ENVIRONMENTAL VERIFICATION REPORT

Shell Blackhorse

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Prepared for

Shell UK Oil Products UK Ltd

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Background and Objective

AECOM was requested by Shell to provide environmental support during redevelopment of Shell Blackhorse, located at 174 Sheen Road, Richmond, London, TW9 1XD.

Redevelopment Activities

The redevelopment was conducted under a Town Planning consent granted by London Borough of Richmond Upon Thames on 20th September 2013 (ref: DC/CHB/13/2161/FUL/FUL). As part of these redevelopment works, the existing underground storage tanks, fuel lines, fuel dispensers, site interceptor, drainage, and surface hardstanding were removed and replaced.

Scope of Work

Prior to commencing soil verification sampling, a Groundwater and Vapour Monitoring Event (GVME) was undertaken to update groundwater and soil vapour quality conditions. The AECOM scope of work during the redevelopment activities included delineation trial pitting, drilling soil bores to detect and delineate the presence of hydrocarbon impact, two further GMEs and one Vapour Monitoring Event (VME) and verification sampling of the sidewalls and bases of the excavations resulting from removal of the fuel infrastructure. A total of fifty-four (54) soil samples were collected and analysed to be representative of material remaining in-situ.

Conclusions

A Stage 2 risk assessment was performed on the data collected from the verification sampling to assess potential risks to human health and controlled waters. The principal findings of the risk assessments are as follows:

- Concentrations of COPC (Chemicals of Potential Concern) measured at the site were considered unlikely to represent an unacceptable risk to human health receptors.
- Potential risks to the underlying Secondary A Aquifer were considered to be acceptable.

1. INTRODUCTION

AECOM Infrastructure & Environment UK Limited (AECOM) was requested by Shell UK Oil Products Ltd. (Shell) to provide environmental support during the redevelopment of Shell Blackhorse, located at 174 Sheen Road, Richmond, London, TW9 1XD.

The redevelopment works at the site were managed by Shell's Engineering Construction PMC (Artelia) on behalf of Shell, and comprised the removal and replacement of existing underground storage tanks (USTs), forecourt canopy, fuel islands, fuel lines, interceptor, off-set fills, tank vents, site drainage/services, and site hardstanding. The site programme commenced on 16th November 2015 and the site was reopened on 15th April 2016.

The Town Planning application (ref: DC/CHB/13/2161/FUL/FUL) for the redevelopment was submitted by Artelia and was granted consent for the redevelopment on 20th September 2013 by London Borough of Richmond Upon Thames. The environmental planning conditions (Appendix A) associated with soil and groundwater were as follows:

U63611 Protect Major Tree Root Treatment

- E) Backfilling should be undertaken in accordance with Section 7.2.4 of BS5837:2012.

U63613 Pollution Management

No development shall commence until a scheme to manage the pollution risks associated with the operations of the proposed petrol filling station have been submitted to and approved in writing, by the local planning authority. The scheme shall include and address the following components:

1. The location and design of groundwater monitoring boreholes comprising of at least one up hydraulic gradient and two down gradient boreholes: one of these to be located down gradient of the underground fuel tanks. The information must include proposed frequency of monitoring and reporting to relevant authority. These boreholes must be constructed in a manner that ensures they do not provide a pathway for spillages to enter the ground or groundwater from the site surfacing.

1.1 Objectives

The objectives of the verification report detailed herein were as follows:

- Obtain validation data to allow for assessment of material left in-situ; and to advise that residual impact, if present, does not represent a significant risk to identified receptors.
- Advise on soil removal, if required.
- Demonstrate completion of the works, as set out in the RSK Environmental Strategy Plan (ESP) (Ref. 2). The strategy is based on the assumption that the site would be remediated for Continued Oil Use, with redevelopment of the petrol station forecourt.
- To satisfy Condition U63611 Protect Major Tree Root Treatment - Backfilling should be undertaken in accordance with Section 7.2.4 of BS5837:2012- of the Planning Conditions in order to achieve Planning Approval for the redevelopment of the site.

1.2 Scope of Work

The scope of work for this verification report included:

- A GVME of site groundwater and vapour wells;
- Decommissioning of monitoring wells MW1/VM1 and MW2/VM2;
- Installation of VP201 and MW201;
- Two GMEs and one VME during construction;
- Undertaking asbestos analysis via seven (7) trial pits across the site;
- Collection, field screening, and chemical analysis of soil verification samples from the base and sides of fuel infrastructure excavations, including those for tank farms, interceptor, pump islands and fuel lines, and from imported fill material, to characterise the material left in-situ.
- Subject to field screening results, removal of significantly hydrocarbon-impacted soils in association with infrastructure removal.
- If required, risk assessment of material left in-situ that could not be safely or practically removed.

- Verification reporting including assessment of risks to controlled waters and human health receptors associated with materials left in-situ and collation of waste transfer and backfill certification documents.

2. BACKGROUND INFORMATION

2.1 Site Identification Details

Table A – Site Information	
Site Name	Shell Blackhorse
GSAP ID Number	12038435
Site Address	The site is located at Shell Blackhorse Filling Station, 174 Sheen Road, Richmond, London, TW9 1XD. Figure 1 provides a site location plan.
Grid Reference (easting and northing)	518950 (E), 175050 (N)
Reported Site Area	Approximately 1,000 square metres (m^2)
Freehold/Leasehold	Freehold. AECOM understands that the site is owned by Shell.
Land Use Zoning	Continued Oil Use. AECOM understands that the site land use and zoning are not due to change.
Surrounding Land Use	North: Adjacent to site is an indoor bowls club with residential properties beyond. South: Sheen Road is adjacent to site with residential properties and a school beyond. East: Residential properties with associated gardens. West: Grena Road is adjacent to site with residential properties and associated gardens beyond.

2.2 Environmental Setting

<table>
<tr><th colspan="2">Table B – Environmental Setting</th></tr>
<tr><td>Topography</td><td>The site is located at an approximate elevation of 15m Above Ordnance Datum (AOD).
The topography of the surrounding area slopes downwards toward the north.</td></tr>
<tr><td>Surface Water Features and Surface Water Abstractions</td><td>The closest surface water feature is an un-named stream associated with the reservoir/pond 120m south of the site. A drainage ditch is also present approximately 170m east of the site to the west of East Sheen Common. The River Thames is located 1.5kmm south west of the site.
There are no reported surface water abstractions located within 500m of the site.</td></tr>
<tr><td>Geology</td><td>Available British Geological Survey (BGS) geological maps indicate that the site lies on the boundary of superficial deposits comprising the Taplow Gravels (sands and gravels) to the south and the Head Deposits (clay, silt, sand and gravel) to the north. Intrusive investigations carried out by RSK (Ref. 3) suggest that the Taplow Gravels are the superficial deposit underlying the site.
Based on the geology encountered during intrusive investigation activities conducted by RSK, the site may be underlain by the following geological sequence:
<table>
<tr><th>Unit</th><th>Description</th><th>Maximum Depth to Top of Unit (m)</th><th>Maximum Thickness (m)</th></tr>
<tr><td>Made Ground</td><td>Concrete</td><td>Surface</td><td>0.25</td></tr>
<tr><td>Made Ground</td><td>Silty clayey sand with gravels of flint, plastic, brick and concrete with concrete and brick cobbles.</td><td>0.25</td><td>3.05</td></tr>
<tr><td>Taplow Gravel Formation</td><td>Silty clayey SAND with variable gravel flint gravel content.</td><td>3.3</td><td>7.00 - Base not proven</td></tr>
<tr><td>London Clay Formation (Encountered in MW4 in south west of site only)</td><td>Stiff to very stiff brown mottled grey CLAY.</td><td>8.4</td><td>Base not proven</td></tr>
</table></td></tr>
<tr><td>Hydrogeology</td><td>The Environment Agency (EA) classifies the Taplow Gravel Formation and the Head Deposits as Secondary A Aquifers and the London Clay Formation as Unproductive Strata.</td></tr>
<tr><td>Groundwater Abstractions and SPZs</td><td>No licensed or private groundwater abstractions are reported within 500m of the site (Ref. 1).
The site is not located within an EA defined source protection zone (SPZ).</td></tr>
</table>

Table B – Environmental Setting	
Depth to Groundwater	The average depth to groundwater measured at the site during the RSK 2012 GME (Ref. 3) was 7.128m below ground level (bgl).
Inferred Groundwater Flow	The RSK 2012 GME (Ref. 3) inferred to flow in a north westerly direction towards the River Thames.

