GEOPHYSICAL SURVEY REPORT

sumo Survey

GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Victoria Tower Gardens, Westminster, London

Client
Atkins Ltd

Survey Report
11461

Date
September 2017

Incorporating

GSB PROSPECTION LTD

and

STRATASCAN LTD

SUMO Services Ltd
Cowburn Farm
Market Street
Thornton
Bradford
BD13 3HW
T: 01274 835016

SUMO Services Ltd
Vineyard House
Upper Hook Road
Upton upon Severn
Worcestershire
WR8 0SA
T: 01684 592266

geophysics@sumoservices.com
www.sumoservices.com

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Victoria Tower Gardens, Westminster

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Client:
Atkins

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Field co-ordinator:
Richard Fleming

Field Team:
Stephanie Rhodes BSc (Hons) FGS
Robert Knight BA (Hons)
Charlie Burton
Neil Leen
Chuma Eze

Report written by:
Stephanie Rhodes BSc (Hons) FGS
David Elks MSc ACIfA

CAD illustrations by:
Stephanie Rhodes BSc (Hons) FGS
Magdalena Udyrysz MSc

Project Manager:
Simon Haddrell BEng AMBCS PCIfA
Peter Marsh (utilities)

Report approved by:
David Elks MSc ACIfA

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1 SUMMARY

SUMO Services have been commissioned by Atkins to undertake a geophysical survey to investigate the below ground environment at Victoria Tower Gardens, Westminster, London. The site is being considered for the location of a prominent and iconic National Memorial to the Holocaust, with either a two or three storey basement for a new education centre. The project is being developed by the United Kingdom Holocaust Memorial Foundation (UKHMF). Atkins have been appointed by the Department for Communities and Local Government as Technical Advisor.

The overall aim of the geophysical investigation is to identify potential below ground hazards and constraints that may have implications on the design and construction of the proposed development. The constraints which may be encountered and are being investigated further by this study are: archaeology, tree roots, utilities, unexploded ordnance, and geological boundaries.

Where successful, the data results from the survey are generally good. There have been many limitations to the survey methods, specifically limited GPR penetration depth, ferrous material in the Made Ground affecting the EM data, and additional background vibrations recorded within the seismic data due to the localised urban environment. All of these are to be expected on an urban central London site and have limited the extent of the interpretations.

The archaeological evidence suggests that the remains of post medieval buildings may be present in the west of the site. A boundary line has been identified which initially divides the site in to a western part and eastern part. This boundary potentially marks the division between the land and a former foreshore and correlates well with that shown on the 1893 OS map. Land to the east has subsequently been reclaimed and raised with imported made ground to match the height to the west. There may be remains of a river wall or wharf along this boundary line, although no specific evidence can be seen in the data to prove this. To the north, remains of the 1935 garden layout have been detected showing the arrangement of former footpaths within the Park.

No conclusive evidence has been gathered to show the presence and location of roots associated with the trees lining the edge of the garden or the sporadic trees within the gardens. It is assumed that they have too narrow a diameter to have been resolvable by the survey method.

The utility survey has detected and mapped numerous cables and pipes crossing the site. None of the utilities shown on the statutory records have been detected on site. Whether this is due to the inherent inaccuracies of statutory drawings, or if the utilities may be deeper, or narrower, or are undetected for another reason is unclear.

The EM survey to locate potential UXO has identified 1300 ferrous targets. When this list is filtered to remove those caused by other sources such as services, manhole covers, bins, and benches etc. 135 potential UXO targets remain.

The data from the ERT and seismic lines have shown that the thickness of Made Ground typically increased in thickness towards the east. This supports the archaeological evidence indicating the N-S boundary marking the former foreshore in the east of the site which has subsequently been reclaimed and raised with imported material.

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2 INTRODUCTION

2.1 Background synopsis

SUMO Services have been commissioned by Atkins to undertake a geophysical survey to investigate the below ground environment at Victoria Tower Gardens, Westminster, London. The site is being considered for the location of a prominent National Memorial to the Holocaust and is being developed by the UK Holocaust Memorial Foundation. Atkins have been appointed by the Department for Communities and Local Government as Technical Advisor.

2.2 Site details

NGR / Postcode	TQ 302 791 / SW1P 3JH
Location	The triangular shaped gardens are located on the north bank of the River Thames. The Houses of Parliament are immediately north, River Thames east, and Millbank forms the western boundary to the site. The site became a public garden in 1879 and was extended to the south in 1914 (Atkins, 2017). Much of the land it occupies was reclaimed from the Thames foreshore in the post-medieval period (ibid.).

View of the gardens looking towards the Houses of Parliament to the north and River Thames just beyond the tree line to the east.

Historic Environment Record (HER)	Greater London
District	City of Westminster
Parish	St James's
Topography	The site is relatively flat and ranges from 4.407m – 5.218m AOD
Current Land Use	Public park laid to grass with paved and asphalt footways.
Weather	Mild/sunny
Geology & Soils	*Extract from "Technical Note: UK Holocaust Memorial, Westminster. Atkins Ltd 9 March 2017".* "A search was carried out of the available borehole information nearby on the British Geological Survey (BGS) database. A location plan of the BGS borehole records that have been analysed for this technical note

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are presented in Figure 2-1. These boreholes identify the geology at site to comprise the following stratigraphy:

- Made Ground
- Alluvium
- Kempton Park Gravel Formation (River Terrace Gravels)
- London Clay Formation
- Lambeth Group
- Chalk Formation (undifferentiated).

As presented in Figure 2-1 there are limited boreholes within the site boundary. All available boreholes will be fully assessed in detail to create a geological ground model. Although the logs are of poor quality and of great age they confirm the anticipated geology listed above.

The level of the gardens is about 4.5 to 5mAOD.

