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NATIONAL GRID PROPERTY LTD
GEOTECHNICAL AND ENVIRONMENTAL ASSESSMENT SITE INVESTIGATION FACTUAL REPORT
PROPOSED CABLE ROUTE, TOTTENHAM

GEOTECHNICAL AND ENVIRONMENTAL ASSESSMENT SITE INVESTIGATION FACTUAL REPORT

PROPOSED CABLE ROUTE, TOTTENHAM

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1 August 2013

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**PROJECT 305008-00018 51603-00 - GEOTECHNICAL AND ENVIRONMENTAL ASSESSMENT SITE
INVESTIGATION FACTUAL REPORT**

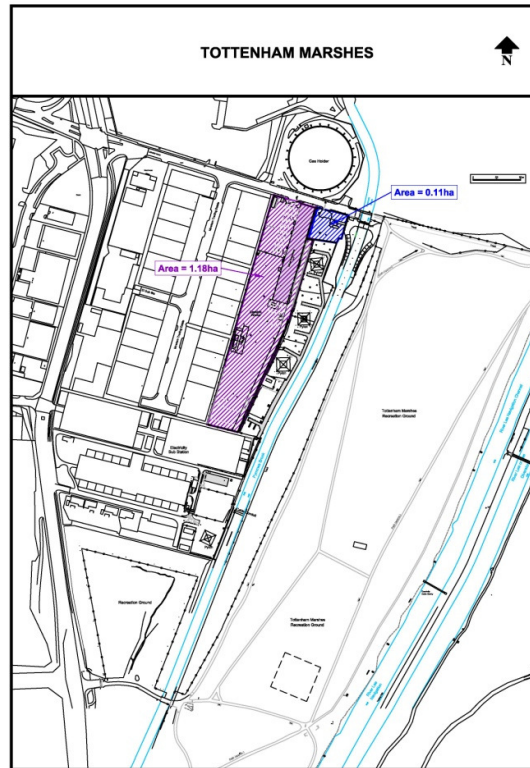
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Site Address:	National Grid, Leaside Road, Tottenham, N17 0SG	NGP Document Tracking Code	
Report Title	GEOTECHNICAL AND ENVIRONMENTAL ASSESSMENT SITE INVESTIGATION FACTUAL REPORT		
Report Type	SI	Retention Period	Indefinitely
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Draft/Final	Final V1	H & S File?	Yes
Work Stage*	Site Investigation		
Brief description of contents	Summary of current site status, geology, hydrogeology and site history. Site investigation activities and summary of geotechnical and laboratory data.		
Access Permitted	NGPH Land Regeneration Team	NGPH Contact	Rachel Tullis



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EXECUTIVE SUMMARY

**Site Location/
Description and
Current Site Status**

The site is located approximately 0.75 miles east of the centre of Tottenham, in the London Borough of Haringey, North London.

The site covers an approximate area of 14 hectares and is divided into four distinct areas for the purposes of this report:-

- Storage yard on Leaside Road, owned by NGPH. ,
- NGET tenanted Arriva bus depot
- Site on Leaside Road owned by the EA, housing sluice gates for the Pymmes Brook.
- LVRPA land known as Tottenham Marshes.

Site History

The Arriva site was formerly operated as Leaside Works (a civil engineering plant depot), which appeared on maps from 1967. Several ponds, were also located on the southern portion of the site. The artificial pond was later labelled as a sludge pit. By 1991 the site was labelled only as Leaside Works. In addition the ponds were no longer present, presumably they had been filled and the building locations were changed to their current layout.

The Tottenham Marshes land is reported to have been lammas meadows (common land) during the 19th century until the early 20th century. The Marsh was then used as an allotment during the first world war. During the late 1940's waste was tipped on the site which raised the ground level by approximately 2 m. The origin of the waste is unknown.

Geology

Information obtained from the British Geological Survey (BGS) 1:50,000 scale sheet 256 and previous reports indicates that the site is underlain by the following sequence:

- Made Ground of varying thickness;
 - Alluvial deposits between 1 and 2 m thickness, predominately clay rich and often containing peat layers;
 - Kempton Park Gravel between 2 and 3 m thickness, comprising variable sands and gravel, locally with lenses of silt clay or peat;
 - London Clay, typically comprising a grey fine sandy, silty clay/clayey silt;
 - Lambeth Group, mainly comprising interbedded layers of sands, clays and silts with glauconite, carbonate concretions
-



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- and shelly fragments or fine shelly sands;
 - Thanet Sands;
 - Chalk formation.
-

Hydrogeology

The Kempton Park Gravels and the Thanet Sands are classified by the Environment Agency as Secondary A aquifers. The Chalk is classified as a Principal Aquifer (EA, 2013).

Groundwater flow in the Kempton Park Gravels is thought to be towards the River Lee to the east or south east of the site. The regional groundwater flow direction in the Chalk is generally towards the south east or east.

Previous ground investigation has reported shallow ground water present in both the Made Ground and Kempton Park Gravels at the site.

