



ENVIRONMENTAL CONSULTING

Phase II-III
Groundwater Risk Assessment

Wessex Yard
8 New Lane
Havant
PO9 2JJ

Prepared for

Days Estates Ltd
3 Marmion Road
Southsea
Hampshire
PO5 2AT

Omnia ref: A10708/ 2.0 Draft
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Quality Assurance

Remarks	DRAFT	FINAL
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Executive Summary	
Site Address	Wessex Yard, 8 New Lane, Havant Hampshire PO9 2JJ
National Grid Reference	472139, 106616
Site Area	0.328 hectares
Current Site Use	The site comprises the former Wessex Yard, on New Lane, Havant, to the north of the Portsmouth to London railway line. The site comprised a roughly rectangular plot of land and is currently occupied by A1 Recovery and Practical Car & Van Rental, a vehicle storage and repair company, with their offices and garage located in the south of the site and vehicle storage and parking occupying the rest of the site.
Site History	Previous reports did not locate any plans from either the Hampshire Records Office or the National Gas Archives which indicated the historical layout of the former Gasworks site. However, information was obtained from the Contaminated Land Officer (CLO) which summarised information held on the Local Authority GIS system. This indicated that three gasometers had been located on site between c. 1879 and c. 1933 but did not provide details about other historical structures. Information was also provided on the presence of a neighbouring infilled pit to the east extending onto the eastern site boundary; infill was noted as an 'Unknown Waste Type', leading to the conclusion that infill of this pit is likely associated with the gas works waste.
Environmental Setting	Groundwater data provided by the Environment Agency groundwater data and information provided within a statutory response from Portsmouth Water indicates that the site is located within a groundwater Source Protection Zone 1c (SPZ 1c) associated with the Bedhampton Springs. In the case of the subject site the SPZ1c applies to the Chalk aquifer which is located at depth beneath a confining layer of the London Clay Formation and the Lambeth Group. The site is located 403m south of the SPZ1 which is attributed to unconfined Chalk strata. No groundwater abstraction licenses or public water supplies were identified within a 1km radius of the site, the closest being Bedhampton Ps Spring No.2 located 1091m west of the site.
Geology, Hydrology & Hydrogeology	The site was underlain by a cohesive unit of Made Ground, over superficial River Terrace Deposits further underlain by bedrock of London Clay Formation and the Bognor Sand Member. River Terrace Deposits were recorded as a lithologically variable unit grading between gravelly CLAY and clayey SAND, with the London Clay Formation logged as a laterally uniform stiff grey CLAY grading into a gravelly CLAY as the base of the unit. Directly underling this, the Bognor Sand Member was encountered at depths from 7.60-11.00m bgl and comprised of a dense, greenish grey gravelly silty SAND. <u>Hydrogeology</u> Groundwater was encountered at depths varying between 1.00 to 2.60m bgl within intrusive locations, WS101 and WS106 – WS108. Given the absence of water strikes at the majority of shallow locations, and the variability in the depth to groundwater strikes, it is considered that the shallow water strikes represent locally perched water within the Made Ground. It is considered that groundwater was encountered within sandy and gravelly horizons within the London Clay Formation at depths ranging from 7.60 – 10.50m bgl. The presence of cohesive strata attributed to the London Clay Formation is considered to act as an aquitard.

	High resolution groundwater monitoring, utilising data loggers has confirmed a hydraulic gradient reducing to the south west, evident of a south westerly flow direction.
Revised Conceptual Site Model – Controlled Waters	
Upon completion of the Risk Assessment, no active pollution pathways have been identified in relation to the risk to Controlled Waters.	
Recommendations	
A Remediation Method Statement (RMS) should be prepared for the site to address risks posed to future site users from near surface soils, as set out in OEC Report A10708/ 1.1 and summarised within Section 6.3.1 of this report. It is recommended that a Piling Risk Assessment is prepared to assess the potential risk to Controlled Waters during the piling process. Consideration should be given to the potential for mobilisation of near surface contaminants into the underlying aquifer through potential bridging of the underlying aquitard (London Clay). Depending on pile depth consideration should also be given for the potential for turbidity on the aquifer. Should additional sources or evidence of contamination be encountered during site works, works should be halted and contact made with a suitably qualified Environmental Consultant. At this stage, further investigation and risk assessment should be undertaken, and contact made with the Local Authority.	