Typically the Made Ground encountered on site ranges between 0.5m and 5m in thickness, but is typically 2m in thickness. The underlying alluvial deposits appear to range between 1m and 2m in thickness, with variations across the site.

The available borehole logs suggest that the top of the Kempton Park Gravel Formation may be at an elevation varying between -2 and -3m AOD and the elevation to the underlying London Clay Formation at about -4 and -6m AOD."

"It is anticipated that the groundwater level at the site will be at an elevation of about -2 and -3m AOD, with possible perched groundwater in the overlying Made Ground. The river level is tidal."

Survey Methods	Ground penetrating radar (GPR) Radio Frequency Location (RFL) Electromagnetic (EM) Electrical Resistivity Tomography (ERT) Seismic Refraction (SR)
Study Area	2ha

2.3 Aims and Objectives

The overall aim of the geophysical investigation is to identify potential below ground hazards and constraints that may have implications on the design and construction of the proposed development.

The constraints which may be encountered and are being investigated further by this study are:

- To identify the presence of any buried archaeological features;
- To identify any former foundations present on site from the former buildings and structures;
- To investigate former wharfs and the locations of the former river side wall/s if present;
- To investigate the locations of buried services (general utilities and a sewer) and ducts;
- To provide an insight into the extent of below ground disturbance caused by bombing during the Second World War and to identify the presence of unexploded ordnances (UXOs) on site;
- To possibly confirm the extent of the root mass for the line of mature trees that edge the gardens;

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- To identify the depth and nature of near surface geological boundaries and to understand if there are any variations of these across the site (i.e. base of Made Ground, Alluvium and River Terrace Deposits).

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3 METHODS, PROCESSING & PRESENTATION

3.1 Survey methods

Several different geophysical techniques will be applied to investigate the wide range of potential targets that may be discovered. These are described below.

Detailed GPR and EM surveys were chosen as an efficient and effective method of locating archaeological anomalies, including foundations and wharfs. GPR was also used to detect tree roots and, in conjunction with RFL, the detection of utilities.

EM survey was also used as the most effective method of locating any potential ferrous UXO targets in the area.

ERT and SR surveys were used to penetrate deeper than the above methods and investigate geological boundaries.

The following table summarises the potential constraints and the primary technique(s) that have been used to reveal details regards that constraint. Note that the output of each technique will not be solely limited to meeting the constraint shown. Each will contribute towards a greater understanding of the site as a whole, and may add further information to support other objectives.

Constraint	Primary Techniques
Archaeology (inc. foundations and wharfs)	GPR, EM
Tree roots	GPR
Utilities	GPR, RFL
Unexploded Ordnance	EM
Geological boundaries	ERT, SR

The following table describes the make and model of the equipment used along with the traverse and sample intervals.

Technique	Instrument	Traverse Interval	Sample Interval
GPR	MALA Mini MIRA	0.08m	0.08m
RFL	Radiodetection RD8000	0.5m	NA
EM	Geonics EM61	1m	0.2m
ERT	Allied Tigre128	Varied	Varied
SR	Geometrics Geode 48	Varied	Varied

A grid was set out across the site using a Trimble R8 Real Time Kinematic (RTK) VRS Now GNSS GPS system. An RTK GPS (Real-time Kinematic Global Positioning System) can locate a point on the ground to a far greater accuracy than a standard GPS unit. A standard GPS suffers from errors created by satellite orbit errors, clock errors and atmospheric interference, resulting in an accuracy of 5m-10m. An RTK system uses a single base station receiver and a number of mobile units. The base station re-broadcasts the phase of the carrier it measured, and the mobile units compare their own phase measurements with those they received from the base station. This results in an accuracy of around 0.01m.

More information regarding the background to these techniques is included in the Appendices at the end of this report.

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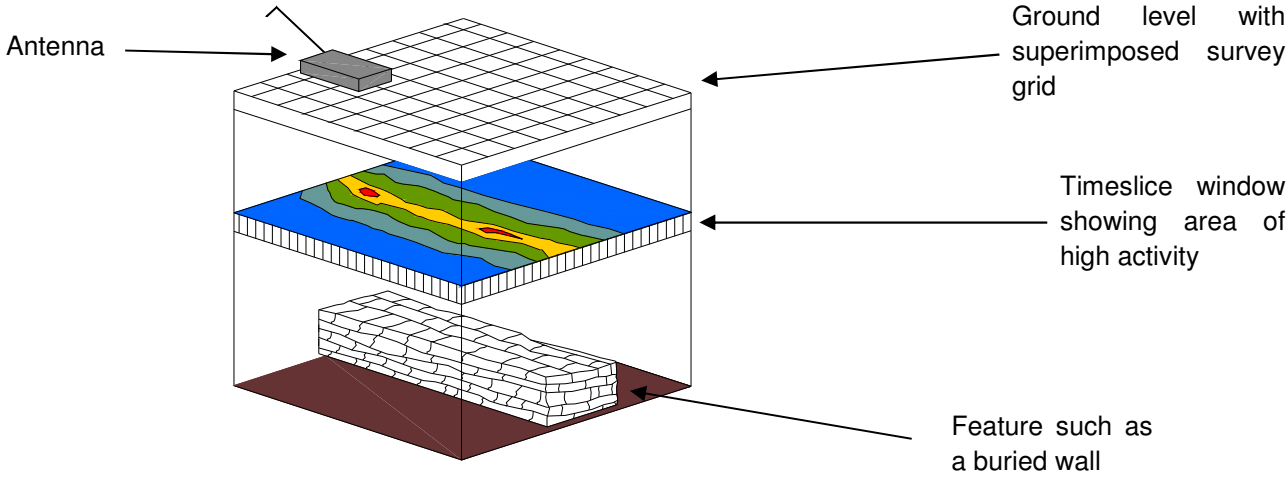
3.2 Ground Penetrating Radar (GPR) Data Processing & Presentation

Processing is performed using specialist software (Mala Rslicer). There are a wide range of filters available, the application of which will vary depending on the project. The below shows the processes used for this data included in this report:

Gain	Amplification to correct for weakening of signal with depth.
DC-Shift	Re-establishes oscillation of the radar pulse around the zero point)
Dewow/Ringdown Removal	Removes low frequency, down-trace instrument noise
Bandpass Filter	Suppresses frequencies outside of the antenna's peak bandwidth thus reducing noise
Background Removal	Can remove ringing, instrument noise and minimize the near-surface 'coupling' effect
Migration	Collapses hyperbolic tails (also known as 'diffractions') back towards the reflection source
Amplitude Envelope	Simplifies pulses for production of time-slice maps by summing peak values, regardless of polarity, over a given time-window.