Hydrology

The nearest surface watercourse is the Pymmes Brook, which runs through the EA compound and forms the western boundary of Tottenham Marshes. The site is identified to be in the currently defined 1 in 1000 year flood plain of the River Lea (EA, 2013).

The River Lea Navigation Channel and the River Lea are also present within 250m of the site, located further to the east. The water courses are all lined adjacent to the site, however the River Lea ceases to be lined south east of the site.

Works Carried Out

WorleyParsons undertook the main site investigation between 15 April and 14 May 2013. A survey of investigation locations was completed on 20 May 2013. The first round of groundwater monitoring was completed on 20 May 2013. The second round of groundwater monitoring was undertaken on 28 May 2013.

Eleven boreholes were drilled as part of the investigation. All of the boreholes were installed as groundwater monitoring wells with response zones in the River Terrace Deposits (RTD).

The boreholes were drilled using rotary and percussive drilling techniques. All of the boreholes progressed through the superficial deposits and into the London Clay Formation. One borehole was progressed through the London Clay into the Lambeth Group.



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Geotechnical and Environmental data was collected from each location.

Ten hand dug pits were completed for the purposes of in situ thermal resistivity testing. A further eighteen pits were completed in order to undertake repeat testing in locations where thermal resistivity exceeded the threshold value.



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1. INTRODUCTION

WorleyParsons was retained by National Grid Property Holdings Ltd (NGPH) to undertake a geotechnical and environmental site investigation in relation to land owned by NGPH, National Grid Electricity Transmission Ltd (NGET), the Environment Agency (EA) and Lee Valley Regional Park Authority (LVRPA); hereinafter referred to as “the site”. The site location is shown on Figure 1.

The site covers an approximate area of 14 hectares and is divided into four distinct areas for the purposes of this report:-

- Storage yard on Leaside Road, owned by NGPH. ,
- NGET tenanted Arriva bus depot
- Site on Leaside Road owned by the EA, housing sluice gates for the Pymmes Brook.
- LVRPA land known as Tottenham Marshes.

1.1 Objectives

The objective of this commission was to obtain factual geotechnical and environmental data in the vicinity of a proposed new high voltage cable route at locations specified by National Grid to assist with geotechnical design and environmental assessment.

1.2 Report Format

The report is subdivided as follows:

Section 1	Introduction
Section 2	Site information – location, current use, ground conditions etc
Section 3	Summary of regional geological, hydrogeological and hydrological conditions
Section 4	Environmental setting – summarises surrounding land uses and potentially contaminative or sensitive sites.
Section 5	Site history – relating to the sites former land use, former site investigations and environmental incidents.
Section 6	Site investigation methodology – investigative techniques and analytical analysis.
Section 7	Site Investigation Findings – ground conditions and visual/olfactory evidence of contamination.
Section 8	References and contacts.

Supporting information is included in Figures, Plates, Tables and Appendices following the main text of the report.



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2. SITE INFORMATION

Site information is summarised below in Table A:

Table A: Site Information

Site Address	Leeside Road, Tottenham, N17 0SG.
National Grid Reference	535447, 191499 (National Grid Compound)
Site Area	Approximately 13.50 ha. The site areas are broken down as follows:- • 1.18 ha NGET tenanted Arriva bus depot, • 0.11 ha NGPH compound, • Approximately 0.25 ha EA land (boundary not defined), • Approximately 13.00 ha LVRPA Tottenham Marsh (boundary not defined).
Site Location & Setting	The site is located approximately 0.75 miles east of the centre of Tottenham, in the London Borough of Haringey, North London. The surrounding land use is a mix of commercial and industrial to the west and north with the Tottenham Marshes public open space extending further to the east of the site. The Mowlem Trading Estate is adjacent to the Arriva bus depot. The National Grid owned Leeside Road Gasholder Station and other vacant land is located immediately north of the site. The Tottenham Marshes Electricity Transformer Station is located immediately south of the Arriva bus depot and west (and north) of the Tottenham Marshes. The Pymmes Brook runs through an open concrete culvert through the centre of the site between the EA compound and the Tottenham Marshes. The River Lee (also spelt Lea) and various reservoirs are present beyond the Tottenham Marshes to the east of the site. A location and site layout plan indicating the different site areas is included as Figure 2.
Site Ownership	NGPH, NGET, EA and LVRPA
Current Site Use	<i>Arriva bus depot</i> This area is currently occupied by Arriva who have operational offices, bus storage, maintenance and driver training. This site is operational 24 hours a day.