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1.0 INTRODUCTION

1.1 Background

Omnia Environmental Consulting (OEC) have been commissioned by Days Estates Ltd to undertake a Phase II - III Groundwater Risk Assessment at the site of a proposed residential development at Wessex Yard, New Lane, Havant, PO9 2JJ. A site location map is presented as Figure 1.0 in Appendix III.

The site has previously been subject to a Phase I Desk Study by Soils Limited entitled 'Phase I Desk Top Study, Former Town Gas Works, 8 New Lane, Havant, Hampshire, PO9 2JJ' (ref: 15214/DS) and a subsequent Phase II Ground Investigation Report, dated January 2016.

Following a review of the Soils Phase II Report undertaken by the Environment Agency (EA) and in light of the EA comments a further Phase II site investigation was undertaken by OEC and detailed within the report entitled 'Phase II-III Geo-Environmental Assessment, Wessex Yard, 8 New Lane, Havant, PO9 2JJ (ref: A10708/1.1)' dated November 2016. The report concluded that the site did not have the potential to present a significant risk to controlled waters and that the risk to human health was limited to the potential for vapour and ground gas migration into buildings. The assessment was based on all areas of external space. Limited concentrations identified within the underlying groundwater were attributed to an infilled gravel pit neighbouring the site to the east.

The previous phases of Ground Investigation are discussed in Section 6.

Comments received from the EA suggested that further consideration should be made to assessing the risk posed to controlled waters and recommended that contact with Portsmouth Water was established before construction works took place. Following on from this OEC proposed further site assessment, including the monitoring of existing wells to provide further surety on groundwater flow direction using high resolution data, and for the collection of additional groundwater samples utilising low flow methodology on a further three occasions. HBC's acceptance of this proposal and subsequent comments are set out in letter ref. CONS/17/00343, dated 17th March 2017 (Appendix VII).

1.2 Proposed Development

It is understood that the proposed development will comprise the construction of three (3no.) apartment blocks fronting onto New Lane to the west and Eastern Road to the north. The apartments are understood to range from three to four storeys in height and comprise a total of thirty-nine (39no.) one and two bedroom apartments with associated parking and areas of raised planting.

The outline proposed site layout is presented as Figure 2.0 (Appendix III).

1.3 Objectives

The objectives of the Water Risk Assessment are to:

- Undertake a review of previous Phase I and Phase II investigation reports pertaining to the site;
- Undertake an assessment of near surface soils through intrusive site investigation;
- Undertake an assessment of the groundwater conditions through intrusive site investigation and return groundwater monitoring; and,
- Assess the implications of any potential groundwater contamination which may present a risk to future controlled waters.

1.4 Sources of Information

Background information was sought from the following sources:

- Soils Limited Report 15214/DS– ‘Phase I Desk Top Study at Former Town Gas Works, 8 New Lane, Havant Hampshire, PO9 2JJ. Dated October 2015;
- Soils Limited Report 15295/GIR– ‘Phase II Ground Investigation Report at Former Wessex Ste, 8 New Lane, Havant’. Dated January 2016;
- OEC Report A10708/1.1 – ‘Phase II-III Geo-Environmental Assessment, Wessex Yard, 8 New Lane, Havant, PO9 2JJ’. Dated November 2016;
- Environment Agency Groundwater Vulnerability Map (www.environment-agency.gov.uk/wiyby);
- British Geological Survey Map Sheet 316, Fareham, Solid & Drift Edition at a scale of 1:50,000;
- British Geological Survey Map Sheet 9 Hydrogeological Map of The Hampshire and Isle of Wight 1:100,000;
- Environment Agency, proposed residential development comprising 39 one and two bed apartments with associated car parking, cycle and refuse storage, following demolition of existing buildings, of planning permission of APP/15/01425 for residential development, ref. HA/2016/117926/01-L01. Dated 11th February 2016.
- Havant Borough Council, proposed residential development comprising 41 one and two bed apartments with associated car parking, cycle and refuse storage, following demolition of existing buildings (Approved 07/07/16) Request to discharge condition 9 (11/01/17), of planning permission of APP/15/01425 for residential development, ref. CONS/17/00343. Dated 17th March 2016.