The presentation of the results involves timeslice plots of processed data. Anomalies are identified, interpreted and plotted onto the 'Interpretation' drawings.

The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way, it is easy to see if the high activity areas form recognisable patterns.



The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within a range. The 3D file can be sampled to produce activity plots at various depths. As the radar is measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Based on an average velocity calculations have been made to show the equivalent depth into the ground.

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The weaker reflections in the time slice windows are shown as light grey colour. The stronger reflections are represented by colours such black and dark grey.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as foundations or surfaces within the soil matrix.

The maximum depth of penetration achieved was approximately 2.5m. The typical depth of penetration for this survey was 1.70m.

3.3 Utilities

The utilities report and site work have been conducted in accordance with PAS 128:2014 document (The British Standard Institution 2014) to Level M4P standard. This includes the collection of statutory utility records and on site detection with RFL and GPR methods. The statutory records search was conducted by Atkins Ltd “Ready To Dig” service. Their report is included as Appendix I and the latest version (V4) was received 23rd August 2017.

The RFL survey used a Radiodetection RD8000 and GPR survey used a MALA Mini MIRA high density system. Upon completion of the fieldwork and interpretation made of the data, quality levels (QL) were applied to each segment of utility surveyed in accordance to PAS 128.

QL-D – This is applied to utilities only indicated by the Type D record search and not supported by any of the field work. The location accuracy is undefined.

QL-C – This quality level is used where there is an indication from the Type D search and supported only by physical surfaces features such as road reinstatement scars; but not by the detection survey. The location accuracy is undefined.

QL-B – is subdivided into four subsections to reflect the confidence obtained from the detection techniques. Each of these can be further enhanced by post processing the radar in which case the suffix P is added.

QL-B4 and B4P – A utility segment which is suspected to exist but has not been detected and is therefore shown as an assumed route. The location accuracy is undefined.

QL-B3 and QL-B3P – Horizontal location only of the utility detected by only one of the detection techniques used. The horizontal accuracy is ±500mm and vertical accuracy is undefined.

QL-B2 and QL-B2P – Horizontal and vertical location of the utility detected by one of the detection techniques used. The horizontal accuracy is ±250mm or ±40% of the detected depth, whichever is greater and a vertical accuracy of ±40%.

QL-1 and QL-1P – Horizontal and vertical location of the utility detected by multiple detection techniques used. The horizontal accuracy is ±150mm or ±15% of the detected depth, whichever is greater and a vertical accuracy of ±15%.

QL-A – Where a visual inspection has taken place either through an excavation or from exposing the utility at access points, the highest quality level and accuracy can be attributed (±50mm horizontally and ±25mm vertically).

3.4 Electromagnetic (EM) Data Processing & Presentation

Traverses were conducted with reference to the aforementioned grid that had been set out on the site using an RTK GPS.

The electromagnetic survey used a Geonics EM61 system with a 1x0.5m coil. Data was collected along 1m traverses with readings taken every 0.2m. The EM61 system is able to

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detect an aerially delivered 50kg bomb to a depth of 4.55m, with smaller items, such as small arms munitions, to a depth of 2m provided the areas have a relatively quiet background.

The presentation of the data for the site includes a plot of the processed data as colour plots. Magnetic and metallic anomalies identified and modelled according to depth and weight as possible UXO are plotted onto the 'Electromagnetic Data with Surface and Buried Targets' drawing.

When interpreting the results several factors are taken into consideration, including the nature of UXO being investigated and the local conditions at the site (geology, recent land use, topography etc.). Areas with high levels of background magnetic fields, caused by surface metallic features and buildings, make discrimination between readings from possible UXO and background readings impossible.

Each anomaly is modelled with a depth and mass using Oasis Montaj software. Please note that all modelling assumes that the anomalies are caused by compact discrete features, such as a bomb, and any non-compact features will not give accurate depths or masses. In this case anomalies will usually appear with a greater depth and mass than the feature actually has.

3.5 Electrical Resistivity Tomography (ERT)

Seven ERT lines were undertaken over the site. See table below for details of the number of electrodes used, their separation, line length, and maximum penetration depth and target resolution.

Line No.	Approx. Orientation	No. of Electrodes	Electrode Separation (m)	Length (m)	Depth (m)	Resolution (m)
1	W-E	64	1	63	7.68	0.5
2	N-S	96	1.5	142.5	17.28	0.75
3	N-S	96	1.5	142.5	17.28	0.75
4	N-S	54	1	53	6.48	0.5
5	W-E	30	1	29	3.60	0.5
6	W-E	40	1.5	58.5	7.20	0.75
7	W-E	32	1.5	46.5	5.76	0.75

The ERT survey was carried out using the Allied Tigre128 system. This technique employs a line of metal stakes (electrodes) temporarily inserted in the soil through which an electrical current is passed. Four electrodes are used to take each measurement of the ground resistivity, two conducting current and two measuring the electrical potential difference (voltage).