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	<i>NGPH compound</i> This area is used by National Grid Gas (NGG) as a storage compound for equipment. It is secure and regularly visited, but not manned. <i>EA compound</i> This area houses the Leaside Road Sluice Gates and comprises a slipway into the Pymmes Brook. It is a maintained secure site that is infrequently visited by the EA. <i>Tottenham Marshes public open space</i> This area is a managed public green space that is part of the 26 mile long, 10,000 acre Lee Valley Regional Park. The area relevant to this site investigation includes a mixture of densely vegetated land, rough open grassy areas and paved and cut grass footpaths. The Tottenham Marshes is open to the public 24 hours a day and is used for a variety of recreational activities including walking, cycling, jogging and fishing.
Site Access	The Arriva bus depot, NG compound and EA compound are all accessed from Leaside Road. Pedestrian access to the northern end of the Tottenham Marshes is via a footbridge over the Pymmes Brook at the end of Leaside Road. Vehicle access onto the Tottenham Marshes is via a locked gate off of Watermead Way, opposite Marigold Road. Access to Tottenham Marshes is arranged through the Lee Valley Regional Park Authority.
Site Boundaries	<i>Arriva bus depot</i> Approximately 2.5m high palisade fencing The perimeter of this area is 574 m <i>NG compound</i> Approximately 2.5m high palisade fencing The perimeter of this area is 130 m <i>EA compound</i> Approximately 2m high chain link and palisade fence The perimeter of this area is 300 m <i>Tottenham Marshes public open space</i> Site boundaries not clearly defined.



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	The perimeter of this area is 1450 m
Ground Cover	<i>Arriva bus depot</i> • Hardstanding (typically tarmacadam and concrete) – 80 % • Buildings – 20 % • Softcover of gravels and grass – 0 % <i>NG compound</i> • Hardstanding (typically tarmacadam and concrete) – 25 % • Heavily compacted hard earth softcover – 40 % • Soft standing with shrubs and grass – 30% • Soft standing with long grass and sparse shrubs – 5 % <i>EA compound</i> • Softcover with grass, brambles, trees and shrubs – 80% • Hardstanding (concrete) – 20% <i>Tottenham Marshes public open space</i> • Hardcover footpaths – 3 % • Softcover with long grass, brambles and shrubs – 67% • Softcover with dense brambles, trees and shrubs – 30 %
Site Topography and Elevation	All areas of the site are generally level and have an average elevation of approximately 10.5 mAOD.
Plant and Equipment	There is no known active plant on the site itself. The site is adjacent to Tottenham substation. A purged gasholder is present immediately north of the Arriva bus depot.
Services	A number of live above and below ground services are present on certain parts of the site, including overhead and below ground high voltage (HV) electricity cables, telecommunications cables and surface water drains. Known utility service locations are shown in Figure 3, and the original drawings provided by the utility companies are provided in Appendix I.



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3. GEOLOGY, HYDROGEOLOGY AND HYDROLOGY

3.1 Geology

Information obtained from the British Geological Survey (BGS) 1:50,000 scale sheet 256 and previous reports indicates that the site is underlain by the following sequence:

- Made Ground of varying thickness;
- Alluvial deposits between 1 and 2 m thickness, predominately clay rich and often containing peat layers;
- Kempton Park Gravel between 2 and 3 m thickness, comprising variable sands and gravel, locally with lenses of silt clay or peat;
- London Clay, typically comprising a grey fine sandy, silty clay/clayey silt;
- Lambeth Group, mainly comprising interbedded layers of sands, clays and silts with glauconite, carbonate concretions and shelly fragments or fine shelly sands;
- Thanet Sands;
- Chalk formation.

This geological sequence generally dips towards the south east (Mortimore, 2009).

Ground conditions encountered during the recent phase of intrusive investigation are discussed further in Section 7.

3.2 Hydrogeology

The Kempton Park Gravels and the Thanet Sands are classified by the Environment Agency as Secondary A aquifers. The Chalk is classified as a Principal Aquifer (EA, 2013).

Groundwater flow in the Kempton Park Gravels is thought to be towards the River Lee to the east or south east of the site. The regional groundwater flow direction in the Chalk is generally towards the south east or east.

Previous ground investigation on the Arriva site (WorleyParsons, 2013) has reported perched water present above the alluvial deposits across the site

Groundwater observations identified during the site investigation and subsequent monitoring rounds are discussed further in Section 7.3.

The site is located within groundwater Source Protection Zone (SPZ) 1, inner protection zone (Landmark Group, 2012). This relates to the chalk aquifer.

3.3 Hydrology

The nearest surface watercourse is the Pymmes Brook, which runs through the EA compound and forms the western boundary of Tottenham Marshes. The site is identified to be in the currently defined 1 in 1000 year flood plain of the River Lea (EA, 2013).



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The River Lea Navigation Channel and the River Lea are also present within 250m of the site, located further to the east. The water courses are all lined adjacent to the site, however the River Lea ceases to be lined south east of the site.

Previous ground investigation on the Arriva site has reported shallow ground water present in both the Made Ground and Kempton Park Gravels at the site.

3.4 Groundwater Abstractions

There are 22 recorded groundwater abstractions reported to be present within 1 km of the site and eight within 500 m. The nearest of which is licenced to Montagus Ltd. for laundry use, located 322 m west of the site. Thames Water Utilities Ltd. hold several of the abstraction licences located within 1 km of the site. The nearest of these is located 494 m to the south west and is used for potable water supply (Landmark Group, 2012).

There are no licensed surface water abstractions reported to have been present within a 2 km radius of the site (Landmark Group, 2012).