1.5 Limitations

The limitations of this report are presented in Appendix I.

1.6 Confidentiality

OEC has prepared this report solely for the use of the Client and those parties with whom a warranty agreement has been executed, or with whom an assignment has been agreed.

Should any third party wish to use or rely upon the contents of the report, written approval must be sought from OEC; a charge may be levied against such approval.

2.0 SITE SETTING

2.1 Site Details

Site Address	Wessex Yard, 8 New Lane, Havant, Hampshire PO9 2JH
National Grid Reference	472139, 106616
Area	~0.33Ha

All acronyms used within this report are defined in the Glossary presented in Appendix II

A site location map is presented as Figure 1.0 (Appendix III).

2.2 Current Site Use

Site Description

The site comprised a roughly rectangular plot of land which at the time of the site investigation was occupied by A1 Recovery, a vehicle storage and repair company.

Site access was via an entrance between two buildings in the south-western corner of the site with one building located either side of the access route. The buildings comprised a two-storey commercial unit, rectangular in shape, aligned approximately east to west and utilised as offices for A1 Recovery and Practical Car & Van rental, located to the south of the site. The second building comprised a reversed 'L-shape' and was located adjacent to the western boundary of the site. The two buildings were observed to have several different uses including vehicle repair workshop, which utilised the majority of the ground floor of the larger building, tyre storage and welfare facilities. The external areas of the site comprised concrete hardstanding and were utilised for the storage of recovery trucks, the storage of crash-damaged vehicles as well as parking.

The site is bound to the south by a section of the Havant railway line, running approximately east to west. To the north of the site was bound by Eastern Road and to the west of the site was New Lane. The area immediately east of the site was occupied by a Gregory Bros Ltd a building company and adjacent storage facilities. To the south-east of eastern boundary of the site is a large electrical substation associated with the railway. At the time of the site walkover the site was partially encircled by metal palisade fencing to the north, north-west and south-east and with a brick wall topped by palisade fencing to the east, and buildings to the south-west and south.

Hazardous Materials Storage

Located to the northeast of the main building two rectangular uncontained Above Ground Storage Tanks (ASTs) were noted, with a smaller metal tank stacked on top of a larger tank. From discussion with site occupants the tanks are understood to have formally been used for

oil storage. Adjacent to the rectangular ASTs was an IBC which appeared to be utilised for the storage of waste fuel. A yellow spill tray was located underneath the IBC. On the most recent site visit, anecdotal evidence was obtained suggesting that the former ASTs are now filled with rainwater.

Waste Storage

A large skip was located to the south of the site containing mixed waste. Adjacent to this was several large blue barrels, which had been filled with rainwater, and an area where waste wood was stored, assumed to be awaiting collection.

2.3 Surrounding Area

The surrounding land uses are summarised below:

Direction	Land Use
North	Cemetery (north) and residential with private gardens (north west)
East	Commercial properties and electricity substation associated with the railway.
South	Commercial building and railway line.
West	Residential with private gardens with commercial units beyond.

3.0 SITE HISTORY

3.1 On-Site Historical Development

Information obtained from the Contaminated Land Officer (CLO) summarised information held on the Local Authority's GIS system. This indicated that three gasometers had been present on site between c.1879 and c.1933. Information was also provided on the presence of a neighbouring infilled pit to the east. The pit is noted to extend to the eastern site boundary and to be infilled with an 'Unknown Waste Type', as detailed in the previous OEC report (A10708/1.1) Figure 4.0 and 4.1.