By traversing the four electrodes along a line and repeating the process at increasing electrode spacing (providing greater depths of investigation), it is possible to build-up a two-dimensional representation of the variation in ground resistivity (measured in Ohm metres, Ohm-m). Complex processing of the measured resistivity data produces the final resistivity image, which may then be used to interpret geological variations. This is displayed as a colour scale cross section.

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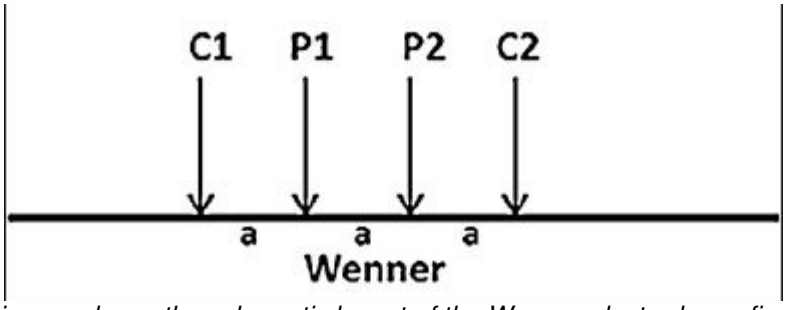
The data has been collected using the Wenner electrode configuration. Spacing between electrodes (a) varied between each survey line with respect to total survey line length and desired resolution of data and penetration depth.



The above image shows the schematic layout of the Wenner electrode configuration. This has an equispaced distance between each of the electrodes (a). The current is injected via the outer electrodes (C1 and C2) and the potential difference (voltage) measured between the inner electrodes (P1 and P2).

The position of each individual electrode is measured using a Total Station set to the parameters created using the RTK GPS to record the latitude, longitude and elevation. Topographic corrections are added, post survey, into ImagePro software and data exported into RES2DINV software for further processing including an inversion process. The inversion uses the apparent resistivity measured to model the true resistivity of the subsurface. Following inversion of the data, a refinement process is applied, this lowers the RMS (route-mean squared) errors to account for the strong near surface variation. However, the model with the lowest possible RMS error can sometimes show large and unrealistic variations in the model resistivity values and might not always be the “best” model from a geological perspective.

In general the most prudent approach is to choose the model at the iteration after which the RMS error does not change significantly. This usually occurs between the 3rd and 5th iterations.

3.6 Seismic Refraction

Five seismic lines of 24 and 48 geophones were undertaken over the survey area. See table below for details.

Line	Approximate orientation	No. of Geophones	Geophone Separation (m)	Length (m)	Approximate Depth (m)
1	N-S	24	2	46	9
2	W-E	24	1	23	10
3	N-S	48	3	141	28
4	W-E	24	2.5	57.5	18
5	W-E	24	2.5	57.5	8

Seismic measurements (or ‘shots’) were taken at regular intervals along each seismic line using 5-7 hammer blows (stacking) to improve signal to noise ratio. Weather during data collection was mostly fine but some wind deteriorated the data quality. See Appendix E for a detailed explanation of survey equipment and methodology. The geophones are sensitive and can detect small unwanted vibrations from many sources these included; wind in the trees, water flowing along the River Thames, vehicular and pedestrian traffic, road works to the north west of the site.

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Processing of signals received is usually minimal in the case of seismic refraction, however due to the nature of this site, air waves and other 'noise' created by the river, traffic, road works, etc. have obstructed the first breaks in the first layer, and in some lines the second layers too. This was filtered using a high-cut filter and may have the effect of reducing the accuracy of the plotted first breaks. Due to the noise constraints on this particular site, survey Line 1 and Line 3 have too much noise to accurately detect the 'first breaks' (See Appendix G) and have not been included in the report. Signal modification applied in all cases was a high pass filter to remove wind noise, the air wave, and other high frequency events. Normalised gain and signal clipping is applied as a visual tool to aid interpretation only and is not a permanent signal modification.

The position of each individual geophone is measured using a Total Station set to the parameters created using the RTK GPS to record the latitude, longitude and elevation. Topographic corrections are then made to the data for greater degree of accuracy.

'First breaks' have been manually picked for each shot using the Pickwin module of Seisimager software by Geomatrix Earth Science Ltd. Velocity models have been processed using Rayfract (see Appendix E for an explanation of seismic refraction principles).This provides an inverted tomography model for the data, this has the advantage that velocity layers do not need to be picked manually and horizontal velocity changes within a layer are properly represented, however, where there is a sudden vertical layer change this can get smoothed out in to a gradual change instead and gaps in the data get filled in with imaginary computer generated values.

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4 RESULTS ARCHAEOLOGY

4.1 Standards and Guidance

This report and all site work have been conducted in accordance with the latest guidance documents issued by Historic England (EH 2008) (then English Heritage), the Chartered Institute for Archaeologists (CIfA 2014) and the European Archaeological Council (EAC 2016).

4.2 Site History

Extract from Atkins, 2017. UK Holocaust Memorial Heritage Appraisal.

General
There is a general potential for finds dating to the prehistoric period and archaeological remains dating to the Roman and early medieval periods to be identified within the Site. Although no assets dating to these periods have been located within the Site the recovery of prehistoric artefacts and the presence of identified Roman and Saxon activity within 250m means there is a possibility for previously unrecorded remains to be uncovered.

Prehistoric deposits such as peat and organic clay have been recorded within the area surrounding the Site. There is a general potential for similar deposits to be identified within the Site, in particular in the eastern half of the Site where former sections of the Thames foreshore were reclaimed in the mid-19th century.

There is also a general potential for medieval remains relating to riverside activities and river walls to be identified within the Site. The presence of a medieval water break within Black Rod's Garden immediately to the north of the Site indicates that such features survive within the area.

Specific
There is no specific potential for remains dating to the prehistoric, Roman or early medieval periods to be identified within the Site.

