data were checked for integrity, and any suspicious measured apparent resistivity (very small number) data records were removed. The data inversion was performed, using the L2 norm and a grid of half electrode spacing.

For each profile, the inversion of both Schlumberger and Dipole-Dipole array data converged on resistivity models with similar anomalies, each with a Root-Mean-Square (RMS) error of approximately 1%. This also applies to the combined inversion of Schlumberger and Dipole-Dipole array data, demonstrating the high quality of the data and the robustness of the resulting resistivity models.

Finally, the maximum depth of the investigation / survey reached approximately 22-23 m at the central part of each of the 120-meter ERT profiles and 15 m at the central part of each of the 80-meter ERT profiles.

4. ERT RESULTS

The 2D resistivity models produced by the combined inversion show the actual subsurface resistivity distribution along each profile as a function of depth from ground level (Figure 3). A uniform color scale has been applied to all profiles for comparison purposes, enabling the extraction of valuable information.

All the resistivity models reveal the presence of two distinct layers of different resistivity, likely corresponding to different geological/lithological formations.

The deeper layer had resistivity values less than 50-60 Ohm.m (blue colors), and the superficial one with resistivity values mainly between 60 and 90 Ohm.m (green colors). The reduction in resistivity values at greater depths may be associated with a layer of higher clay content (more marly), underlying a less marly formation. The depth of this interface varies approximately from 5 to 12 m throughout the study area.

The surface layer exhibits areas of increased resistivity, exceeding 90-100 Ohm.m (indicated by yellow to red colors), which could signify either coarse or cohesive material formations, or potentially problematic weathered zones that may contain voids.

Specifically, in “profile 1” which passes close to the existing large-size sinkhole, the problematic zone coincides with one of the previously mentioned zones of higher resistivity, approximately in the middle of the profile. The same applies also to the resistivity model at the start (SSE end) of “profile 3”, where a relatively small-size sinkhole was encountered.

All higher resistivity zones, probably related to lower relative density zones, have been marked on the ERT profiles and presented in Figure 3.

To further assess the parameters / properties of the identified high-resistivity zones, additional surveys in the form of intrusive ground investigations (GI) are recommended. This will enable to physically test and sample the underlying ground as well as identify presence of groundwater at areas of identified ERT anomalies, which will help to better determine the prevalent ground model of the site. The collected samples will be subsequently scheduled for geotechnical laboratory testing that will provide key properties/geotechnical parameters of the underlying strata.

For better understanding the spatial distribution of the anomalous zones, a 3D representation image of the inverted ERT profiles in their real coordinates has been generated and shown in Figure 4.

DISCUSION

Due to the uncertainty and non-unique nature of geophysical interpretations, it is strongly recommended that direct (intrusive) survey methods are used to verify and calibrate the interpretation of the geophysical data results. This will help derive a more accurate ground model at the site, which can then be used with greater confidence for any future remedial design options and recommendations.

Taking into consideration the geophysical survey results and the size of the site, it is recommended that a program of a supplementary intrusive ground investigation (GI) is carried out. This should include a series of exploratory holes as described below.

Recommended GI:

It is suggested to carry out four (4No) cable percussive (CP) boreholes with sampling (BH1 to BH4) to enable ground profiling and geotechnical testing, together with sixteen (16No) dynamic probing (T1 to T16) as shown in Figure 5. These locations correspond to the areas of high resistivity as marked on the ERT profiles (marked by yellow & red lines in the figure).

Additionally, it is suggested that another seven (7No) locations of dynamic probing (T17 to T23) are carried out in areas lacking the anomalous zones (high resistivity areas) identified elsewhere, and four extra ones (T24 to T27) situated between the ERT profiles, which may assist in identifying the continuation of the identified anomalous zones.

The suggested coordinates (in WGS84) of all recommended exploratory holes are provided in Table 1 in Appendix A. Additionally, photographic record of the site is presented in Appendix B of this report.