3.2 On site Tanks

Information provided by the Council suggests that the site had various tanks associated with gasometers underlying the subject site.

4.0 ENVIRONMENTAL SETTING

4.1 Geology & Hydrogeology

The British Geological Survey (BGS) map for the site (Fareham, Sheet 316, Solid and Drift Edition at a scale of 1:50,000) indicates that the site is underlain by the following geological sequence:

Geological Unit	Classification	Description	Aquifer Classification
Superficial	River Terrace Deposits (undifferentiated)	Sand, silt and clay	Secondary (A) Aquifer
Bedrock	London Clay Formation (Northern Half)	Clay, silt and sand	Unproductive Strata
	Bognor Sand Member (Southern Half)	Sand	Secondary (A) Aquifer

The superficial River Terrace deposits are classified as a Secondary (A) Aquifer, with bedrock of the London Clay Formation classified as an unproductive aquifer and bedrock of the Bognor Sand Member classified as a Secondary (A) Aquifer.

The site is located within a Source Protection Zone 1c (SPZ1c) for subsurface activity which is associated with the Bedhampton and Havant Springs, a public water supply, relating to the Principal Chalk Aquifer. The Chalk is located at depth and is beneath a confining layer comprising London Clay Formation and Bognor Sand Formation. The SPZ1 associated with the Havant & Bedhampton Springs is located approximately 403m south of the site boundary.

SPZ1c is a relatively new definition which is applied to aquifers that were previously considered to be protected from contamination due to low permeability overlying geology, but where activities such as deep drilling could present a risk to controlled waters.

No groundwater abstraction licenses or public water supplies were identified within a 1km radius of the site.

Based on BGS Hydrogeological Mapping for the area, it is considered that regional groundwater flow will be in a south-westerly direction towards Portsmouth Harbour. The BGS Hydrogeological map also indicates that the base of Tertiary deposits overlying the Chalk to be at approximately -50mAOD. Given that Ground Level (GL) at the site is at an elevation of approximately 12.0m AOD, this indicates that the top of the Upper Chalk to be approximately site is located at approximately 62m bGL.

4.2 Hydrology

One (1no.) surface watercourse was identified within a 250m radius of the site and comprising an unnamed tertiary river and culvert, located 190m west of the site.

The site is not located within a currently defined flood risk zone, and is situated within an area with limited potential for groundwater (clearwater) flooding.

4.3 Industrial Land Uses

The previous Desk Study report indicates that there are six (6no.) industrial land uses within 100m of the site, with five (5no.) located on site and one (1no.) adjacent. The on-site industrial land uses are summarised below:

- Garage services with tanks;
- Builder's merchants;
- Car breakdown and recovery service;
- Licenced waste management facility, unspecified; and,
- Registered waste transfer site, unspecified.

The one (1no.) off-site entry within 100m of the site is attributed to railway line located 14m south of the site.

4.4 Historical Industrial Land Uses

The previous DTS report identified ten (10no.) historical industrial uses within a 250m buffer of the site, with two (2no.) located on site and eight (8no.) located off-site. The historic land uses are summarised below.

On-site:

- Three entries of tank/gasworks dated c.1867-1897;
- Depot, dated c.1993.

Off-site:

- Gasworks/pit, located 2m east, dated c.1867-1953;
- Pit (backfilled), located 4m east, dated from c.1867-1953;
- Railway line, located 14m south, dated c.1866-present;
- Timber yard, located 86m west, dated c.1897-1932;
- Builders Yard, located 168m south-west, dated c.1965-1973;
- Electrical sub-station, located 168m east and 171m north east, dated c.1965-1973;
- Warehouses, located 198m west, dated c.1960-1963; and,
- Works, located 250 north-east, dated c.1960-1993.

4.5 Sensitive Land Uses

The site is located within a currently defined Nitrate Vulnerable Zone (NVZ), however, there are no other environmentally sensitive land uses within 250m of the site.