2.3 Chronology of Activities

Table C – Previous Site Investigations and/or Remedial Works	
Date	Summary
October 2012	RSK, Phase 1 investigation: preliminary risk assessment: Blackhorse service station, Richmond, Surrey (report ref. 25986-2(00)) Ref. 1 The phase 1 preliminary risk assessment identified a number of potentially complete human health and controlled water pollutant linkages.
December 2012	RSK, Phase2 investigation: comprehensive environmental assessment report: Blackhorse service station, Richmond, Surrey (report ref. 25986-R01(00)) Ref. 2 Potentially complete pollutant linkages were identified, these comprised: • Risks to potential construction workers during any redevelopment • potential risks arising because of possible future construction activities – e.g. dust generation Risks to human health and controlled waters receptors from the COPC assessed at the site were considered low. Based on the information presented in the report, there were no requirements to devise a specific remedial strategy for this site.
April 2013	RSK, Environmental Strategy Plan: Blackhorse Service Station, Richmond, Surrey (report Ref. 25986 R03(00)) Ref. 3 Presents a selection of tasks that are either planned to be carried out, or serve as contingency in the event that circumstances at the site indicate they should be performed. A programme of intended works along with an anticipated timescale is also detailed.

3. FUEL INFRASTRUCTURE

3.1 Summary of Site Equipment Pre- and Post-Redevelopment

The following information regarding fuel infrastructure prior to site redevelopment has been obtained from RSK Phase 1 Investigation: Preliminary Risk Assessment (Ref. 1) and Petroleum Officer Report (Ref. 1), with the information regarding fuel infrastructure post redevelopment obtained from Shell drawing 1345-06-GENWK-2013.

Table D – Site Equipment and Infrastructure Pre- and Post- Redevelopment (2016)

Site Feature	Pre-Redevelopment	Post-Redevelopment
Site Age	Information obtained from historical RSK reports indicate that the site has been used for the retail of petroleum products, with the first tanks recorded as being installed in 1942 (from Petroleum Officer).	
Known prior redevelopment on the site	Available information from the Petroleum Officer (PO) and historical RSK reports indicate that there are six (6) active tanks, with installation dates ranging from 1962 to 1991. In addition to the six (6) active tanks onsite, the PO indicated that a number of tanks are assumed to remain in-situ as no removal records are available. These include (1) 1,000 gallon tank installed in 1942 that was slurry filled in 1972, three (3) 500 gallon tanks installed in 1942 that were solid filled in 1972, and one 1000 gallon tank installed in 1942 used for the storage of paraffin for which no further records are available.	
Number of fuel islands and pumps (Cars and HGVs)	Cars: four (4) fuel islands (eight (8) dispensers). HGVs: 0	Cars: four (4) fuel islands (eight (8) dispensers). HGVs: 0
LPG on the site	No	No
Number of above ground tanks, capacity and contents	None	None
Number of active underground tanks / compartments	Three (3) single walled steel underground tanks, and three (3) double walled steel underground storage tanks on site.	Two (2) double-skinned underground tanks with a total of four (4) compartments.
Number of abandoned underground tanks on-site	One (1) 1,000 gallon tank that was slurry filled in 1972, three (3) 500 gallon tanks that were solid filled in 1972, and one 1000 gallon tank installed in 1942 used for the storage of paraffin for which no further records are available.	None Known.
Underground tanks installation strata	Taplow Gravel Formation	Taplow Gravel Formation
Number of off-set fill points	Five (5) above ground off-set fill points underneath the canopy in between pumps 7 and 3	Four (4) above ground off-set fill points underneath the canopy in between pumps 7 and 3.
Overfill protection	Unknown.	OPW 61 SO overfill prevention valves and high level alarm connected to gauges
Pipework system	Suction	Suction

Table D – Site Equipment and Infrastructure Pre- and Post- Redevelopment (2016)		
Tank manholes	All tank access chambers were constructed from brick.	All tank access chambers are constructed from brick.
Site interceptor	Interceptor located in the eastern part of the site.	One (1) 9,000 litre class 1 interceptor Entec with coalescent filter with hydrocarbon sensor located north of the new tank farm to the east of the site.
Interceptor drainage	Foul drainage, situated to the north eastern site boundary.	Foul drainage, situated to the north eastern site boundary.
Soakaway on the site	None identified.	None identified.
Car wash	None.	None.
Jetwash	None	None
Known accidental release on-site or wet stock variance	RSK historical reporting indicates that there was one spill on the 19th May 1987 of 5-10 litres during delivery, and a further spill of between 200 to 1300 litres of petrol onto the public highway during a tanker delivery in August 1993.	

3.2 Tank Summary – Prior to Redevelopment

The following information is based on the RSK Phase 1 Investigation Report (Report Ref. 1) and on observations made during redevelopment activities.

Table E – Summary of On-site Fuel Tank / Compartments – Prior to Redevelopment						
Tank number or ID	**Tank 1**	**Tank 2**	**Tank 3**	**Tank 3**	**Tank 4**	**Tank 4**
Compartment number or ID	**Compartment 1**	**Compartment 2**	**Compartment 3**	**Compartment 4**	**Compartment 5**	**Compartment 6**
Tank type	Single Walled Steel	Single Walled Steel	Single Walled Steel	Double Walled Steel	Double Walled Steel	Double Walled Steel
Tank size (litres)	13,415	26,789	26,789	13,194	20,944	8,903
Product stored	VP - Diesel	Diesel	Premium unleaded	VP-Gasoline	Premium Unleaded	Diesel
Status	Active	Active	Active	Active	Active	Active
Date of installation	1962	1972	1972	1991	1991	1991
Relative level (RL) of tank base	3.0m bgl	4.0m bgl	4.0m bgl	3.75m bgl	3.75m bgl	3.75m bgl

Tank number or ID	**Tank 7**	**Tank 8**
Compartment number or ID	**Compartment 7**	**Compartment 8**
Tank type	Single Walled Steel	Single Walled Steel
Tank size (litres)	4550	4550
Product stored	unknown	unknown
Status	Abandoned	Abandoned
Date of installation	1942	1942
Relative level (RL) of tank base	3m bgl	3m bgl

3.3 Tank Summary – Post-Redevelopment

The following information has been obtained from Shell drawing 1345-GENWK-2013.

Table F – Summary of On-site Fuel Tank / Compartments – Post Redevelopment				
Tank number or ID	**Tank 1**	**Tank 1**	**Tank 2**	**Tank 2**
Compartment number or ID	**Compartment 1**	**Compartment 2**	**Compartment 3**	**Compartment 4**
Tank type	Double Walled GRP	Double Walled GRP	Double Walled GRP	Double Walled GRP
Tank size (litres)	20,000	20,000	40,000	40,000
Product stored	VP Gasoline	VP Diesel	Unleaded	Diesel
Status	Active	Active	Active	Active
Date of installation	2016	2016	2016	2016
Relative level (RL) of tank base	Approximately 4.5m bgl	Approximately 4.5m bgl	Assumed to be 4.5m bgl	Approximately 4.5m bgl

3.4 Site Redevelopment Works

As part of the redevelopment works a total of eight (8) historical storage tanks were removed from the site. Six (6) tanks (with a total of eight (8) compartments) were operational prior to the redevelopment works and two (2) were unchartered and sand-filled. A buried brick lined structure was also encountered onsite on the former use of which is unknown (see photo in Appendix C). Redevelopment works also included removal of the existing forecourt canopy, fuel islands, fuel lines, interceptor, off-set fills, tank vents, and site drainage/services. A plan of the site prior to redevelopment is presented as Figure 2.

Following completion of the site redevelopment, the site will comprised a refurbished shop, a new canopy, Two (2) new USTs (with a total of four (4) compartments) and vents, above ground off-set fill points, a new forecourt interceptor, four (4) new pump islands and new fuel lines and site drainage / services. A plan of the site post-site redevelopment is presented as Figure 3.

The engineering works conducted by Artelia included the following:

- One excavation to remove one existing UST (T1) and its concrete cradle located in the centre of the forecourt.
- One excavation to remove two existing USTs (T2 and T3) and their concrete cradles located on the eastern side of the site and install 2 new tanks (4 compartments) in same location.
- On excavation to remove existing 3 stage interceptor in the north eastern part of the forecourt and install one new superceptor located in the same location.
- Removal of existing USTs (T4, T5 and T6). The concrete cradles of these tanks remain insitu.
- Removal and replacement of fuel lines.
- Removal and replacement of pump islands.
- Backfilling of the brick-lined structure located to the western side of the site with bentonite grout plug at the base.

After completion, excavations were be backfilled with imported clean material sourced from a quarry or suitable site won materials and then surfaced with concrete.

4. FIELD WORK

4.1 Summary of Field Work

Table G – Summary of Field Work	
Site Activities	Prior to the site redevelopment works commencing, AECOM undertook one round of GVME (Groundwater and Vapour Monitoring Event) between 21st and 22nd September 2015 to update soil and groundwater quality data for the site. The site was closed on 16th November 2015 and was reopened on 12th April 2016 while site, redevelopment works are being undertaken by Shell, under management of their Principal Contractor, Artelia Group (Artelia). The contractor Toureen Mangan (Toureen) was contracted directly by Artelia to undertake the decommissioning works. During site closure AECOM conducted environmental activities including drilling of new soil bores, installation of new groundwater and vapour monitoring wells, well decommissioning of existing wells, trial pitting, one more GVME, another GME and verification sampling. Photographs taken during the AECOM field activities are presented in Appendix B.