3.5 Discharge Consents

Eight licensed discharge consents were reported within 1 km of the site. The nearest active licensed discharge is c.550 m south east of the site and is operated by Thames Water Utilities Ltd. to discharge process water into a North London Artificial Recharge Scheme (NLARS) borehole (Landmark Group, 2012). The nearest active licensed discharge to surface water is c. 960 m south of the site and is operated by Thames Water Utilities Ltd. to discharge sewage discharges into the River Lea (Landmark Group, 2012).

3.6 Flood Risk

The site is identified in an area classified as Zone 2 – Extreme flooding from rivers or sea without defenses.

The chance of flooding each year is greater than 1.3 % (1 in 75) (EA, 2012).



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4. ENVIRONMENTAL SETTING

4.1 General

Details of the site's environmental setting including potentially contaminative surrounding land use are provided below. Information has been taken from the Landmark Envirocheck report where applicable.

4.2 Landfills

The Envirocheck report did not identify any known operating or historical landfills within 500 m of the site.

4.3 Licenced Waste Management Facilities (WMF)

The Envirocheck Report 2012 has identified 20 licenced waste management facilities within 1 km of the site. Table B below summarises the identified waste management facilities within 500 m of the site.

Table B: Waste

Facility or Site Name/Owner	Distance From Site (m)	Type of Waste (Site Category)	Dates of Operation
London Restoration (Civil Engineering) Ltd, Leaside Road.	11 northeast	Household, Commercial and Industrial Transfer Stations	1992 – 2008
Deery Construction, Leaside Road.	30 northeast	Physical Treatment Facilities	1993 – unknown
V H E Construction Plc, Leaside Road	30 northeast	Physical Treatment Facilities	1993 – 2005
Hales Waste Control Ltd, 81 Garman Road	219 northwest	Household, Commercial and Industrial Transfer Stations	1992 – unknown
Biffa Waste Services Ltd, 81 Garman Road	219 northwest	Household, Commercial and Industrial Transfer Stations	1992 – unknown
Environmental Tyre Disposal Ltd, Phoenix Warf	454 northeast	Transfer Stations Taking Non-biodegradable Waste	1996 – 2004
Environmental Tyre Disposals Ltd, Phoenix Warf	493 northeast	Physical Treatment Facilities	2004 – unknown



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4.4 Permits

The Envirocheck report identified no Integrated Pollution Controls (IPC) and Integrated Pollution Prevention and Control (IPPC) sites within 500 m of the site. The closest IPPC permit is located 657 m northeast of the site and is registered to Pure Fuels Limited.

4.5 Health, Safety and Environment Reports

The Envirocheck report identifies two Control of Major Accident Hazards sites (COMAH) within 500 m of the site boundary. The closest COMAH site is the gasholder site located 44 m north and registered to National Grid Gas Plc.

4.6 Registered Radioactive Sites

The Envirocheck report does not identify any registered radioactive sites within 500 m of the site.

4.7 Sensitive Land Uses

There are five sites of ecological sensitivity located within a 500 m radius of the site. Table C summarises the areas deemed sensitive below:

Table C: Sensitive Land Uses

Authority / Source	Distance From Arriva Site (m)	Direction From Site	Type of Sensitivity (Site Category)
London Borough of Haringey	24 m	Southeast	Areas of Adapted Green Belt
London Borough of Waltham Forest	286 m	East	Areas of Adapted Green Belt
London Borough of Enfield	292 m	East	Areas of Adapted Green Belt
Department of Environment, Food, and Rural Affairs	-	-	Nitrate Vulnerable Zone, aquifer underlying the site
Natural England	469 m	South	Lea Valley – Ramsar Site, Site of Special Scientific Interest, Special Protection Areas

Following the site walkover no additional ecological receptors (besides those discussed above), as defined in Part IIa of the Environmental Protection Act (1990), were identified within the immediate vicinity of the site.



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4.8 National Monuments and Archaeological Information

A review of available information provided in the National Monuments Archive has identified no national monuments or identified archaeological sites, on or with 250 m of the site boundary.



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5. HISTORICAL DEVELOPMENT

5.1 Site History - On and Surrounding the Site

The historical maps available from circa 1868 to 1920 show the site and surrounding area to be undeveloped open fields. A drainage ditch bisects the site itself. Pymme's Brook is shown running through the site.

The 1935 map shows the first appearance of the gasholder located directly north of the site. A small pond is present on the southern end of the site in the maps and aerial photographs from 1935 through 1967.

An aerial photograph from circa 1945-1950 shows possible aboveground storage tanks at the adjacent land to the northeast. Several subsequent maps through to 1991 label this area as 'tanks'.

The 1956 map, shows an area to the northwest of the site labelled as 'Leeside Depot'. Significant change to this area does not occur until 1967 when the depot appears to expand along the entire western edge of the Arriva site.

The 1967 map also shows the area site north of the site labelled as 'Leeside Works'. An 'Electricity Transfer Station' is present in the south of the site. Two ponds are shown towards the south of the site

The southern of the two ponds is no longer identified on the 1974 map and the more northern of the two ponds is now labelled as a 'Sludge Pit'.