4.6 Site Sensitivity Assessment

The site is considered to be located within a moderate to high sensitivity setting for the

following reasons:

- Underlying geology comprises a superficial Secondary (A) Aquifer overlying the London Clay classified as unproductive Aquifer, subsequently underlain by the Bognor Sand Formation classified as a Secondary (A) Aquifer. This is all further underlain by a Chalk classified as a Principal Aquifer, attributed to the Bedhampton Springs;
- The site is located within a Groundwater Source Protection Zone 1c (SPZ1c), for Bedhampton and Havant Springs, a public water supply;
- Historically the site has been used as a Gas Works as well as garages and vehicle repair; and,
- Residential properties are located in close proximity to the subject site.

5.0 CONSULTATIONS

5.1 Environment Agency

As summarised in Section 1.1, the previous Site Investigation Report (ref: 15295/GIR) was submitted to the EA for review prior to the commencement of additional ground investigation works. The EA raised concerns of risks posed to groundwater and indicated that gasworks contamination had previously been identified on another development site to the south of the railway line (as set out in letter ref. HA/2016/117926/01-L01).

The EA suggested that further consideration should be given to assessing the risks posed to controlled waters and recommended that contact was made with Portsmouth Water and Havant Borough Council before construction works took place.

5.2 Havant Borough Council

Contact was made with Havant Borough Council regarding the scope of investigation planned for the site. Upon review of OEC report ref: A10708/1.1, Havant Borough Council recommended further rounds of sampling of existing wells to determine the range of groundwater surface gradient, vertical range of groundwater movement as set out in letter ref. CONS/17/00343, dated 17th March 2017.

6.0 PREVIOUS INVESTIGATIONS

The site has been subject to at least three (3no.) phases of previous site investigation. An initial Phase I Desk Top Study (DTS) and subsequent Phase II Ground Investigation Report (GIR) produced by Soils Limited as well as a Phase II ground investigation undertaken by OEC are summarised in the following section.

6.1 Soils Limited report, Phase I Desk Top Study Former Town Gas Works, 8 New Lane, Havant, Hampshire, PO9 2JJ (ref: 15214/ DS) – October 2015

A Phase I Desk Top Study (DTS) report was produced by Soils Limited in October 2015 and identified the following potential sources of contamination.

Potential Source	Potential Contaminants	Potential Impact
On Site		
Gas Works	Metals (As, Cd, Pb, Hg, Se, Ni), Asbestos, PAH and TPH, ammoniacal liquors	Human Health Controlled Waters Future Site Users
Gas works/pit (Historic)	Metals (As, Cd, Pb, Hg, Se, Ni), Asbestos, PAH and TPH, ammoniacal liquors	Human Health Controlled Waters Future Site Users
Garage services	Metals (As, Cd, Pb, Hg, Se, Ni), Asbestos, PAH and TPH, Volatile Organic Compounds (VOC)	Human Health Controlled Waters Future Site Users
Above ground Storage Tanks (AST)	Polycyclic Aromatic Hydrocarbons (PAH) and TPH	Human Health Controlled Waters
Licensed Waste Management Facilities	Metals (As, Cd, Pb, Hg, Se, Ni), Asbestos, PAH and TPH	Human Health Controlled Waters
Made Ground	Metals (As, Cd, Pb, Hg, Se, Ni), Asbestos, PAH and TPH	Human Health
Off Site		
Historic infilled ground associated with historic gas works (4m east)	Metals (As, Cd, Pb, Hg, Se, Ni), Asbestos, PAH and TPH Ground gas	Future Site Users
Railway Line (14m South)	Metals (As, Cd, Pb, Hg, Se, Ni), Asbestos, PAH and TPH	Future Site Users

Historical Gasworks

The DTS did not locate any plans from either the Hampshire Records Office or the National Gas Archives which indicated the historical layout of the former Gasworks site. However, information was obtained from the Contaminated Land Officer (CLO) which summarised information held on the Local Authority GIS system. This information indicated that three gasometers had been located on site between c.1879 and c.1933.