Table G – Summary of Field Work

Dates of Field Work

AECOM field works were carried out on the following dates:

Date	Activity
21/09/15 – 22/09/15	Pre-construction monitoring and sampling of four (4) groundwater monitoring wells, MW1 to MW4, three (3) vapour monitoring wells, VM1 to VM3, and active and static potable water samples.
30/11/15 – 04/12/15, 18/12/15	Coring, vacuum excavation and drilling of five (5) soil bores, SB201 to SB205, one (1) groundwater monitoring well location, MW201, and one (1) vapour monitoring well, VP201.
07/12/2015	Decommissioning of two (2) monitoring well locations, MW1/VM1 and MW2/VM3.
07/12/15 – 09/12/15	Monitoring and sampling at two 2 installed groundwater monitoring wells (MW3 and MW4) and one (1) newly installed vapour monitoring well (VP201).
07/12/15	Excavation and sampling of seven (7) trial pits, TP101 to TP107.
09/12/15	Verification sampling of existing tank, T2 and T3 (excavation EXA).
09/12/15	Verification sampling during removal of two (2) unchartered tanks (excavation EXD).
11/12/15	Supervision of DMW excavation and sampling from two trial pits to assess the potential presence of asbestos containing material (ACM) in made ground.
14/12/15	Verification sampling during removal of site interceptor (excavation EXC).
17/12/15 – 18/12/2015	Verification sampling during removal of existing tank, T1 (excavation EXB), two (2) pump islands (samples, PI) and fuel lines (FL).
1/5/16	Monitoring and sampling of one (1) newly installed groundwater monitoring well (MW201).
16/02/2016	Verification sampling during removal of two (2) pump islands (samples, PI).
08/04/16	Gauging of three groundwater monitoring wells, MW3, MW4 and MW201.

Table G – Summary of Field Work

Health and Safety Arrangements / Procedures Undertaken Working with Artelia	In advance of the site works, AECOM prepared a site-specific health and safety plan. All fieldwork was conducted by a holder of an SPA contractor's safety passport, and fieldwork was conducted in accordance with Shell's safety procedures and requirements. All of the excavation works were undertaken by Toureen supervised by the Toureen Site Manager or Foreman, under permits issued to Toureen by Artelia. The AECOM engineer observed the works being undertaken. As the works progressed, the AECOM engineer liaised with Artelia and Toureen to coordinate the validation sampling with the site infrastructure removal works.
Monitoring Well Decommissioning	Prior to commencing site redevelopment, two (2) dual install monitoring wells (MW1/ VM1 and MW2/VM3, were decommissioned to prevent the creation of preferential pathways for the potential migration of chemicals of potential concern (COPC) during or following completion of the redevelopment works. Decommissioning was completed by ADP Group Ltd. (ADP) using a Commachio 205 drill rig, utilising hollow stem auger drilling technique, under the supervision of an AECOM engineer. Groundwater and vapour monitoring wells were decommissioned by over drilling the wells and pumping bentonite grout into the boreholes to ground level using a tremie pipe. Details of well decommissioning are as follows:

Borehole ID	Depth to Product (m bgl)	Depth to GW (m bgl)	Depth to Base (m bgl)	Approximate Volume of Grout (Litres)
MW1	-	7.247	8.301	450
VM1	-	-	1.527	-
MW2	-	7.247	8.597	450
VM3	-	-	1.335	-

Later in the programme, during the excavation of the new tank farm, vapour well, VP201, was dug out and removed.

The remaining three (3) monitoring wells were not located within areas affected by the construction activities. Figure 3 shows the location of the decommissioned monitoring wells and the remaining monitoring wells.

The well groundwater monitoring network following completion of construction complies with requires of planning condition U63613 Pollution Management; MW3, MW4 and MW203 represent downgradient wells, whilst one tank observation well installed by Artelia during construction in the south east corner of the site (Figure 3) represents an upgradient well.

Table G – Summary of Field Work	
Groundwater and Vapour Well Installation	In order to obtain groundwater quality data mid-way along the western boundary of the site, MW201 was installed and in order to obtain soil vapour quality data next to the residential property to the north east of the site VP201 was installed. Under supervision of AECOM, MW201 and VP201 were completed by ADP Group Ltd using a Commachio 205 drill rig, utilising rotary and flight auger drilling techniques. VP201 was drilled to a depth of 1.0m bgl and MW201 was drilled to 9.0m bgl. VP201 was screened across the Made Ground between 0.5 mbgl and 1.0mbgl. MW201 was screened across the Taplow Gravel Formation between 5.0mbgl and 8.0mbgl. All well installations comprised a 50 millimetre (mm) diameter, 1mm-slotted, flush-threaded high-density polyethylene (HDPE) well screen and finished with a sufficient length of compatible HDPE riser. The annulus surrounding each well was filled with clean, washed 3-6mm gravel to a minimum of 0.2m (groundwater monitoring wells) or 0.15m (vapour wells) above the top of the screened interval, and topped with a layer of activated bentonite to act as a seal. Each well was finished in a protective well vault placed flush to surface and set in a concrete pad. The well locations are shown on **Figure 4.** AECOM personnel logged and screened soil arisings during drilling and the borehole logs are presented in **Appendix C**.
Soil vapour Sampling	Prior to construction works between 21st and 22nd September 2015, and in order to obtain more recent soil vapour quality across the site,vapour monitoring was undertaken of the vapour wells onsite (VM1, VM2 and VM3). Vapour monitoring from VP201 also took place on 9th December 2015 following its installation in November 2015. Prior to soil vapour sample collection, each well was purged of three (3) well volumes using an air pump to remove standing ambient air from the well. Ground gas monitoring using a portable infrared ground gas monitor (GFM435 Infrared Gas Analyser) and measurements of Volatile Organic Compounds (VOCs) were taken using a photo ionisation detector (PID) equipped with a 10.6 electron-volt (eV) lamp. Monitoring results are presented in **Table 2 Appendix C.** The vapour monitoring samples were collected in absorbent tubes.
Potable water sampling	Two (2) samples of potable water were collected from the staff kitchen within the retail shop on 21st September 2015. One (1) 'static' potable sample was collected immediately after the tap was open and one (1) 'active' potable sample was collected after water was left to run for five minutes to represent water being sourced from pipe-work off-site.

Table G – Summary of Field Work	
Groundwater Well Sampling	Prior to construction works, between 21st and 22nd September 2015, and in order to obtain more recent groundwater quality across the site, a GME (Groundwater Monitoring Event) was undertaken of the groundwater wells onsite (MW1, MW2, MW3 and MW4). A second GME was undertaken of MW3 and MW4 on 5th December 2015 following the installation of MW201 and decommissioning of MW1 and MW2 in November 2015. A third GME was undertaken of MW201 on 5th January 2016. To develop MW201, between 35l and 50l of water were removed by over pumping, to remove sediment and facilitate groundwater flow into the well. Prior to sampling, the depth to groundwater and light non-aqueous phase liquids (LNAPL) (if present) was gauged using a portable oil / water interface probe. Groundwater gauging results are presented in **Table 1** in **Appendix C**. During each GME Groundwater wells were purged and sampled using low-flow sampling method utilising a peristaltic pump incorporating a flow through cell and dedicated tubing. During well purging activities, water was periodically monitored for temperature, pH, conductivity, dissolved oxygen (DO), and oxidation/reduction potential (ORP or Redox) using a water quality meter to determine when representative formation waters were being encountered. **Table 2** in **Appendix C** provides details of the purging, and indicates if any wells did not recharge sufficiently to allow low flow sampling, and a sample was taken once water recharged. All groundwater samples were collected into laboratory supplied containers, labelled and placed on ice.
Depth to Groundwater	Prior to construction works between 21st and 22nd September 2015, groundwater was recorded within all four (4) new monitoring wells (MW1 to MW4), at depths ranging from 6.91 m bgl to 7.25 mbgl. Following installation of MW201 in December 2015, MW201 and MW3 and MW4 were gauged on 9th December 2015 and groundwater was recorded within all three (3) monitoring wells at depths ranging from 7.02 m bgl to 7.18 mbgl. The depth to groundwater in MW201 on 5th January was 7.02 m bgl. Groundwater level data are presented in **Table 1**.
Inferred Groundwater Flow	Groundwater is inferred to flow in a north westerly direction with a hydraulic gradient of 0.009 (**Figure 5**). The flow direction is consistent with the previous monitoring rounds in December 2012 (Ref. 3) and the hydraulic gradient which was 0.004 when measured between MW1 and MW3.
Soil Bores	A total of five (5) soil bores were advanced to a maximum depth of 6.0m bgl to predetermine the soil quality of the across the site prior to the removal of fuel infrastructure. Drilling was completed by ADP using a Commachio 205 drill rig, utilising hollow stem auger drilling technique, under supervision of an AECOM engineer. Once cores were recovered for inspection and sampling, the soil bores were backfilled with bentonite grout pumped into the well under pressure using the drill rig. Waste soil arising were added to site waste stream controlled by Toureen which predominantly consisted of soil removed for the installation of the new tank farm.
Trial Pitting to delineate asbestos	Following the discovery of an asbestos fragment (bitumen piping) in SB205, a total of seven (7) trial pits (TP101 – TP207) were excavated to the depth of the made ground (typically 1mbgl) to delineate the presence of asbestos across the site. Trial pitting was overseen by an asbestos specialist contractor, DMW Ltd (DMW) under supervision of AECOM. The results of the soil matrix asbestos analysis are provided in Appendix C. Given the absence of asbestos in the soil matrix within almost all samples, DMW were not required to keep a presence onsite following the trial pitting works.
Removal of Asbestos	Asbestos Containing Materials (ACM) identified onsite (bitumen piping) was double bagged, labelled and disposed and board packers to drain cover encountered in TP104 by DMW was disposed off by Axiom Building Solutions Ltd (Appendix H).