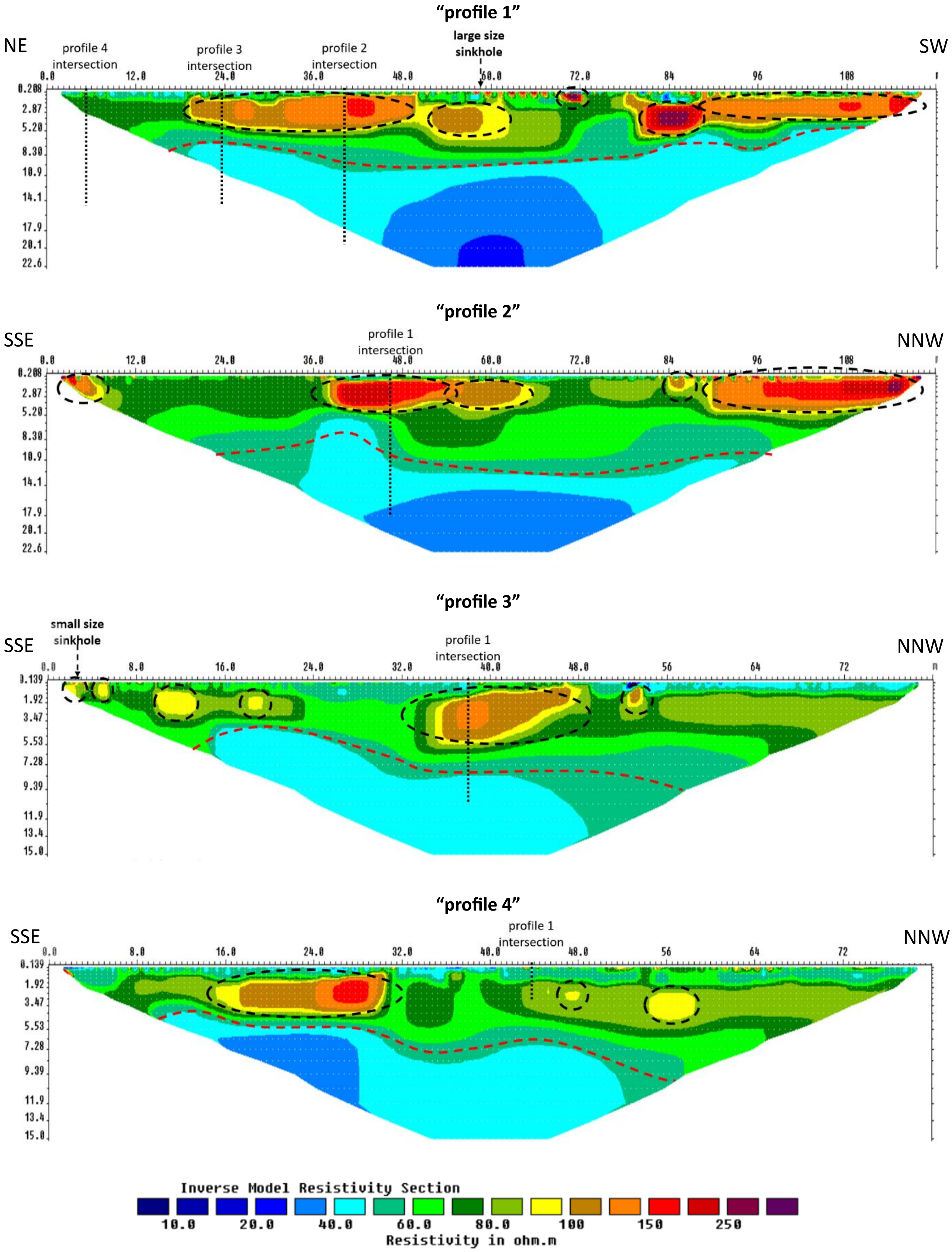

Figure 3 The 2D resistivity models of the ERT profiles, produced by the combined inversion of Schlumberger and Dipole-Dipole array data.