Information from the Local Authority also indicated the presence of Above Ground Storage Tanks (ASTs) with distribution points as well as an Underground Storage Tank (UST), all of which relate to more recent land use as a Depot.

Adjacent Infilled Pit

The DTS identified a large gravel pit to the east of the site and associated with the development of the Gas Works. Records indicated that the pit was infilled with an 'unknown waste type'. The gas work pit is identified on historical mapping from c.1867 with the pit being infilled prior to c.1953.

The conclusions and recommendations of the Phase I site investigation were as follows:

- The Phase I investigation concluded that the risks summarised in the table above presented a moderate risk to soils, groundwater and ground gas and a risk to future site users.

6.2 Soils Limited report, Phase II Ground Investigation Report at Former Wessex Ste, 8 New Lane, Havant (ref: 15295/ GIR) – January 2016

A Phase I and II site investigation report was produced for the site by Soils Ltd in January 2016 and identified the following potential sources of contamination.

Potential Source	Potential Contaminants	Potential Impact
On Site		
Made Ground containing elevated concentrations of heavy metals, TPH and PAH across the site.	Heavy Metals (As & Pb), PAH and TPH	Human Health & Controlled Waters
Groundwater containing TPH	TPH (C ₁₆ -C ₂₁ & C ₂₁ -C ₈₅)	Controlled Waters

The conclusions and recommendations of the site investigation were as follows:

- The ground investigation identified elevated concentrations of lead and PAHs which were considered to pose a risk to human health and controlled waters;
- Elevated concentrations of hydrocarbons were identified in groundwater samples taken from the northeast and southwest of the site.
- It was therefore recommended that additional work was undertaken including investigation in areas highlighted to contain contamination within shallow and deep samples, investigation of former gas holders and storage tanks and installation of deep boreholes to enable gas and groundwater monitoring to take place.

6.3 OEC Report A10708/ 1.1 – Phase II – III Geoenvironmental Site Assessment, dated November 2016

A supplementary Phase II site investigation report was produced for the site by OEC in November 2016 and identified the following potential sources of contamination.

Potential Source	Potential Contaminants	Potential Impact
On Site		
Made Ground containing elevated concentrations of heavy metals, PAH and TPH.	Heavy Metals (As, Be, Pb), Asbestos, PAH and TPH	Human Health & Controlled Waters
Groundwater containing elevated concentrations of Metals and PAH	Heavy Metals, PAH	Human Health & Controlled Waters
Made Ground	Ground Gas (CH ₄) and (CO ₂)	Human Health

Conclusions from the OEC Report A10708/ 1.1

- OEC report A016708/2.0 identified exceedances of heavy metals, PAH and TPH within Made Ground. It was concluded that the exposure pathway for heavy metals and PAH would be severed by the presence of hardstanding and raised areas of soft landscaping. However, elevated concentrations of TPH were identified beneath the proposed building footprints. The exposure pathway for these determinants is through vapour inhalation, therefore it was considered likely that elevated concentrations of cyanide, PAH and TPH would pose a significant risk to human health and that mitigation systems in the form of a vapour resistant membrane within buildings would need to be installed.
- The investigation also identified potentially active pollution linkages within the near surface in relation to the migration of vapours into buildings. The site was classified as Characteristic Situation 2 due to the presence of elevated ground gas concentrations.
- It was recommended that a Piling Risk Assessment was undertaken to assess the potential risks posed to controlled waters during the piling process. The report stated that consideration should also be given to the potential for mobilisation of near surface contaminants into the underlying aquifer through potential bridging of the underlying aquitard (London Clay).

7.0 CONCEPTUAL SITE MODEL (CSM)

The Conceptual Site Model set out below considers only risks relating to Controlled Water. Near surface soils have been considered separately within OEC report reference A10708/1.1.

7.1 Initial CSM

In accordance with Environment Agency, CLR 11 (2004) and BS 10175 (Code of Practice for Investigation of Potentially Contaminated Land), Omnia Environmental Consulting have developed an initial CSM to identify potential contamination sources, migration pathways and receptors within the study area.