<table>
<tr><th colspan="2">Table G – Summary of Field Work</th></tr>
<tr><td>Excavations</td><td>The excavation locations are presented on Figure 4.
<table>
<tr><th>Excavation</th><th>Details</th></tr>
<tr><td>EXA</td><td>Two operational tanks (T2 & T3) were removed and replaced with two (2) tanks with four (4) compartments. Verification samples collected from the resultant excavation were taken between 13th and 14th January 2016.</td></tr>
<tr><td>EXB</td><td>One operational tank (T1) was removed and backfilled. Verification samples collected from the resultant excavation were taken on the 17th December 2015.</td></tr>
<tr><td>EXC</td><td>One operational interceptor was removed and replaced, with samples being collected from the base and sides of the excavation on the 9th December 2015.</td></tr>
<tr><td>EXD</td><td>Two (2) abandoned tanks (T7 and T8) were discovered in the south western margins of the site during vacuum excavation. Base and side wall samples were collected from this excavation on the 9th December 2016.</td></tr>
<tr><td>Western Tank Farm</td><td>Three operational tanks (T4, T5 and T6) were removed from the western tank farm, however due to the presence of tree roots on the underside of their tank cradles, and on advisory of a tree root specialist (Aspect Tree Consultancy Ltd), the concrete cradles were not removed.</td></tr>
<tr><td>FL</td><td>Samples taken from the base of existing fuel line infrastructure</td></tr>
<tr><td>PI</td><td>Samples taken from the base of existing pump islands</td></tr>
</table></td></tr>
<tr><td>Soil Waste Removal</td><td>Approximately 1,320 tonnes of excavated material was removed from site which comprised: 860 tonnes of inert waste and 460 tonnes of crushed concrete which were both sent to Brett Aggregates Limited, Hithermoor Quarry, Leylands Lane, Stanwell Moor, Staines-upon-Thames, TW19 6AZ.

No non-hazardous waste was sent offsite and the only hazardous waste (bitumen pipe and board packers to drain covers) were sent to S.B Waste Management & Recycling, 26 Purbrook Road, Wolverhampton, WV1 2EJ. Waste transfer notes are presented in Appendix E.</td></tr>
</table>

<table>
<tr><th colspan="2">Table G – Summary of Field Work</th></tr>
<tr><td>Imported Soil Material</td><td>A total of 340 tonnes of Pea Shingle and 560 tonnes of Type 1 were imported to the site from Brett Aggregates Littleton Lane, Shepperton, Middlesex TW17 0NF and Day Aggregates, Transport Avenue, Brentford TW8 9HF (these volumes do not take into account poured concrete or tarmac) for use in backfilling excavations. Import material certificates from the suppliers are presented in Appendix G.

Two (2) samples of the imported fill material (Backfill 1 and Backfill 2) were collected by AECOM and submitted to the laboratory for chemical analysis (Appendix C). Copies of the laboratory analytical reports are presented in Appendix E. Only limited excavation works were undertaken around the protected tree roots (less than 1m^3 of soil) and in compliance with planning condition U63611 Protect Major Tree Root Treatment only soil excavated from around the tree roots was used as backfill around the tree roots.</td></tr>
<tr><td>Field Screening and Verification Sampling</td><td>Soil samples were collected from the sidewalls and base of each excavation, soil bores and from each trial pit for logging and screening for the presence of volatile organic vapour.

A total of fifty four (54) soil verification samples were collected and analysed to evaluate the soil conditions in the locations described below and all of these samples represent in-situ soil conditions remaining following construction activities. Validation samples were collected in accordance with the Technical Method Statement SG30. Sample locations are indicated on Figure 5.

Soil sample descriptions and field observations are presented in the following sections. Analytical results are presented in Appendix C. Copies of the laboratory analytical reports are presented in Appendix F.

<table>
<tr><th>Sample Locations</th><th>Number of Samples Collected</th></tr>
<tr><td>Delineation trial pit samples</td><td>7 (TP101 - TP107)</td></tr>
<tr><td>Operational tank farm (T2 – T3) excavation (EXA)</td><td>12 (EXA01 – EXA12)</td></tr>
<tr><td>Historic tank farm (T1) excavation (EXB)</td><td>5 (EXB1 – EXB5)</td></tr>
<tr><td>Interceptor excavation (EXC)</td><td>8 (EXC01 – EXC08)</td></tr>
<tr><td>Abandoned tank (T7 – T8) excavation (EXD)</td><td>7 (EXD01 – EXD07)</td></tr>
<tr><td>Dispenser islands</td><td>2 (PI01 – PI02)</td></tr>
<tr><td>Fuel Lines</td><td>2 (FL101 – FL102</td></tr>
<tr><td>Soil Bores</td><td>9 (SB201-SB205)</td></tr>
<tr><td>Monitoring Wells</td><td>2 (MW201), 1 (VP201)</td></tr>
</table>
</td></tr>
</table>

Table G – Summary of Field Work	
Sustainability	In implementing the scope of works outlined above, AECOM made the following considerations of sustainability: • Field work was staffed from local AECOM office to reduce travel impact. • Liaison with Artelia and Toureen regarding progress of redevelopment works to minimise the number of AECOM site visits.

4.2 Field Screening Results / Observations

4.2.1 Delineation Trial Pits

Seven (7) trial pits were excavated across the site in order to assess the presence of asbestos within the made ground. Trial pit locations are presented on Figure 5. Trial pit logs are presented in Appendix D. A summary of field observations of trial pit samples are presented in Table H below:

Table H – Delineation Trial Pit Sample Field Observations

Sample ID	Depth (m)	Max. PID (ppm)	Location	Sample Description	Visual and Olfactory Observation
TP101	0.5	<0.1	East of shop entrance.	MADE GROUND: Brown to grey, silty, sandy, fine to coarse, angular to sub-rounded brick and concrete GRAVEL. Sand is medium to coarse.	Dry, NVO.
TP102	0.5	2.1	West of new interceptor area.	MADE GROUND: Brown to grey, silty, sandy, fine to coarse, angular to sub-rounded brick and concrete GRAVEL. Sand is medium to coarse.	Dry, NVO.
TP103	0.6	3.2	West of pump islands 7/8.	MADE GROUND: Brown to grey, silty, sandy, fine to coarse, angular to sub-rounded brick and concrete GRAVEL. Sand is medium to coarse.	Dry, NVO.
TP104	0.6	6.1	South of pump islands 3/4.	MADE GROUND: Brown to grey, silty, sandy, fine to coarse, angular to sub-rounded brick and concrete GRAVEL. Sand is medium to coarse.	Dry, NVO.
TP105	0.6	<0.1	North margins of old tank 3.	MADE GROUND: Brown to grey, silty, sandy, fine to coarse, angular to sub-rounded brick and concrete GRAVEL. Sand is medium to coarse.	Dry, NVO.
TP106	0.6	<0.1	South of pump islands 1/2.	MADE GROUND: Brown to grey, silty, sandy, fine to coarse, angular to sub-rounded brick and concrete GRAVEL. Sand is medium to coarse.	Dry, NVO.
TP107	0.8	1.2	South margins of old tank 2.	MADE GROUND: Brown to grey, silty, sandy, fine to coarse, angular to sub-rounded brick and concrete GRAVEL with metal and wood. Sand is medium to coarse.	Dry, NVO.

Notes:

MG – Made Ground

NVO – No Visual or Olfactory evidence of hydrocarbon impact

4.2.2 Infrastructure Excavations

Verification samples were collected from the sidewalls and bases of the excavations to remove and replace the site infrastructure

Estimated excavation extents and verification sample locations are presented on Figure 5. A summary of field observations of verification samples are presented in Table I below:

Table I – Verification Sample Field Observations

Sample ID	Depth (m)	Max. PID (ppm)	Location	Sample Description	Visual and Olfactory Observation
EXA01	2.5	16.9	Western wall of tank excavation	Orange to brown, gravelly coarse SAND. Gravels are fine to medium.	Slight HC odour.
EXA02	2.5	9.8	Western wall of tank excavation	Orange to brown, gravelly coarse SAND. Gravels are fine to medium.	NVO.
EXA03	2.5	13.2	Southern wall of tank excavation	Orange to brown, gravelly coarse SAND. Gravels are fine to medium.	NVO.
EXA04	2.5	0.9	Southern wall of tank excavation	Orange to brown, gravelly coarse SAND. Gravels are fine to medium.	NVO.
EXA05	2.5	0.2	Eastern wall of tank excavation	Orange to brown, gravelly coarse SAND. Gravels are fine to medium.	NVO.
EXA06	2.5	<0.1	Eastern wall of tank excavation	Orange to brown, gravelly coarse SAND. Gravels are fine to medium.	NVO.
EXA07	2.5	11.9	Northern wall of tank excavation	Orange to brown, gravelly coarse SAND	HC odour.
EXA08	2.5	20.1	Northern wall of tank excavation	Orange to brown, gravelly coarse SAND. Gravels are fine to medium.	NVO.
EXA09	4.5	6.5	Tank excavation base	Orange to brown and grey, gravelly coarse SAND	NVO.
EXA10	4.5	625	Tank excavation base	Orange to brown with some black staining, gravelly coarse SAND.	Strong HC odour.
EXA11	4.5	17.3	Tank excavation base	Orange to brown, gravelly coarse SAND	NVO.
EXA12	4.5	5.1	Tank excavation base	Orange to brown, gravelly coarse SAND	NVO.