There is specific potential for medieval remains relating to the Abbot's Mill, the canalised section of the River Tyburn and the Slaughterhouse recorded on Norden's 1593 map of Westminster to be identified within the Site. These also present the possibility of associated waterlogged deposits to be recovered from within the Site.

There is extensive evidence that the Site was developed throughout the post-medieval period and remains relating to a wide range of riverside and industrial activities are likely to survive over much of the area. Historic maps dating from the late 17th century onwards indicate the potential for buried archaeological remains ranging from the remains of buildings to in-filled docks. The presence of post medieval water-logged deposits within the Site is likely due to the known presence of both made-ground and in-filled docks.

4.3 Discussion

The most prominent anomaly detected by the GPR is a circular 'roundabout' feature towards the north of the site. This is relatively shallow at 0.2m depth. A review of historic maps included in the DBA provided by Atkins shows that this relates to a garden feature highlighted on the 1935 OS map. It is probably caused by remains of a central circular pathway. Some linear stubbs can also be seen likely to be the pathways leading to and from this central circular path.

Also in the northern part of the site are other similar responses which are curved and are approximately the same width at 3m. One of these is visible as a pathway dating from a 1999 Google Earth photograph so it seems likely that they are all caused by former pathways no longer extant.

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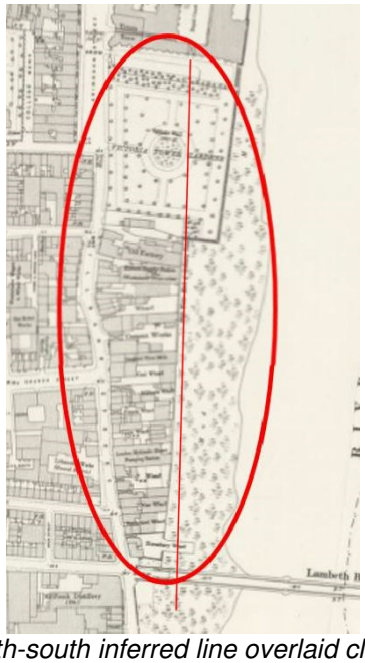
Scattered across the site, but predominantly in the central area are numerous smaller complex GPR responses. These anomalies seem sporadic and do not form a recognisable regular pattern. They do correspond with an anomaly in the EM data. It is possible to speculate that they may relate to structural remains of the many buildings that have stood on the site particularly from the 1700s through to the creation of the gardens in 1879. This is of course tentative at best and is based purely on circumstantial evidence. It is interesting to note that less of these types of response are seen in the east of the site which is known to be reclaimed land. Perhaps this concentration of anomalies can be used to infer a line demarcating a previous foreshore or wharf. This line has been speculatively drawn on the GPR interpretation figure. Other responses seen in the EM data also seem to obey the edge of this line adding further evidence which does suggest a distinct change is occurring at this point. The historic maps support this in depicting that the shore line is further west than its present location. It is not possible to georeference many of the older historic maps to the current landscape and so a direct comparison of the positions is not possible. The 1893 OS map can be overlain to the current landscape and shows that the inferred boundary aligns well with the mapped Victorian shore line.



1893 OS map with the north-south inferred line overlaid clearly following the mapped foreshore (within the inaccuracies expected).

In the south of the site a linear anomaly can be seen which is similar to the pathways discovered in the north. No pathways are known to have existed here based on historic OS maps and more recent Google Earth imagery. The anomaly occupies a similar location and orientation as the former shoreline and so could relate to a river wall or wharf. This would require further investigation to clarify. Several other anomalies in this vicinity seem to form a clear rectilinear pattern. These could also relate to buildings or the line of the wharf, but again the data is inconclusive and would require further investigation to clarify. They do seem to obey the same line as set out above and could mark a continuation of the river wall or wharf further south.

5 RESULTS TREE ROOTS

Trees typically have a relatively shallow and wide spread root structure. The majority of roots are within the upper 0.6m, some can extend to 2m (Forestry Commission, 2017). There is a link between the height of the tree and the spread of the root. Depending on the species the root system usually spreads laterally at least as far as the tree is tall, and sometimes up to three times the height of the tree (RHS, 2017). As a rough guide GPR will be able to resolve a

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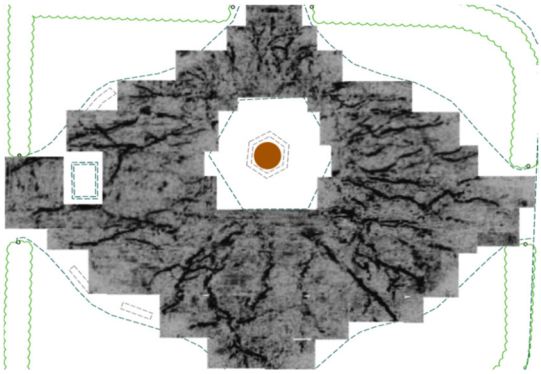
root whose diameter is 10% or greater than its depth. For example a root at 0.5m deep would need to be 5cm or larger in diameter.

No clear radiating patterns have been detecting adjacent to any of the trees present (an example of what this can look like is shown below). Some weak linear anomalies are observed around the extremities of the site. These are predominantly located along the western edge of the site. Whether these are due to roots or simply noise as a result of footpaths in these areas is unclear. This suggests that the roots radiating from these trees have a narrow diameter which can not be resolved by the radar. It is possible that the majority of the roots radiate away from the gardens. Although given the proximity of growth restrictions in other directions (Millbank built environment on one side and the river wall and brackish water of the Thames Tideway on the other) this seems unlikely.



Example GPR timeslice showing tree root pattern radiating out from a central tree.