The 1991 map shows a number of rectangular buildings within the site boundaries. The building located in the north eastern corner of the site in the 1991 map is also noted in the 2006 and 2012 1:10,000 maps. The 1:10,000 maps from 2006 and 2012 show the current long rectangular building in the north eastern corner. A very small square building located just south of the rectangular building is the only other noted feature on site in these maps.

The Tottenham Marshes land is reported to have been lammas meadows (common land) during the 19th century until the early 20th century. The Marsh was then used as an allotment during the first world war. By the 1920's the marshes had tennis courts, football pitches, swings and roundabouts. During the late 1940's waste was tipped on the site which raised the ground level by approximately 2 m. The origin of the waste is unknown (Source: LVRPA noticeboard).

Evidence of earthworks on the Marshes can be seen in the 1945-1950 aerial photograph.

5.2 Historical Structures and Plant

With regards to the area currently identified as the Arriva bus depot towards the north of the site, this has been a depot and civil engineering works for a significant portion of the twentieth century. Furthermore there is potential for infilled ground from the former onsite pond, sludge lagoon and drainage ditch.

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The Arriva bus depot is located in a current and historically industrial area, with former gasworks, chemical works and electricity transfer to the north, northwest and southeast, respectively. Above ground storage tanks may also have been present on the adjacent site to the northwest. A site plan provided by National Grid identified a tank on-site adjacent to the eastern site boundary and located south of the current bus garage. Potentially contaminated land uses are presented in Table D below.

Table D: Potentially Contaminated Land Uses

Description	Years Observed		Location
	From:	To:	
Infilled Pond	1956	1967	South of Arriva area
Pond (Later Sludge Pit)	1967	1974	Central Arriva area
Works (Civil Engineering Depot)	1967	1977	North half of Arriva area
Bus Garage	1991	Present	Northeast of Arriva area
Fuel tank	1991	Present	West central of Arriva area
Unknown tank	unknown	unknown	East central of Arriva area
Landfilling	1945	1960	Tottenham Marshes area

5.3 Summary of Previous Site Investigations and Remediation

A ground investigation was undertaken across the bus depot section of the site in January 2013. The focus of this investigation was to provide information as to the current environmental risks from contaminated soil and groundwater at the site.

Prior to this no previous environmental investigations are known to have been completed. During the present site investigation however, several historical sampling points were located at the site arriva bus depot. It is unknown when these were completed and for what purpose. There appears to have been no previous investigations on the remainder of the site.

5.4 Pollution Incidents

The Envirocheck report identifies five recorded pollution incidents within 500 m of the site boundary.

The closest incident was located 77 m north-east of the site and occurred in 1989. This related to a miscellaneous pollutant and was classed as a minor category 3 incident.

5.5 Possible Contaminants

Table E summarises potential contaminant groups based on previous and current on-site activities:



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Table E: Possible Contaminant Groups – On Site

Source	Possible Contaminant Groups
Sludge Pit	The sludge pit may have been infilled with a variety of materials from industrial sites within the local area. If the pit was associated with sewage sludge metals and ground gases are likely to be the primary contaminants. Common contaminants include metals, total petroleum hydrocarbons (TPH), poly aromatic hydrocarbons (PAH) and asbestos.
Garage / Workshop/Fuel Tank	TPH, PAH, volatile organic hydrocarbons (VOCs) and asbestos.

Table F summarises potential contaminant groups based on previous and current off site activities:

Table F: Possible Contaminant Groups – Off Site

Source	Location	Possible Contaminant Groups
Gasworks and chemical works	North of site	TPH, PAHs, phenols, metals, cyanides, sulphates
Electricity Transfer Station	South of site	TPH, PCBs, metals
'Depot' Land	West of site	TPH, metals



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6. SITE INVESTIGATION METHODOLOGY

6.1 Site Investigation Works

6.1.1 Site Management

Suitably experienced WorleyParsons staff, using approved sub-contractors, supervised the investigation. The investigation was carried out in accordance with Construction (Design and Management) Regulations, 2007. A site and task-specific health and safety plan was prepared and used, and incident response measures were formulated and implemented.

WorleyParsons undertook the main investigation between 15 April and 14 May 2013. A survey of investigation locations was completed on 20 May 2013. The first round of groundwater monitoring was completed on 20 May 2013. The second round of groundwater monitoring was undertaken on 28 May 2013.

6.1.2 Underground Service Locations

Prior to the commencement of intrusive works, utility service clearance was undertaken across the site. Underground services were located using utility plans supplied by the respective utility supply companies and by visual inspection of manholes and scanning using signal generators and detectors. Where a signal was detected the locator marked the route using spray paint. The utility clearance plans were put onto a compositional figure.

In addition to the utility service clearance a further service check was undertaken prior to the intrusive works. A cable avoidance tool (and signal generator, where appropriate) was used, by suitably qualified personnel, to clear each hand pit and borehole location. Starter pits were excavated using hand pitting, where appropriate, to a minimum of 1.2 m below ground level (mbgl).

6.1.3 Live Plant, Equipment and Services

Utility service locations are shown in Figure 3, and the original drawings provided by the utility companies are provided in Appendix I.