Sample ID	Depth (m)	Max. PID (ppm)	Location	Sample Description	Visual and Olfactory Observation
EXB1	1.6	46.3	Northern wall of tank farm	Brown, sandy, fine to medium, sub-rounded to angular GRAVEL. Sand is fine to coarse.	Dry, NVO.
EXB2	2.0	196	Eastern wall of tank farm	Light brown, gravelly, medium to coarse SAND. Gravel is fine to medium, rounded to sub-angular.	Dry, slight HC odour.
EXB3	1.7	433	Southern wall of tank farm	Light brown, gravelly, medium to coarse SAND. Gravel is fine to medium, rounded to sub-angular.	Dry, slight HC odour.
EXB4	1.5	83	Western wall of tank farm	Brown, sandy, fine to medium, sub-rounded to angular GRAVEL with rootlets. Sand is fine to coarse.	Dry, Slight HC odour.
EXB5	3.5	368	Base of tank farm	Brown to grey slightly silty, sine to medium SAND.	Moist, NVO.
EXC01	1.8	2.1	Northern wall of interceptor excavation	Brown, sandy, gravelly SILT. Sand is medium to coarse. Gravel is fine to coarse, angular to sub-angular brick and concrete.	Dry, NVO.
EXC02	1.8	2.9	Northern wall of interceptor excavation	Brown, sandy, gravelly SILT. Sand is medium to coarse. Gravel is fine to coarse, angular to sub-angular brick and concrete.	Dry, NVO.
EXC03	2.0	5.9	Eastern wall of interceptor excavation	Brown, sandy, gravelly SILT. Sand is medium to coarse. Gravel is fine to coarse, angular to sub-angular brick and concrete.	Dry, NVO.
EXC04	1.7	6.2	Southern wall of interceptor excavation	Brown, sandy, gravelly SILT. Sand is medium to coarse. Gravel is fine to coarse, angular to sub-angular brick and concrete.	Dry, NVO.
EXC05	1.7	4.3	Southern wall of interceptor excavation	Brown, sandy, gravelly SILT. Sand is medium to coarse. Gravel is fine to coarse, angular to sub-angular brick and concrete.	Dry, NVO.
EXC06	1.8	2.1	Western wall of interceptor excavation	Brown, sandy, gravelly SILT. Sand is medium to coarse. Gravel is fine to coarse, angular to sub-angular brick and concrete.	Dry, NVO.
EXC07	3.0	5.1	Base of interceptor excavation	Brown, sandy, fine to medium, sub-angular to rounded flint and natural stone GRAVEL. Sand is medium to coarse.	Dry, NVO.
EXC08	3.0	5.6	Base of interceptor excavation	Brown, sandy, gravelly SILT. Sand is medium to coarse. Gravel is fine to coarse, angular to sub-angular brick and concrete.	Dry, NVO.

Sample ID	Depth (m)	Max. PID (ppm)	Location	Sample Description	Visual and Olfactory Observation
EXD01	2.5	2.1	Eastern wall of tank excavation	Brown, silty, gravelly, medium to coarse SAND. Gravel is fine to medium, angular to sub-rounded flint.	Dry, NVO.
EXD02	2.5	3.8	Eastern wall of tank excavation	Brown, silty, gravelly, medium to coarse SAND. Gravel is fine to medium, angular to sub-rounded flint.	Dry, NVO.
EXD03	3.3	4.4	Base of tank excavation	Brown, silty, gravelly, medium to coarse SAND. Gravel is fine to medium, angular to sub-rounded flint.	Dry, NVO.
EXD04	2.5	7.1	Southern wall of tank excavation	Red to brown, silty, gravelly SAND.	Dry, NVO.
EXD05	2.2	32.1	Western wall of tank excavation	Brown, gravelly, sandy, SILT. Sand is fine to coarse. Gravel is fine to medium, angular to sub-rounded brick and stone.	Dry, NVO.
EXD06	2.3	37.9	Northern wall of tank excavation	Red to brown, silty, gravelly SAND.	Dry, NVO.
EXD07	3.2	18.4	Base of tank excavation	Brown, gravelly, medium to coarse SAND. Gravel is fine to medium, sub-angular to rounded flint and stone.	Dry, NVO.

Sample ID	Depth (m)	Max. PID (ppm)	Location	Sample Description	Visual and Olfactory Observation
FL101	0.6	3.2	Centre of forecourt	Brown to grey gravelly silt with organic matter.	Dry, NVO.
FL102	0.6	185	Centre of forecourt	Brown to grey gravelly silt with organic matter.	Dry, slight HC odour.
PI01	1.5	0.6	Pump Island 7/8	Brown, sandy, gravelly SILT with rootlets. Sand is medium to coarse. Gravel is Fine to coarse, rounded to sub-angular stone, concrete and brick,	Moist, NVO.
PI02	1.5	1.0	Pump Island 3/4	Brown, sandy, gravelly SILT with rootlets. Sand is medium to coarse. Gravel is Fine to coarse, rounded to sub-angular stone, concrete and brick,	Moist, NVO.
MW201	0.65	0.2	South western forecourt area.	Brown, sandy, fine to coarse, angular gravel of brick, flint and concrete with frequent concrete cobbles. Sand is coarse.	Wet off Vac, NVO.
MW201	7.0	1.8	West of T5.	Brown coarse SAND.	Moist, NVO.
SB201	0.5	0.5	West of T5.	Brown gravelly, sandy soil. Sand is coarse. Gravel is fine to coarse, angular and of brick, concrete and flint.	Wet off Vac, NVO.
SB201	2.5	26.2	South of T6.	Brown gravelly coarse SAND. Gravel is fine to coarse, sub-angular and of flint.	Dry, NVO.
SB202a	0.8	0.5	South of T6.	Brown-light brown slightly clayey, sandy, fine to coarse, sub-angular to angular gravel of flint, brick and concrete with frequent cobbles of brick and concrete. Sand is coarse.	Wet off Vac, NVO.
SB203	1.1	0.3	North west of pumps 7 & 8	Brown, clayey gravel. Gravel is fine to coarse, angular and of flint, brick and concrete.	Wet off Vac, NVO.
SB203	5.0	18.1	North west of pumps 7 & 8	Brown coarse SAND.	Moist, NVO.
SB204	1.1	0.3	West of old tank 2	Brown, sandy, fine to coarse, angular to sub-rounded gravel of brick and flint. Sand is fine. Brown, sandy, fine to coarse, angular to	Dry, NVO.
SB204	2	4294	West of old tank 2	Brown, sandy, fine to coarse, angular to sub-rounded flint GRAVEL. Sand is fine.	Moist, black staining, HC odour.
SB205	0.7	0.3	South east margins of the site forecourt	Brown, slightly clayey, gravelly coarse sand. Gravel is fine to coarse, angular of brick, concrete and flint with occasional flint and concrete cobbles.	NVO.

Sample ID	Depth (m)	Max. PID (ppm)	Location	Sample Description	Visual and Olfactory Observation
SB205	6.0	11.6	South east margins of the site forecourt	Brown coarse clayey SAND.	Moist, NVO.
VP201	0.5	0.3	North east margins of the forecourt.	Brown, slightly clayey, sandy, fine to coarse, angular brick, concrete and flint GRAVEL with frequent brick and concrete cobbles.	Wet off Vac, NVO.

Notes:

MG – Made Ground

GREY text – represents soil which has been removed from site

NVO – No visual or olfactory evidence of impact.

4.3 Analytical Schedules & QA/QC

Table J – Analytical Information

Analytical Laboratory	Soil samples were analysed by Alcontrol Laboratories of Chester. Copies of the Chain of Custodies (COCs) and laboratory certificates are presented in Appendix F.
Analytical Schedule	The following schedule of analysis was completed for this Verification Report, excluding QA/QC samples.