Contaminant Sources

On-site Potential Sources

- Elevated concentrations of Heavy Metals within groundwater;
- Elevated concentrations of PAH within groundwater; and,
- Elevated concentrations of TPH within groundwater.

Potential Pathways

- Vertical and lateral migration.

Potential Receptors

- Controlled Waters.

An Initial Conceptual Site Model has been prepared for the site and is presented below within Table 7.1.

Table 7.1 Initial Conceptual Site Model

Source	Contaminant	Potential migration pathway	Potential Receptors	Likelihood of Occurrence	Magnitude of Occurrence	Overall Risk Rating	Active/ Inactive
On Site							
Elevated concentrations within Groundwater	Metals (As, Cd, Cr, Pb, Hg, Se, Ni), PAHs and TPH	Vertical and lateral migration	Controlled Waters	Medium	Medium	Moderate	Potentially Active

8.0 SITE INVESTIGATION

8.1 Summary of Previous Works

The site has been subjected to several phases of intrusive site investigation resulting in the advancement of a number of shallow and deep boreholes installed as environmental monitoring points. The environmental monitoring points installed by OEC were subsequently sampled for groundwater. The installation details of the sampling points are summarised in Table 8.1 below.

Table 8.1 Summary of Previous Fieldwork

OEC Report	Location No	Rationale	Type	Maximum Depth	Monitoring Well Response Zone (m bgl)
A10708/1.1	BH101 BH102A BH103	General spread across the site for assessment of potential contamination within the underlying soils and groundwater monitoring.	CP	14.00	8.00 - 11.00 (BH101) 7.00 - 11.00 (BH102A) 6.50 - 10.50 (BH103)
	WS104	Targeting historic gas works for potential contamination. Ground gas monitoring Within close proximity of historic gas.	WS	4.00	0.50-3.50
	WS108 WS110	General spread across the site for assessment of potential contamination. Ground gas and groundwater monitoring.	WS	5.00	1.00-2.50 (WS108) 0.50-2.50 (WS110)

8.2 General

A ground investigation was designed based on the findings of all previous reports and considering comments and recommendations made by the Environment Agency and Havant Borough Council (ref. HA/2016/117926/01-L01, ref. CONS/17/00343 and ref. CONS/16/00061).

The exploratory hole locations from the ground investigation conducted by OEC are illustrated in Figure 3 (Appendix III). Ground conditions encountered are presented on exploratory hole logs, which are provided in Appendix IV.

8.3 Groundwater Monitoring

Three (3no.) phases of groundwater monitoring have been undertaken by OEC following

completion of site works, between July and September 2016 with the third phase of monitoring and sampling undertaken during July 2017.

The first phase of sampling utilised a bailer to obtain grab samples, resulting in a high proportion of suspended solids within the samples and was therefore considered to be unsuitable to provide an assessment of concentrations within the underlying groundwater. All subsequent monitoring has utilised the low-flow (micropurging) sampling methodology utilising a peristaltic pump and YSI multi-parameter meter as preferred by the Environment Agency. The low-flow sampling technique allows for a sample to be collected directly from formation water without overt agitation of the water column present within the monitoring pipe and therefore minimises the mobilisation of either product residue adhered to the well casing, or of suspended fines with sorbed contaminants and therefore provides a reliable estimate of dissolved-phase contaminants.

As set out in Section 2.2, an open topped, decommissioned AST was situated close to location WS108, and was observed to be leaking water onto the hardstanding, within the vicinity of WS108. The water from the tank was sampled on 20th July 2017 and submitted for analysis to facilitate a comparison to groundwater concentrations present in location WS108.

8.4 Laboratory Analysis

Selected soil samples were previously submitted for a range of chemical analysis including, metals, pH, water-soluble sulphate (2:1 extract), total cyanide, phenols, speciated Polycyclic Aromatic Hydrocarbons (PAHs), asbestos fibres in soil and banded Total Petroleum Hydrocarbons (TPH). Groundwater samples were submitted for a range of chemical analysis including metals, PAHs, TPH-CWG, BTEX, phenols & cresols, sulphate, pH and total cyanide. Selected samples were also analysed for total dissolved sulphur, chloride, nitrate, ortho phosphate, Fe II and Fe III.