6.1.4 Monitoring Well Installations

Eleven boreholes were drilled as part of the investigation. All of the boreholes were installed as groundwater monitoring wells with response zones in the River Terrace Deposits (RTD).

Intrusive drilling works were carried out by CC Ground Investigations Ltd.

The boreholes were drilled using rotary and percussive drilling techniques. All of the boreholes progressed through the superficial deposits and into the London Clay Formation. One borehole was progressed through the London Clay into the Lambeth Group.

During drilling, the geology was logged from returned cores and samples were logged in accordance with BS5930:2011 and BS EN ISO 14688. *In situ* geotechnical testing was conducted



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at regular intervals during the drilling process using Standard Penetration Tests (SPT) and any evidence of contamination was recorded. Disturbed soil samples were taken from returned drill cores and undisturbed samples were returned in cohesive geology. Drilling equipment was jet-washed between each borehole as required.

Each groundwater monitoring well was completed using 50 mm internal diameter, 1 mm slotted, high density polyethylene (HDPE) screen. The slotted well screen was wrapped in a filter sock and surrounded with 2-3 mm gravel. A hydraulic seal of hydrated bentonite pellets was placed above the gravel pack, with bentonite cement grout used below the gravel pack. The bentonite cement grout was used to prevent the well annulus acting as a conduit for potential contamination in the river terrace deposits migrating into deeper strata. The monitoring wells were capped at surface using flush steel covers.

After a minimum wait of 48 hours the wells were then developed by purging at least three volumes of the screened well.

6.1.5 Thermal resistivity pits

In total twenty eight hand excavated pits were dug to 1 m depth to allow for *in situ* thermal resistivity testing. A KD2 Pro thermal properties analyser was used to test the thermal resistivity of the made ground beneath the site. Each test was repeated three times in each pit. Between each test the probe was relocated within the pit.

Initially ten thermal resistivity pits were completed (TR1 – TR10) and three measurements of thermal resistivity were taken from each pit. Where measurements were above a threshold value of $1.3 \text{ m}^2\text{K.W}^{-1}$, three further pits were dug less than 2 m away and three further measurements taken from each pit. The additional pits were labelled separately. For example, the additional pits tested in the vicinity of TR1 were labelled TR101, TR102 and TR103. In total, 18 additional pits were completed.

In six of the ten locations, the thermal resistivity values exceeded the threshold value in the initial and repeat tests. It should be noted that all thermal resistivity tests were all undertaken in Made Ground, which typically persists to between 1.5 and 3.0mbgl in the Marshes area, possibly due to historical landfilling. The made ground is variable in composition, but is predominantly granular in nature containing ash, clinker, brick and other debris.

Results of the thermal resistivity tests are presented in Table 5.

6.1.6 Trial trench

A hand dug trial trench was excavated in order to try and locate and positively identify a surface water drain shown on Thames Water service drawings in proximity to the proposed location of BH2. The dimensions of the trench were 3.0 m by 0.3 m in plan and 1.7 m deep at its deepest point. The surface water drain was not located with the trial trench and instead the location for BH2 was



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relocated a safe distance from the indicated position of the surface water drain. The trench was backfilled with arisings. The proposed and revised location of BH2 is shown on Figure 4

6.1.7 Groundwater Sampling

Groundwater monitoring was completed on two occasions, 20 May 2013 and 28 May 2013.

Boreholes were sampled using low flow techniques. Water quality parameters were taken during the purging (at approximately 1 L intervals) and after sampling to ensure that a representative sample was collected.

Table 1 presents the groundwater elevation data for the two sampling events and the well installation details. During each monitoring round samples were obtained from nine of the eleven monitoring wells. Monitoring well locations were chosen to provide even coverage across the site area.

6.1.8 Surveying

Following the completion of the intrusive works, John Vincent Surveys Limited surveyed all site investigation locations. The surveyed locations of the monitoring wells are provided in Appendix V.

6.1.9 In situ geotechnical testing

In situ standard penetration testing (SPT) was undertaken in each borehole location at 1m intervals until 6m depth, then at 2m intervals thereafter.

The SPT 'n' values are presented on the logs, contained within Appendix II

6.1.10 Laboratory Geotechnical testing

Soil samples obtained from the boreholes were sent to Geolabs Limited for geotechnical testing. Geolabs Limited is UKAS accredited for a wide range of geotechnical tests and is a WorleyParsons approved supplier. The following geotechnical tests were carried out:-

- Undrained shear strength in triaxial compression on 47 samples;
- Hand shear vane tests on 34 samples;
- Thermal resistivity on 9 samples;
- Natural moisture content on 34 samples.

Undisturbed soil samples of 100mm diameter (U100) or 70mm diameter (U70) were taken at 1m intervals until 6m depth, then at 2m intervals thereafter in cohesive soils. Each undisturbed sample was tested for undrained shear strength in triaxial compression (on three 38mm specimens) in accordance with BS1377 : Part 7 : Clause 8 : 1990. Three hand shear vane tests were also performed on the same sample, if sufficient sample was present.