6 RESULTS UTILITIES

6.1 Standards and Guidance

This report and all site work have been conducted in accordance with PAS 128:2014 (The British Standard Institution, 2014) to Level M4P standard.

6.2 Discussion

There is good correlation between the RFL and GPR results which is reflected in the high number of B1P quality levels. The High Density Array Radar detected more possible services which have been marked as unknown.

The results from the record drawings and from the on site detection survey do not correlate. Most of the services from record drawings are located outside the survey area and none of those located within the survey area have been found by RFL or GPR. Where there is information only from the record drawing the quality level is B4.

The EM61 survey also found evidence for several identified utilities including: a W-E orientated unknown service to the north of the site, an identified water utility running approximately N-S in the southwest of the site, an unidentified utility on the eastern site edge, two electric cables in the south of the site.

A very strong square shaped anomaly can be seen in the GPR and corresponding EM data in the south of the site. This is shallow at 0.06m depth. This is characteristic of a metallic object. It seems likely this is caused by a buried manhole despite having detected no utilities in that area.

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Unknown utilities and assumed routes
Several unknown services were detected by the survey across the site. Some of them were detected by RFL and the others by GPR with the EM61 data also corroborating some.

There are number of assumed route utilities that were not detected on site. However, the following are worth mentioning:

i. The gas mains are running outside of the survey area on the record drawings and were not corroborated.

ii. The drainage next to the memorial in the north was only seen next to the gully and manhole, the remaining part is marked as assumed route.

iii. The sewer to the north east of the site was only seen next to the manholes and the remaining parts are marked as assumed route.

iv. The sewers to the east of the site are marked as assumed routes.

The sewer to the south east of the site was only seen next to the manhole and gully and the remaining part is marked as assumed route.

7 RESULTS UXO

7.1 Standards and Guidance

This report and all site work have been conducted in accordance with CIRIA guidelines (CIRIA 2009).

7.2 Site History

Extract from Atkins, 2017. UK Holocaust Memorial Heritage Appraisal.

A number of high explosive bombs are known to have been dropped both within and immediately adjacent to the Site during the Second World War (http://www.bombsight.org). The impact of these upon buried archaeological deposits is likely to have been significant and detrimental although this remains speculation in the absence of specific data. The potential for unexploded ordnance to be encountered within the Site must be considered.

The river wall that defines the eastern edge of the Site was subject to a direct hit by a High Explosive bomb on the night of the 16th/17th May 1941. Although the damage was relatively limited contemporary photographs show water within the bomb crater at high-tide (National Archives WORK 16/2555).

A bomb map of Westminster is held in the borough's archives which records all of the bomb impacts within Westminster between 1940 and 1945. This is not reproduced here for copyright reasons but can be found athttp://www.westendatwar.org.uk/page_id__99_path__0p2p.aspx. This map shows four recorded bomb impacts within Victoria Tower Gardens.

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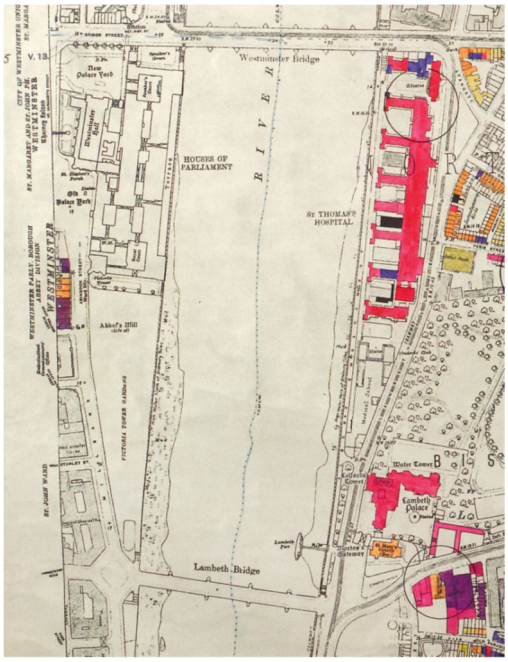

London County Council Bomb Damage Map, c.1945 (Ward, 2015).

The bomb damage map above shows buildings that have been totally destroyed (purple) adjacent to the site on Millbank. On the opposite bank buildings can be seen that have been seriously damaged (red). This clearly demonstrates that the site is within an area subject to air raid and as such has potential to contain UXO.

During post war clearance and re-development any UXO encountered are likely to have been located and removed during the ground works. In places where no further development has taken place, or in environments that are difficult to reach, or in less populated places where UXO may have gone unnoticed, it is possible that UXO may still remain in the ground.

7.3 Discussion

The EM survey has identified a total of 1,300 anomalies that may relate to objects containing ferrous material. The following tables show the distributions of modelled masses and depths of these objects.

The number of anomalies is determined by performing a Blakely test on the electromagnetic data which determines targets. To assess anomaly mass, the relative field strength between each coil on the EM61 is used.

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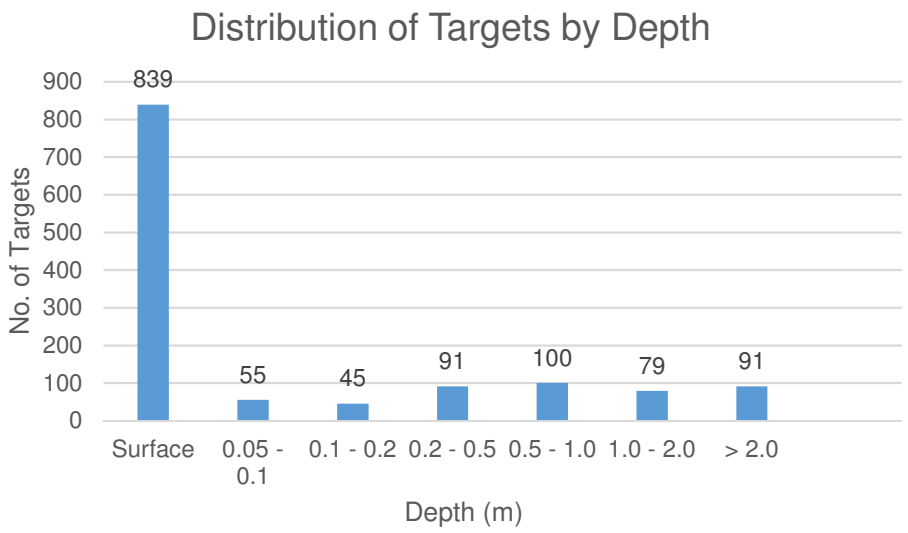