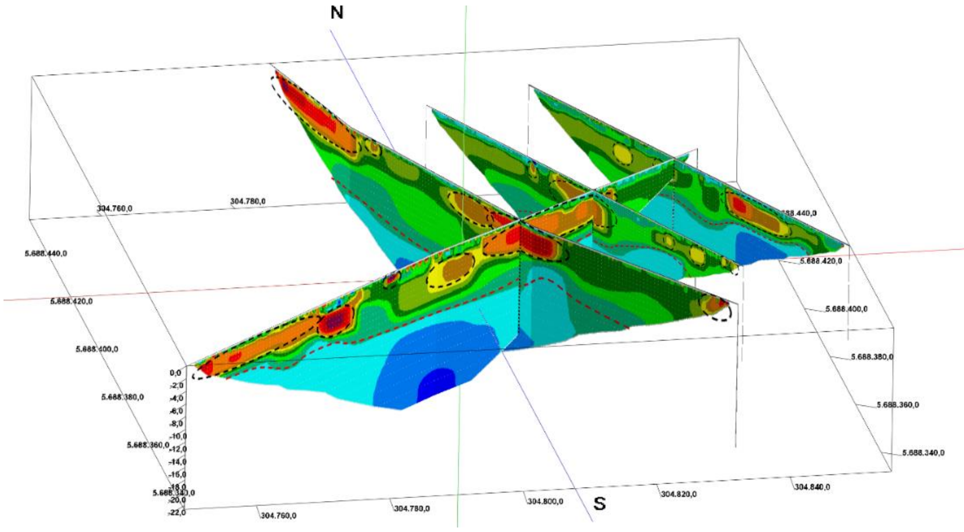

Figure 4 3D representation of the inverted ERT profiles.