Analysis	Number of Soil Samples	Number of Water Samples
Total Petroleum Hydrocarbons (TPH) Health risk fractions including C8-C12	50	9
Benzene, Toluene, Ethylbenzene, Xylenes (BTEX) compounds	50	9
Fuel Oxygenates (methyl tertiary butyl ether (MTBE), tert-butyl ethyl ether (ETBE), di-isopropyl ether (DIPE), tert butanol (TBA), tert-amyl methyl ether (TAME), Ethanol)	50	9
Polycyclic Aromatic Hydrocarbons (PAH) 16 Speciated including naphthalene	50	9
Metals (arsenic, boron, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, tin and zinc)	-	7
Asbestos screen	26	-
Asbestos quantification	3	-
Monitoring Natural Attenuation Parameters (Nitrate, Ferrous Iron, Methane, Manganese, Sulphate)	-	6
Total Organic Carbon (TOC)	47	-

Table J – Analytical Information		
Laboratory quality control sampling	The analytical data have been reviewed for quality assurance and control purposes (QA/QC), the results of which are presented in **Appendix F**. • Laboratory holding times for soil samples were not exceeded in any of the soil, groundwater or soil vapour samples obtained. • There were four surrogate variations above the Upper Concentration Limit in the soil samples. Although these are exceedances they would indicate that the soil analytical results from the site are overestimating the actual concentrations. • The relative percentage difference (RPD) between detected concentrations in the groundwater duplicate samples (VP201 DUP) and the parent sample (VP201) were within acceptable limits. • The relative percentage difference (RPD) between detected concentrations in the groundwater duplicate samples (DUP01) and the parent sample (MW4) in September 2015 and December 2016 were within acceptable limits. • The laboratory blank and reinstate sample were within acceptable limits. In general, the data are considered appropriate for reporting.	

5. HUMAN HEALTH STAGE 2 GENERIC QUANTITATIVE RISK ASSESSMENT

5.1 Methodology

The risk based methodology adopted in this report is primarily based upon the UK Defra and EA "best practice" in regard to the assessment of contaminated land. The approach taken reflects that promoted in CLR11 (Ref 4) and R&D Publication 66 (Ref 5) and the supporting guidance referenced within them. For the assessment of potential risks from vapour intrusion, additional assessment has been completed in line with more recent guidance from the USEPA (USEPA, 2015. Ref. 6).

An assessment of ground gas is in contained in section 4.2. Gas risk assessment has been carried out following guidance in B8485 (Ref. 7) which sets out an empirical semi-quantitative approach for deriving Gas Screening Values based on gas monitoring measurements to select a Characteristic Situation which informs the scope of gas protection measures that could be required, if any.

A screening exercise has then been completed to assess the potential for vapour intrusion pathways to be present between identified impacts and receptors, for acute and chronic vapour risks. The screening process comprises four steps:

1. Identification of priority receptor buildings
2. Evaluate whether screening is applicable, or whether precluding factors mean that this approach is not suitable and assessment should be based on soil vapour measurements and GAC.
3. Screen buildings in or out of the likely zone of vapour migration using the USEPA screening criteria. These criteria are based on the distance between source and receptor, nature and magnitude of impact (LNAPL *vs* dissolved phase) and depth to groundwater.
4. Complete further assessment of any buildings not screened out in the above steps.

Where potential pathways have been identified, further assessment has been completed using generic assessment criteria.

In addition to the above, all data have been screened against generic assessment criteria protective of all potential human health receptors within 10m of the site in order to set potential risks into context within the UK regulatory framework.

5.2 Ground Gas

Ground gas monitoring results collected from VM1, VM2, VM3 and VP201 are presented in **Table 2, Appendix C** and post purge results are summarised as follows:

Table K – Ground Gas Results

	Units	Minimum	Maximum	Comment
Methane	% v/v	<0.1	<0.1	-
Carbon dioxide	% v/v	<0.1	7.3	-
Oxygen	% v/v	17.2	20.1	-
Total ground gas flow rates	litres per hour (l/hr)	<0.1	<0.1	-
Atmospheric pressure	millibar (mBar)	991	992	Stable at the time of monitoring
List any wells where waters level was above well screens		None		

Peak reading were similar to post purge results and have therefore not been separately assessed.

Calculated hazardous gas flow rates based on the maximum recorded flow and concentrations were 0.00 litres per hour (l/hr) of methane and 0.0073 l/hr of carbon dioxide. The characteristic gas situation is classified as 1 for the site, with a risk classification of Very Low (i.e. less than 0.07 l/hr).

Guidance provided within BS8485 suggests that where concentrations of methane and carbon dioxide exceed 1% v/v and 5% v/v respectively then an increase to Characteristic Situation 2 should be considered, but this trigger has not been exceeded.

The characteristic gas situation is classified as 1 for the site, with a risk classification of Very Low. Ground gases have therefore not been considered further in the risk assessment for the site.

5.3 Vapour Intrusion Potential for Acute Risks

As noted in Section 5.1, a vapour screening assessment has been completed in line with recent guidance from the USEPA and is presented below. The first stage of assessment recommended in the guidance is acute risk assessment.

Based on the following thresholds for assessing acute risks from vapour, risks are assessed as negligible based on:

- Methane in all wells is <1% (Characteristic Situation 1 as described in BS 8485 2015);
- Total vapours in all wells (including in subsurface near foundation) were <10% of LEL (assumes attenuation factor of 10 from soil air to indoor air);
- Total hydrocarbon vapours in all wells as measured with PID were <1,000 ppm (ERPG 2, HPA 2011v 3)
- No measurable LNAPL or inferred residual phase LNAPL based on soil, groundwater or soil vapour COPC concentrations within 0.5m distance vertically or laterally from a building foundation

In the absence of indicators of acute risks, no further action has been taken to address these.

5.4 Vapour Intrusion Screening Assessment for Chronic Risks

As noted in Section 5.1, a vapour screening assessment has been completed in line with 2015 guidance from the USEPA (Ref. 6) and is presented below. After assessment of potential for acute risks the second stage of assessment recommended in the guidance is chronic risk assessment.

5.4.1 Identification of Priority Receptor Buildings

Priority receptor buildings at this site include:

- House adjacent to the eastern boundary if of the site and 11m west of the site
- Commercial building adjacent to the north of the site.

In addition to the priority receptor listed above, the site shop has been included within the assessment, although it is recognised that risks to petrol filling station workers from petroleum products are controlled primarily through health and safety systems.

5.4.2 Applicability of Screening Approach, Precluding Factors

Following review of potential for precluding factors none have been identified from the available site information. Information reviewed included service drawings and utility plans (preferential pathways), minimum likely depth to groundwater/perched water, wetstock data (potential for ongoing release), likely foundation depth of priority receptors and analytical data (soil organic content) and presence of lead scavengers above MDL.

No precluding factors were identified therefore the screening approach is appropriate for this site.

5.4.3 Screening Based on USEPA Guidance

Based on the vertical and lateral screening distances presented in the USEPA guidance, the house adjacent to the east of the site, the house 11m to the west of the site and the commercial building to the north of the site has been screened in for further assessment based on the inferred presence of a smear zone <10m laterally and <5m vertically from the building foundation.

5.4.4 Further Assessment

Given receptors have been screened in for further assessment, potential risks from have been assessed further in the following GAC screening section.

5.5 Generic Assessment Criteria (GAC)

5.5.1 Generic Assessment Criteria (GAC) – Potable water

For potable water GAC have based upon the UK Drinking Water Standard (DWS), or where not available EU drinking water standards or World Health Organisation (WHO) drinking water standards. In addition for compounds where published DWS are not available, additional criteria have been considered, as discussed in **Section 6.1.2**.

5.5.2 Generic Assessment Criteria (GAC) – Soil, Groundwater and Vapours

The Stage 2 Generic Assessment Criteria (GAC) for soil, groundwater and vapours were derived using the LQM/CIEH S4UL (Ref. 8) methodology, protective of:

- Off-site residents (adjacent to the west of the site) using a high density residential (HDR) end use scenario.
- On-site workers (including Shell shop staff and site users) and users of the commercial building to the north of the site using continued petroleum use (CPU) end use scenario.