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Samples taken from approximately 2.0 mbgl were tested for thermal resistivity. Where possible, the tests were performed on undisturbed samples. In the majority of locations it was not possible to retrieve undisturbed samples at 2.0m depth, due to the variability and granular nature of the made ground. In these instances, the sample was remoulded in the laboratory using a 2.5kg hammer in accordance with BS1377 : Part 4 : Clause 3.3 : 1990. Thermal resistivity tests were then performed on the remoulded sample.

All geotechnical laboratory test results are presented within Appendix IV

6.1.11 Chemical Analysis of Samples

Soil, groundwater, drinking water and vapour samples were sent to Jones Environmental for chemical analysis, a UKAS and MCERTs accredited laboratory. The laboratory complies with NGPH standards for methods of analysis and is on the NGPH approved list of laboratories. The laboratory is also audited and approved by WorleyParsons.

All details concerning the sampling methods and analyses requested are given in Appendix III.

A total of 34 soil samples were collected from the boreholes and a total of 4 soil samples were taken from the hand pits (including duplicates).

The sampled soils were scheduled for a combination of the following contaminants:

- National Grid Property Holdings soil suite on 33 samples (including duplicates);
- Speciated total petroleum hydrocarbons (TPH CWG) on 9 samples including aromatic / aliphatic banding;
- Fraction of organic carbon (FOC) on 28 samples.
- Sulphate, chloride and pH on 42 samples, including samples at approximately 2m depth.
- National Grid Property Holdings leachate suite on 10 samples.
- Sulphate (Leachate) on 16 samples, including samples at approximately 2m depth.

A total of 19 groundwater samples (including duplicates) were collected from installed monitoring wells across two monitoring rounds. Groundwater samples were scheduled for the following contaminants:

- National Grid Property Holdings Suite on 19 samples (including duplicates);
- Speciated Total Petroleum Hydrocarbons (TPH CWG) on 19 samples including aromatic / aliphatic banding, and;

6.2 Quality Assurance/ Quality Control

An analysis of the quality assurance/quality control (QA/QC) data for soil and water samples was carried out. The results of the analysis are summarised below. The assessment is included in Appendix VI.



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Soil

Duplicate soil samples indicated that a proportion of analytical results gave a relative percentage difference (RPD) of greater than 30%. The majority of high RPD values are attributable to polycyclic aromatic hydrocarbons (PAHs). The RPD variation illustrates the heterogeneous nature of the made ground can have on analytical results. It should be noted that when results approach method detection limits (MDLs) then small changes can result in apparent large RPDs.

Groundwater

A duplicate water sample from BH12 indicated that some analytical results gave a relative percentage difference (RPD) of greater than 20%. The majority of high RPD values were attributable to polycyclic aromatic hydrocarbons (PAHs). It should be noted that when results approach method detection limits (MDLs) then small changes can result in apparent large RPDs.



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7. SITE INVESTIGATION FINDINGS

Observed soils and geology has been logged generally in accordance with the requirements of BS5930:2011 and BS EN ISO 14688 Part 1. A summary of the ground conditions identified during the investigation is given below.

7.1 Ground Conditions

The observed ground conditions are summarised below in Table G. The WorleyParsons site investigation encountered the following general geological succession beneath the site.

Table G: Summary of Ground Conditions

Description of Stratum	Average Thickness (m)	Depth to Base (m bgl)
MADE GROUND: Made ground was encountered in all investigative locations across the site. The Made Ground was highly variable in composition, but was often clayey sands and gravels containing brick concrete, flints, clinker, ash and other debris. It should be noted that the Made Ground persisted to a depth of 6.00 m bgl in BH2, which was not consistent with the remainder of the boreholes. The made ground in this borehole comprised a reworked clay, containing fragments of brick, wood, glass and slate.	1.78	1.20 – 6.00
ALLUVIUM: Alluvium was found to be present in all except for one investigation location and generally comprised a soft to firm organic clay with occasional bands of peat or sand.	2.50	3.1 – 5.85
RIVER TERRACE DEPOSITS: The River Terrace Deposits were found to be present in all investigation locations. The stratum generally comprised sandy flint gravel interspersed with layers of gravelly sand, silt and occasionally thin bands of silty clay. It should be noticed that the RTD was observed to be only 0.30 m thick in BH2, which was not consistent with the remainder of the boreholes.	2.46	5.7– 7.8
LONDON CLAY FORMATION: The London Clay Formation was encountered in all investigation	12.8	19.1



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locations and comprised firm to very stiff clay, with occasional fine sand and rare selenite.

LAMBETH GROUP: The Lambeth Group was only encountered in one location and only penetrated by 0.9 m. The stratum comprised greenish grey slightly sandy clay and clayey sand.

Depth to base not found

Depth to base not found

7.2 Visual and Olfactory Evidence of Contamination

Evidence of Non-Aqueous Phase Liquid (NAPL) was observed at five of the eleven locations within the River Terrace Deposits as an oily sheen coating the gravels. Most commonly the upper portion of the RTD were more heavily impacted than nearer the base of the unit. The exception to this was in BH11 where the more visually impacted material was found nearer the bottom of the RTD. It is possible that the drilling process may have reduced the amount of contamination observed in the gravels deeper within the RTD due to the amount of water flush required to advance the casing.