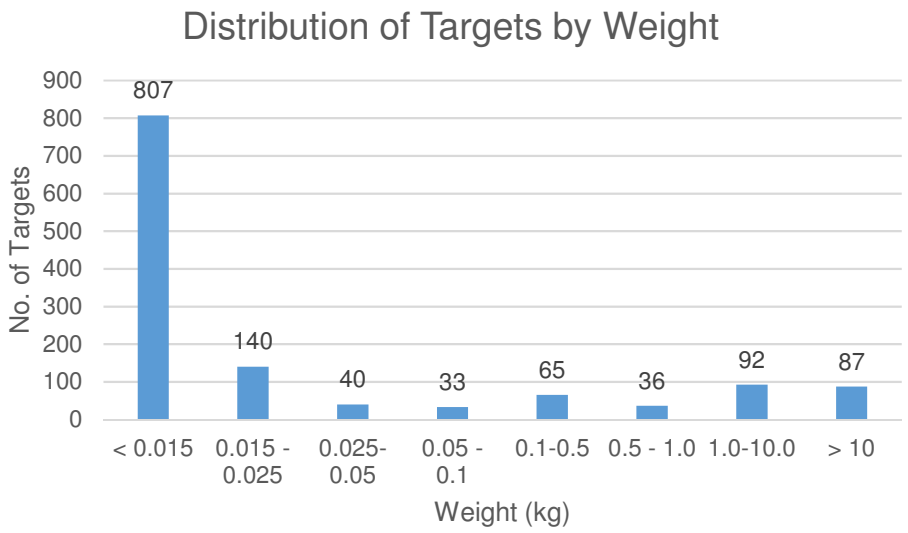

Filters have been applied to reduce the total number of ferrous targets to a total number of possible UXO. These are described in more detail here:

1. Objects less than 5cm deep have been removed. These are assumed to be caused by modern rubbish dropped by the public which has accumulated in the top soil throughout the site's current use as a recreational space.

2. The lightest weight aerially delivered enemy weapon during WWII was 1kg. After 70 years in the ground it is likely that degradation will have altered the weights of any remaining UXO. It is also possible that damaged and broken parts may still remain viable but be smaller and weigh less than the original complete ordnance. The weight of the original ordnance can only be used as a guide to assess UXO potential. For this reason, any object less than 0.5kg has been removed.

3. Objects which are within the zone of a larger regional anomaly or an otherwise explained feature (such as those along the route of a utility) have been removed.

After the application of these filters, 135 objects remain as potential UXO targets. It must be born in mind that despite these logical filtering steps it is possible that any of the detected ferrous objects could relate to UXO.

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8 RESULTS GEOLOGY

8.1 Borehole Data

The site lies on the London Clay Formation with superficial deposits of alluvium and river terrace deposits. Borehole data provided by Atkins shows we can expect to see made ground to depths of -2m AOD across the site. Alluvium between -0.5m and -2m AOD, River Terrace Gravels varying between -2 and -3m AOD and London Clay from approximately-4m to -6m AOD though this will vary across the site. Much of the site, in particular the eastern parts, is on land reclaimed from the Thames foreshore in the post medieval period. Atkins have anticipated the site to have groundwater at -2 to -3m AOD.

All geology interpretations are made with reference to the table in Appendix F (seismic velocities) and Appendix H (resistivity values) in conjunction with existing borehole data of the survey area.

8.2 Discussion

In general terms the ERT data is showing a relative thickening of the upper layer of material towards the east. This is to be expected, and confirms that the eastern parts of the site have been constructed on reclaimed land. The thicker upper layers being increased use of made ground to build up the foreshore to the present ground level. The lower resistance responses are likely to be alluvium and may be wetter which is why they result in lower resistance values. This is best seen in ERT Line 5 and Line 7 where the higher resistance zones extend to around 2m deeper on the eastern side compared to the west. Seismic Line 2 corroborates a depth of made ground to around -1mAOD changing to London Clay around -4mAOD. These represent the seismic velocity step increases at 800m/s and 2500m/s resepctively. It has not been possible to detect the change from alluvium to river terrace deposits which is known to exist from borehole data. Both these materials have similar seismic velocities and resistivities which make it very difficult to detect this subtle change. This could indicate that there is a gradual change in material rather than a strong definitive break, or possibly that the water table is influencing the resistivity measurements and concealing the location of the boundary.

ERT Line 5 and Line 7, along with Line 1, also show a clear break toward the centre of the survey line where, in the case of Line 5, a low resistance protrusion can be seen coming up to the surface. Line 1 and Line 7 show a high resistance break. When these breaks are plotted on the base map they can be seen to create a line running north-south through the site (see Figure 12 and Figure 13). This line almost precisely (within tolerance of expected errors) follows the tentative N-S line that the GPR and EM data have also generated. The correlation of all the data sets indicating this change supports the argument that this line marks the edge of the former foreshore perhaps where a wharf may have existed with thicker deposits of made ground on the river side (east) of this line building up the height of the ground surface. There is also a marked difference between ERT Line 2 (west of the trend line) and ERT Line 3 (east of the trend line). Line 3 shows a series of high resistance pockets extending to depths of around -2mAOD, where the top layer of made ground deposits in Line 2 is perhaps only 2-3m thick. There is one exception in Line 2 where a high resistance pocket can be seen extending to around -10mAOD. It corresponds with a strong EM anomaly. Perhaps this is a backfilled channel, but this is a tentative suggestion only.