Table L – assumptions within the GAC and applicability to the site				
	GAC	**Assumption**	**Applicable at site**	**Likely to over or under simulate risks**
Active Pathways	High Density Residential	Only vapour pathways are viable. No exposure to soils via direct contact pathways including dermal contact and dust inhalation/ingestion as the receptor is off-site	Neighbouring houses with gardens are off site so direct contact and ingestion pathway not active	GAC are applicable to offsite houses
	Low Density Residential	All standard CLEA pathways for Residential use are active.	Potential future redevelopment of site for houses with private gardens (however there is no other expected future use for the site other than CPU)	GAC are applicable to future use scenario
	Commercial GAC	All standard CLEA pathways for Commercial use are active. Includes a potential pathway of exposure through direct contact with the soft landscaping at the site	The site surface is covered in 100% hardstanding	GAC not applicable
	CPU	Only vapour pathways are viable. No exposure to soils via direct contact pathways including dermal contact and dust inhalation/ingestion as the site is fully covered in hardstanding/building footprint and/or managed landscape	The site surface is covered in 100% hardstanding	GAC applicable to site shop and adjacent commercial premises
Model Parameters all CLEA defaults except those listed below	All land uses - Soil and groundwater	0.58% total organic carbon (TOC)	Made Ground samples were not analysed	GAC applicable, TOC content will have negligible effect on modelled risk
		Soil separating the source and the receptor is physically similar to the CLEA Sand soil type.	Site soils typically comprise sands or gravelly sands	GAC are applicable to offsite houses
	All land uses - Soil and vapour	Vertical distance between soil source and receptor for vapour pathways is approximately 0.5m and receptor building directly overlies source	Soils impacted above GAC present from 0.8m bgl	GAC may overestimate risks
	All land uses - Groundwater	Vertical distance between source and receptor for vapour pathways is approximately 1.0m and receptor building directly overlies source	Groundwater is present at 7m bgl	GAC may underestimate risks
	All landuses - Vapour	'Soil vapour to indoor air' factor for volatile compounds set to zero	Soil vapour data collected from wells with top of screen at 0.5m bgl	GAC are applicable

	All landuses -Soil, groundwater and vapour	For volatile compounds it is assumed that vapour ingress is via a 2mm crack between concrete floor slab and walls.	Site shop likely to have a ground bearing slab. Off-site houses likely to have suspended wooden floors.	GAC applicable for site shop, but may underestimate risks to adjacent off-site houses.
	CPU - Soil, groundwater and vapour	Building size set to 14m x 6.5m x 2.4m high representative of a small site shop	Site shop is larger. Offsite commercial building has greater volume	GAC may overestimate risks due to greater dilution of soil air in building than assumed by GAC

Based on assumptions listed above and site characteristics, it is considered CPU and Commercial GAC may underestimate risks and HDR GAC may overestimate risks at this site.

5.6 Analytical Results GAC Screening

Comparison of soil, soil vapour and groundwater analytical results to Stage 2 GAC is provided in Tables 3a, 4b and 4c (Appendix C) GAC exceedances are summarised in the table below:

Table M – GAC and TPH Hazard Index Exceedances

Receptor Type	Screening Criteria	Media	Benzene / TPH Aromatic C_5-C_7	TEX / TPH Aromatic C_7-C_{10}	Other Aromatic TPH	Aliphatic TPH	MTBE	Other Oxygenates	TPH Hazard Index	Other VOCs (vapour)	Naphthalene	Benzo(a)pyrene	Other PAHs
Human Health	CPU	Soil	×	✓	×	×	×	×	×	n/a	×	×	×
		Groundwater	×	×	×	×	×	×	×	n/a	×	×	×
		Soil Vapour	×	×	×	×	×	n/a	n/a	×	×	n/a	n/a
	HDR	Soil	×	✓	×	×	×	×	×	n/a	×	×	×
		Groundwater	×	×	×	×	×	×	×	n/a	×	×	×
		Soil Vapour	✓	×	×	×	×	n/a	n/a	×	×	n/a	n/a
	DWS	Potable	×	×	×	×	×	×	×	n/a	×	×	×

Notes: ✓= Measured in excess of GAC

× = Not measured in excess of GAC

n/a = not applicable

5.7 Discussion of Key Exceedances of Human Health GAC

5.7.1 Human Health - HDR

The following COPC exceeded the human health HDR GAC in the soil verification samples:

- o-xylene and total xylene in the soil sample collected from SB204.
- Naphthalene in the soil sample collected from SB204.
- TPH >EC8-EC10 Aromatic, TPH >EC10-EC12 Aromatics, TPH >C8-C10 Aliphatics and TPH Hazard Index in the soil sample collected from SB204.

Given that there were no exceedances of any COPC in VP201, which is between SB204 and the residential property to the east of the site these COPC exceedances are considered unlikely to pose an unacceptable risk and have not been further assessed.

5.7.2 Human Health – CPU

Potential chronic and acute risks to health of site workers on petrol filling stations are controlled primarily under health and safety legislation; however an assessment of potential chronic risks has been completed in line with the UK regulatory framework for assessing risks from contaminated land to set potential risks into context.

The COPC which exceeded human health CPU GAC are not considered to present an unacceptable risk due to the following:

- The TPH >EC10-EC12 Aromatics exceedance in the soil sample collected in SB204 at 2.0m bgl, was limited (Hazard Index of 3.3).
- The TPH hazard Index exceedance in the soil sample collected in SB204 at 2.0m bgl, was limited (Hazard Index of 2.36).

The reported concentrations measured in the soil vapour samples collected and analysed from VP201, VM1, VM2 and VM3 were more than two orders of magnitude below the CPU GAC, indicating that the risks from soil vapour to on-site workers are considered acceptable. Therefore, the calculated potential risks to human health receptors based on soil and groundwater data appear to have been overestimated due to the inherent conservatism involved in the modelling, and on the assumptions made.

5.7.3 Human Health – Asbestos in Soil

Asbestos was detected and quantified within made ground at three locations; EXA1 (chrysotile), EXA7 (chrysotile) and EXA8 (chrysotile). Once quantified, chrysotile at EXA1 was 0.024%, chrysotile at EXA7 was <0.001% and chrysotile at EXA8 0.17%. The site however, is covered in hardstanding therefore not considered to pose a risk unless ground is broken. Potential risks to visiting contractors undertaking intrusive works should be managed by appropriate PPE, risk assessment and method statements. Risks to visiting contractors excavating the ground have therefore not been further assessed.

5.7.4 Human Health - DWS

COPC in potable water samples did not exceed DWS and have not been further assessed.

5.8 Summary

Human Health COPC exceedances are considered unlikely to pose an unacceptable risk and have not been further assessed.

6. CONTROLLED WATERS STAGE 2 GENERIC QUANTITATIVE RISK ASSESSMENT

6.1 Generic Assessment Criteria

The risk based methodology adopted in this report is primarily based upon the UK Defra and EA "best practice" in regard to the assessment of contaminated land. The approach taken reflects that promoted in CLR11 (Ref 4) and R&D Publication 66 (Ref 5) and the supporting guidance referenced within them.

Analytical results for soil and groundwater samples recovered are tabulated in Tables 4a to 4b and have been compared against Stage 2 Generic Assessment Criteria (GAC), protective of:

- Groundwater within the Taplow Gravel Formation (Secondary A Aquifer).

The AECOM controlled waters soil GAC were derived assuming that unsaturated soils beneath the site typically contained 0.2% TOC. Other assumptions used in the derivation of AECOM controlled waters GAC were 30% total porosity, 7.5% water filled porosity, and 1.86g/cm3 bulk density. The TOC of 0.2% is considered appropriate to derive GAC based on leaching of COPC from the unsaturated zone. The average TOC measured in unsaturated soil samples collected by AECOM was 0.2% which is the same as that used in the derivation of the GAC.

6.1.1 Drinking Water Standard (DWS)

For assessment of groundwater resource potential GAC have based upon the UK Drinking Water Standard (DWS), or where not available EU drinking water standards or World Health Organisation (WHO) drinking water standards. In addition for compounds where published DWS are not available, additional criteria have been considered, although it is recognised that these are not published standards, such as

- published taste or odour data have been used for a number of oxygenates (MTBE, ETBE, TAME, DIPE) which are known to have taste and odour thresholds which are significantly lower than toxicity based criteria,
- WHO (2008) proposals for drinking water guidelines which are based on the TPHCWG approach for TPH fractions
- Risk-based screening levels derived by GSI (2014) for Shell downstream sites, derived to be protective of groundwater ingestion using published toxicity data (for naphthalene, other PAHs, and n-hexane), and derived by AECOM (for TBA).

The groundwater onsite is considered likely to discharge to the River Thames approximately 1.5km to the west of the site. Given the distance to the River Thames, the groundwater within the Taplow Gravel Formation is considered to be the controlled waters receptor.

6.2 Analytical Results Screening

Comparison of soil and groundwater analytical results to Stage 2 GAC is provided in Tables 3b to 3c (Appendix C) and GAC exceedances are summarised in the table below:

Table N – GAC Exceedances

Receptor Type	Screening Criteria	Media	Benzene / TPH Aromatic C_5-C_7	TEX / TPH Aromatic C_7-C_{10}	Other Aromatic TPH	Aliphatic TPH	MTBE	Other Oxygenates	Naphthalene	Benzo(a)pyrene	Other PAHs
Controlled Waters	DWS	Soil	×	×	×	×	×	×	×	×	×
		Groundwater	×	×	×	×	×	×	×	×	×

Notes: ✓= Measured in excess of GAC

× = Not measured in excess of GAC

n/a = not applicable

6.3 Discussion of Key Exceedances of DWS GAC

There were no COPC exceedances.

6.4 Natural attenuation

Natural attenuation (NA) is the process under which contaminants within groundwater will degrade and decrease through any combination of physical, chemical and biological processes.

The field data and geochemical conditions indicate the following:

- Aerobic conditions are present in up, cross and downgradient wells based on measured concentrations of dissolved oxygen, nitrate and sulphate and the lack of detections of iron or manganese.

6.5 Summary

Given there were no COPC exceedances further assessment as Stage 3 was not considered to be warranted.

7. CONCEPTUAL SITE MODEL

The Conceptual Site Model (CSM) presented here is based on the information provided in the historic reports prepared for the site, on observations made during construction works by AECOM, and on the subsequent AECOM generic risk assessments.