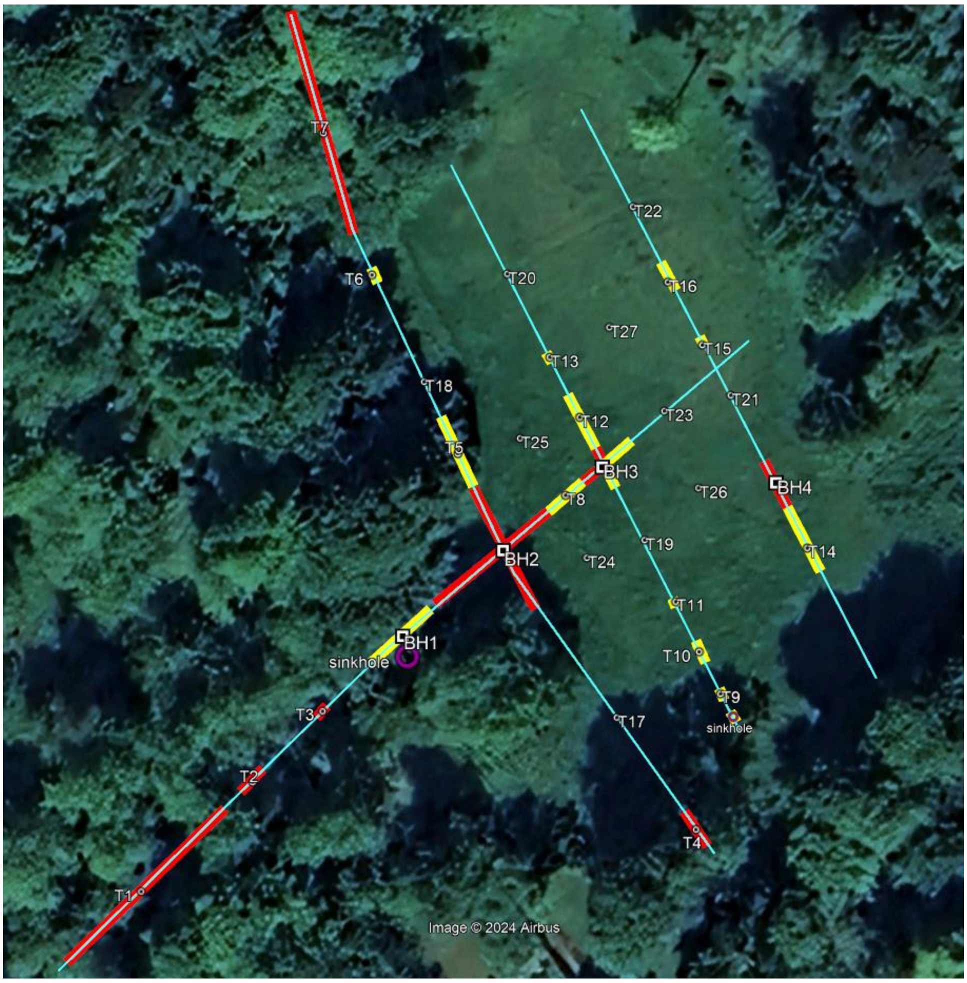

Figure 5 Areas of high resistivity marked on the ERT profiles (yellow & red lines) and indicative locations of potential drill holes and geotechnical testing.

APPENDIX A – Recommended Exploratory Hole Locations

Table 1 Suggested coordinates (WGS84) of indicative locations of recommended exploratory-holes including in-situ testing (see also Figure 5).

Indicative locations of Cable Percussive (CP) boreholes at identified anomalous zones		
Hole ID	**longitude**	**latitude**
BH1	0,19897451	51,31314012
BH2	0,19915755	51,31323785
BH3	0,19933623	51,31333189
BH4	0,19964644	51,31331380

Indicative locations of Dynamic Probing (DP) at identified anomalous zones		
Hole ID	**longitude**	**latitude**
T1	0,19848676	51,31284267
T2	0,19869695	51,31297150
T3	0,19882668	51,31305364
T4	0,19950714	51,31292097
T5	0,19907497	51,31334743
T6	0,19891901	51,31354990
T7	0,19883090	51,31371065
T8	0,19926965	51,31330000
T9	0,19954921	51,31307590
T10	0,19951064	51,31312335
T11	0,19946819	51,31317984
T12	0,19929486	51,31338775
T13	0,19924082	51,31345534
T14	0,19970197	51,31324036
T15	0,19951346	51,31346774
T16	0,19945176	51,31353822

Indicative locations of Dynamic Probing (DP) away from anomalous zones		
Hole ID	**longitude**	**latitude**
T17	0,19936301	51,31304835
T18	0,19901352	51,31342879
T19	0,19941195	51,31324945
T20	0,19916404	51,31354932
T21	0,19956444	51,31341143
T22	0,19938922	51,31362234
T23	0,19944647	51,31339436

Indicative locations of Dynamic Probing (DP) at locations between the ERT "profiles 3 & 4"		
Hole ID	**longitude**	**latitude**
T24	0,19930816	51,31322933
T25	0,19918746	51,31336439
T26	0,19950799	51,31330791
T27	0,19934754	51,31348836

APPENDIX B- Photographic Record

Photo 1 – ABEM Terrameter LS2, used for the geophysical ERT survey

Photo 2 – "profile 1" at near centre, looking towards NE and adjacent to the larger sinkhole (to the right)

Photo 3 – “profile 1”, looking towards SW – surveys extended into late hours.

Photo 4 – "profile 2", from its approximate centre – looking towards SSW.

Photo 5 – "profile 2", from its approximate north end – looking towards NNW.

Photo 6 – "profile 3", from its approximate centre – looking towards SSW.

Photo 7 – "profile 3", from its approximate NNW end – looking towards SSW.

Photo 8 – "profile 4", from its approximate NNW end – looking towards SSE.

Photo 9 – “profile 4", from its approximate SSE end – looking towards NNW.

Photo 10 – locally identified small sinkhole (along “profile 3”) – looking towards “profile 4", towards N.