ERT Line 6 is somewhat ambiguous insofar as the upper layer seems to thicken towards the west, 6.5m thick compared to 4m in the east. The reason for this is unclear. However the east still shows a much higher resistive layer. This may indicate a different type of imported material in this region indicating that it may have been raised on a different occasion adding some evidence, if only weak, support to this theory. The corresponding Seismic Line 5 seems to correlate with ERT Line 6 in as much as it indicates undulating boundaries, including the Made Ground reaching to greater depths (~-5m AOD) in the east.

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ERT Line 4 to the south is generally more uniform with a high resistance pocket in the east which may relate to made ground but this is unclear.

Seismic Line 4 suggests that the London Clay is at a depth of around -10mAOD where the velocity increases beyond 2500m/s which is the characteristic highest speed of alluvium.

Seismic Line 1 was located in the southern section of the site, orientated approximately N-S along the same easting as ERT Line 4. This data is very noisy (see Appendix G). Some picks could be interpreted, but not to a far offset from the shot location. It has not been included in the report.

Seismic Line 3 was the longest survey line, orientated approximately N-S in the northern section of the site. Unfortunately, this line was located very close to road works and subsequently the data was too noisy to pick accurate first breaks. It has not been included in the report. See Appendix G.

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9 DATA APPRAISAL & CONFIDENCE ASSESSMENT

Generally the data has been of good quality, corroborative, and revealing. There have been some limitations which will be discussed here.

The GPR data has limited penetration depth likely to be due to the alluvial environment. Alluvial and clay deposits, often damp, are not ideal conditions for radar. Water being a conductive material tends to attenuate the radar signal which results in reduced penetration depth. This is common in these environments and the maximum depth achieved rarely exceeds 1-1.5m in the London region.

The EM61 survey has been somewhat affected by background responses. Public spaces such as parks and sports fields tend to contain large quantities of small ferrous objects and other debris dropped by people and trodden in to the top soil. These objects can produce magnetic noise which effect EM surveys. Also landscaping and infrastructure can have a similar effect. For example along footpaths, fences, lawn edges, rubbish bins, manholes and so on. These landscaped surface features have been noted in order to account for them in the results. However it can be difficult to account for random debris, some filtering has been carried out on the data in an attempt to do so, and this is described in the processing section of this report.

There is good correlation between the utilities detected by GPR and RFL. The EM61 has also provided corroborative evidence. However, none of the utilities shown on the statutory desk based record search have been detected on site. Statutory records are notoriously inaccurate, and it is not unusual for none to be found. However, bearing in mind the depth limitation of the GPR described above, care should be taken with any ground works in these areas as the services may be deeper or narrower than we have been able to detect.

The ERT survey has produced some good data, however there remains limitations with the interpretations. The thickness of the Made Ground deposits appears clear. The interpretations of the layers below the Made Ground is more subjective. The boundary of the alluvium and river terrace gravels is not distinguishable despite its presence being known from the borehole logs. Both these materials have similar resistivities which make it very difficult to detect this subtle change. This could indicate that there is a gradual change in material rather than a strong definitive break, or possibly that the water table is influencing the resistivity measurements and concealing the location of the boundary.

Of all the techniques used the seismic data has been the most negatively affected. The site was subject to many sources of unwanted vibrations which has resulted in noisy data that has been difficult to process. The geophones are incredibly sensitive and sources of noise which have been problematic include; pedestrians, vehicles, wind noise in the trees, water flowing in the river, and road works. The high noise levels have obscured the first breaks in some of the data which has rendered them unusable. The processing required to remove the noise is so intensive that it also removes much of the “real” data resulting in entirely unreliable lines. For this reason, Line 1 and Line 3 have not been used in this report. The data that has been used is that which was collected at quieter times of the day with less traffic and after the road works had closed.

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10 CONCLUSION

All of the data sets collected have generally provided corroborative evidence supporting each other and providing useful information to allow a reasonable understanding of the below ground environment at Victoria Tower Gardens. This is discussed in more detail below with respect to the objectives of the investigation.

The archaeological evidence suggests that the remains of post medieval buildings may be present in the west of the site. A boundary line has been identified which initially divides the site in to a western part and eastern part. This boundary potentially marks the division between the land and a former foreshore and correlates well with the foreshore on the 1893 OS map. Land to the east has subsequently been reclaimed and raised with imported made ground to match the height to the west. There may be remains of a river wall or wharf along this boundary line, although no specific evidence can be seen in the data to prove this. To the north, remains of the 1935 garden layout have been detected showing the arrangement of former footpaths within the Park.

No conclusive evidence has been gathered to show the presence and location of roots associated with the trees lining the edge of the garden or the sporadic trees within the gardens. It is assumed that they have too narrow a diameter to have been resolvable by the survey method.

The utility survey has detected and mapped numerous cables and pipes crossing the site. None of the utilities shown on the statutory records have been detected on site. Whether this is due to the inherent inaccuracies of statutory drawings, or if the utilities may be deeper, or narrower, or are undetected for another reason is unclear.

The EM survey to locate potential UXO has identified 1300 ferrous targets. When this list is filtered to remove those caused by other sources such as services, manhole covers, bins, and benches etc. 135 potential UXO targets remain.

The data from the ERT and seismic lines have shown that the thickness of Made Ground typically increased in thickness towards the east. This supports the archaeological evidence indicating the N-S boundary marking the former foreshore in the east of the site which has subsequently been reclaimed and raised with imported material.

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