The five most visually impacted wells were all located west of the Pymmes Brook in the EA compound, NG compound and the Arriva bus depot. Photoionisation Detectors (PIDs) were used regularly to test for Volatile Organic Compounds (VOCs). Measured PID concentrations in the most visually impacted wells included a maximum of 566.8 ppm in BH8, 2506 ppm in BH10 and 1757 ppm in BH12. All PID measurements are presented on the logs in Appendix II. An oily sheen was noted on the drill flush water in these locations, with additional observations of NAPL globules in BH10 and BH12.

Within all five of these locations a strong hydrocarbon odour was noted within the Alluvium and RTD with the exception of BH10 and BH12 where it was also noted in the Made Ground. No locations had any visual or olfactory evidence of contamination beyond 0.5 m into the London Clay Formation.

Return monitoring visits recorded approximately 0.4 m thickness of DNAPL in the base of BH11 and 0.25 m thickness of LNAPL present in BH10.

The investigation locations on the Tottenham Marshes area had clinker, ash and some coke in the Made Ground and some of the drill cores were observed to have a weak hydrocarbon odour. This was predominantly within the RTD, but also occasionally within the Alluvium.

7.3 Groundwater Observations

Monitoring wells were screened in the River Terrace Deposits as described in section 6.1.4. Groundwater elevation data is presented in Table 1. Based on level data obtained on 20/05/2013 and 28/05/2013, the average groundwater elevation in the RTD was calculated as 7.3 mAOD, indicating the aquifer is confined by the overlying alluvial deposits. Groundwater elevations indicate the general flow direction in the RTD to be towards the south east. Groundwater levels recorded on the two monitoring visits are presented in Table 1.



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8. REFERENCES AND SOURCES OF INFORMATION

8.1 References

Table H: References

Author	Year	Report Title
Department of the Environment	2013	Industry Profiles
Landmark Information Group	2012	Envirocheck Report [Order number 37535786_1]
EA	2013	What's In Your Backyard, Environment Agency website www.environment-agency.gov.uk last accessed June 2013
Royse, Katherine R.; de Freitas, Mike; Burgess, William G.; Cosgrove, John; Ghail, Richard C.; Gibbard, Phil; King, Chris; Lawrence, Ursula; Mortimore, Rory N.; Owen, Hugh; Skipper, Jackie.	2012	Geology of London, UK. <i>Proceedings of the Geologists' Association</i> , 123 (1). 22-45.
Mortimore, R	2009	London Basin Forum, CHALK An atlas of Stratigraphy Structure and Engineering Geology http://www.bgs.ac.uk/londonBasinForum/docs/281009/Mortimore.pdf Accessed June 2013
WorleyParsons	2013	Environmental Assessment, Factual Site Investigation Report. Arriva Bus Depot, Tottenham, London.



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8.2 Contacts

Table I: Contacts

Site Location	National Grid Gas Compound Leeside Road Tottenham N17 0SG	
Client	National Grid Property Ltd A3 National Grid House Warwick Technology Park Warwick CV34 6DA	Contact name: Rachel Tullis Telephone: 01926 656 660
Consultant / Principal Contractor	WorleyParsons Parkview 27 Great West Road Brentford TW8 9AZ	Project Manager: Philip Harrison Mobile: 07766 164 654 Site Supervisor: Sam Driscoll Mobile: 07920 755 862 HSSE Advisor: Philip Harrison Mobile: 07766 164 654
CDM Co-ordinator	RSK Anerley Court Half Moon Lane Hildenborough Tonbridge Kent TN11 9HU	Contact name: John Robinson Telephone: 01732 835765 Mobile: 07802 828667
Drilling Contractor, Plant and Topographical Survey	CC Ground Investigation Ltd (CCGI) Unit A2, Innsworth Technology Park, Innsworth Lane Gloucester GL3 1DL	Contact name: Jim Constantine Telephone: 01452 739165



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Sample Chemical Analysis (soils and groundwater)	Jones Environmental Laboratory Unit 3 Deeside Point Zone 3 Deeside Industrial Park Flintshire CH5 2UA United Kingdom	Contact name: Janet Jones Telephone: 01244 833780
Geotechnical Testing	Geolabs Limited Bucknalls Lane Garston Watford Hertfordshire WD25 9XX	Contact name: Paul Heritage Telephone: 01923 892 190
Equipment	Pollution Control Technologies 3 – 8 Redcliffe Parade West Bristol BS1 6SP	Contact name: Caroline Horne Telephone: 0117 925 1304
Solid & Liquid Waste Disposal	Chemtech Waste Management Ltd Alchemy House Coppice Side Industrial Park Brownhills West Midlands United Kingdom WS8 7EU	Contact name: Laura Grice Telephone: 0844 692 0000



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Appendix I SERVICE PLANS



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Appendix II EXPLORATORY HOLE LOGS



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Appendix III LABORATORY CHEMICAL DATA



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Appendix IV LABORATORY GEOTECHNICAL DATA



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Appendix V SURVEY DATA



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