7.1 Potential Sources

The following is a list of potential former sources of impact on-site:

- Operational underground storage tanks.
- Accidental releases to ground from off-set fill points and fuel dispensers.
- Accidental releases from fuel lines and vent lines.
- Site interceptor and drainage.

7.2 Potential Pathways, and Receptors

The potential pathways and receptors identified for assessment at Stage 2 are listed in **Tables O and P** below.

7.3 Review of Potential Source-Pathway-Receptor Linkages

The following pollutant linkages were evaluated at Stage 2 given continued oil use. These are also detailed on **Figure 5**.

Table O – Human Health CSM

Source	Pathway	Receptor	Likelihood of Pollutant Linkage Presenting an Unacceptable Risk
Impacted soils / groundwater	Lateral and vertical vapour migration and subsequent inhalation.	On-site shop staff, visiting staff and general public.	Unlikely: Based on Stage 2 assessment.
		Off-site workers in adjacent commercial properties.	
		Residents of properties adjacent to the eastern boundary of site.	Unlikely: Based on Stage 2 assessment.
	Particulate - Ingestion, inhalation, dermal contact with soil particulates.	Visiting on-site contractors excavating ground.	**Possible***
	Permeation – Migration of hydrocarbon substances through plastic potable water supply pipes.	On-site shop staff (ingestion of drinking water on-site).	Unlikely: COPC were reported at concentrations below the drinking water standards in potable water samples recovered from the shop.

* Potential risks to visiting contractors undertaking intrusive works should be managed by appropriate PPE, risk assessment and method statements. Risks to visiting contractors excavating the ground were therefore not assessed within the scope of the QRA.

Table P – Controlled Waters CSM			
Source	**Pathway**	**Receptor**	**Likelihood of Pollutant Linkage Presenting an Unacceptable Risk**
Impacted soils / groundwater.	• Partitioning between soil and pore water. • Leaching of impacted soils into groundwater. • Lateral migration of impacted groundwater.	Taplow Gravel Formation (Secondary A Aquifer).	Unlikely: Based on Stage 2 assessment.

8. CONCLUSIONS

The geology encountered consisted of made ground underlain by superficial deposits of Taplow Gravel Formation (Secondary A Aquifer), which is further underlain by strata of the London Clay Formation (Unproductive Strata) at approximately 8.5m bgl.

Groundwater is inferred to flow in a north westerly direction at an average depth of 7m bgl, and is considered likely to discharge to the River Thames 1.5km to the south west of the site. Given the distance to the River Thames, the Taplow Gravel formation is considered to be the primary controlled waters receptor.

A Stage 2 risk assessment was performed on the data collected from the verification sampling to assess potential risks to human health and controlled waters. The principal findings of the risk assessments are as follows:

- Concentrations of COPC measured at the site were considered unlikely to represent an unacceptable risk to human health receptors.
- Potential risks to the underlying Secondary A Aquifer were considered to be acceptable.

9. REFERENCES

Ref. 1 RSK, Blackhorse Service Station, Richmond Surrey, Phase 1 Investigation: Preliminary Risk Assessment (25986 R01 (00) Final; October 2012.

Ref. 2 RSK, Blackhorse Service Station, Richmond Surrey, Environmental Strategy Plan (25986 R03 (00) Final; April 2013.

Ref. 3 RSK, Blackhorse Service Station, Richmond Surrey, Phase 2 Investigation: Comprehensive Environmental Site Assessment Report (25986 R02 (00) Final; December 2012.

Ref. 4 CLR11, Model Procedures for the Management of Land Contamination

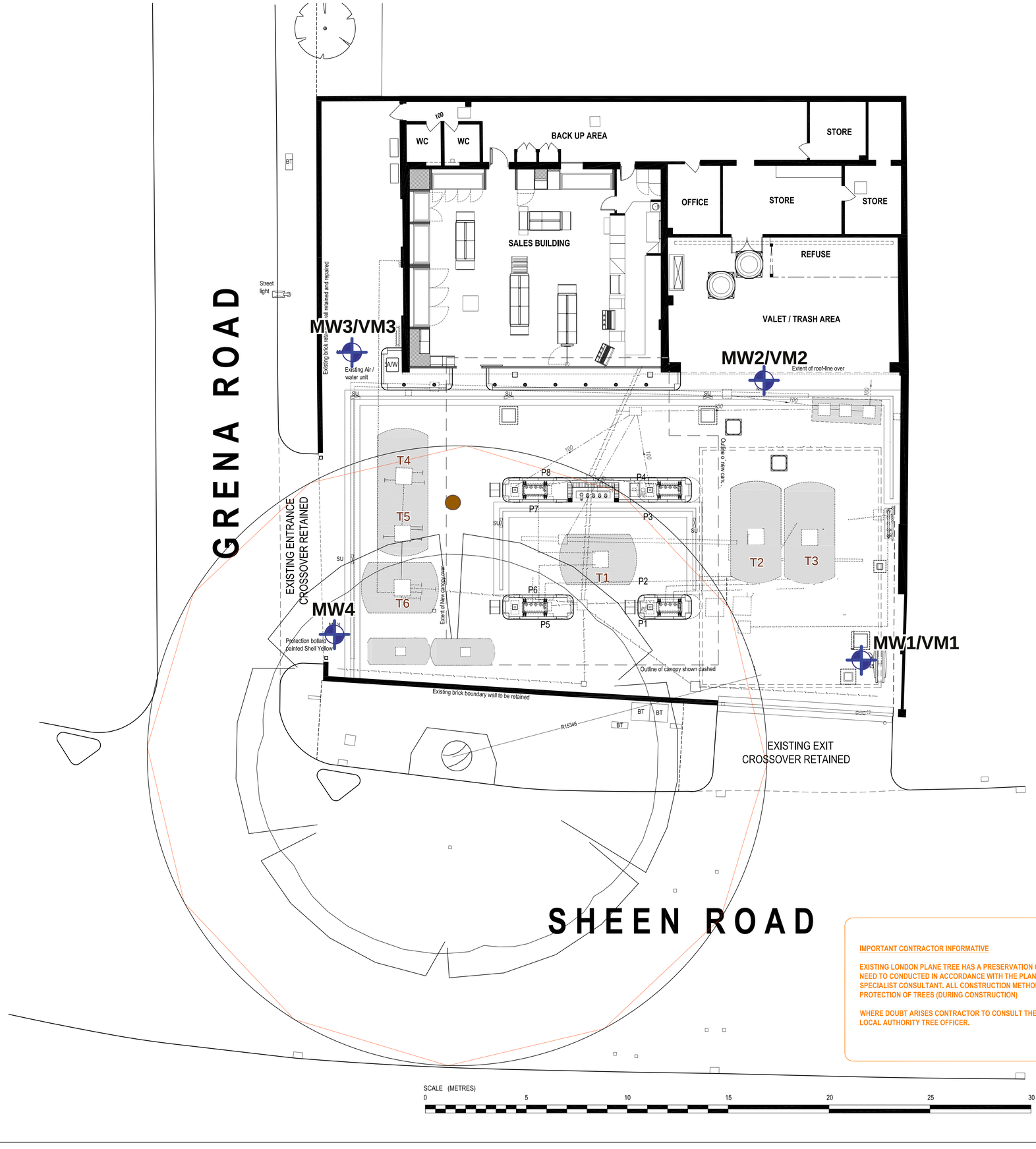
Ref. 5 Guidance for the Safe Development of Housing on Land Affected by Contamination, R&D Publication 66: 2008 (Volume 1), NHBC and the Environment Agency 2008.

Ref. 6 USPEA. Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites. EPA 510-R-15-001. June 2015

Ref. 7 British Standard Institute. Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. BS8485:2015. June 2015.

Ref. 8 LQM/CIEH S4UL methodology

FIGURES



IMPORTANT CONTRACTOR INFORMATIVE

EXISTING LONDON PLANE TREE HAS A PRESERVATION ORDER AND ANY WORKS CARRIED OUT WITHIN ITS VICINITY NEED TO CONDUCTED IN ACCORDANCE WITH THE PLANNING CONSENT UNDER THE DIRECTION OF THE APPOINTED SPECIALIST CONSULTANT. ALL CONSTRUCTION METHODOLOGY TO FOLLOW THE GUIDANCE SET-OUT IN BS5837 - PROTECTION OF TREES (DURING CONSTRUCTION)

WHERE DOUBT ARISES CONTRACTOR TO CONSULT THE ARBORICULTURLIST WHO IS INSTRUCTED TO LIAISE WITH THE LOCAL AUTHORITY TREE OFFICER.

SCALE (METRES)

0 5 10 15 20 25 30

KEY

GROUNDWATER / VAPOUR WELL

HISTORIC TANK

T1

BURIED BRICK WALL STRUCTURE

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DRAWING TITLE
FIGURE 2 - SITE LAYOUT PLAN
(PRE DEVELOPMENT)

DRAWN	DESIGNED	CHECKED	APPROVED	DATE
AM	AM	PA	PA	MAY 2016

SCALE	DRG No.	REV.
	60481674/ FIGURE 2	