Exova Jones Environmental Laboratory undertook the analytical work in accordance with UKAS accreditation where applicable and the testing results are included in Appendix V and discussed in Section 10.

9.0 GROUND AND GROUNDWATER CONDITIONS

9.1 Ground Conditions

9.1.1 Geology

The site was underlain by a cohesive unit of Made Ground, underlain by superficial River Terrace Deposits further underlain by bedrock of London Clay Formation and the Bognor Sand Member. River Terrace Deposits were recorded as a lithologically variable unit grading between gravelly and clayey CLAY and SAND, with the London Clay Formation logged as a laterally uniform stiff grey CLAY grading into a gravelly CLAY as the base of the unit was encountered. Directly underling this, the Bognor Sand Member was encountered at depths from 7.60-11.00m bgl and comprised of a dense, greenish grey gravelly silty SAND.

9.2 Groundwater Conditions

Groundwater was encountered within all cable percussive borehole locations and window sample location WS108. The depth to groundwater strikes encountered are summarised in Table 9.2 below.

Table 9.2 Groundwater Observations

Location	Depth to Strike (m bgl)	Type	Geology
BH101	10.50	Strike	London Clay Formation
BH102A	9.40	Strike	London Clay Formation
BH103	7.60	Strike	London Clay Formation
TP101	1.50	Seepage	Made Ground
WS104	1.10	Strike	Made Ground
WS106	1.00	Strike	Made Ground
WS107	1.00	Strike	Made Ground
WS108	2.60	Strike	Made Ground

9.3 Groundwater Flow Direction

During the current phase of investigation, the X, Y & Z co-ordinates for locations BH101, BH102A and BH103 were surveyed by a specialist utilities firm, using DGPS surveying equipment to allow the confirmation of groundwater flow direction. Solinst levelloggers and a barologger were deployed to provide high-resolution groundwater monitoring data to accurately determine groundwater level at selected monitoring points, to facilitate an accurate calculation of groundwater flow direction and the hydraulic gradient beneath the site.

The co-ordinates of each location and elevation of the standpipe in mAOD are presented in Table 9.3 below.

Table 9.3 – Monitoring Borehole Co-ordinates

Location	Eastings	Northings	Standpipe Elevation (mAOD)
BH101	472129.416	106636.002	12.111
BH102A	472146.547	106601.230	12.210
BH103	472103.901	106600.305	11.617
WS103	472137.911	106585.969	12.161
WS104	472131.795	106611.200	12.086
WS108	472125.038	106627.492	11.865
WS110	472149.678	106641.260	12.168

An additional three rounds of groundwater monitoring and sampling utilising the low-flow sampling technique were undertaken between 15th June and 20th July with the groundwater levels recorded using a dip tape and corrected to Ordnance Datum. Groundwater levels are presented in Table 9.4 below.

Table 9.4 – Groundwater Level

Location	Standpipe Elevation (mAOD)	Groundwater Level						
		15/06/17 (mbgl)	15/06/17 (mAOD)	13/07/17 (mbgl)	13/07/17 (mAOD)	20/07/17 (mbgl)	20/07/17 (mAOD)	Mean GWL (mAOD)
BH101	12.111	2.97	9.141	3.00	9.111	3.025	9.086	9.117
BH102A	12.210	3.13	9.080	3.00	9.210	3.020	9.190	9.160
BH103	11.617	2.67	8.947	2.60	9.017	2.60	9.017	8.993

Levelloggers continuously monitored groundwater level and barometric pressure and were deployed over a two-week period.

The mean groundwater level at each of the locations monitored is presented in Table 9.5 below.

Table 9.5 – Average Groundwater Level - Level Loggers

Location	Standpipe Elevation	Data Logger Period
		15/06/17-20/06/17 (mbgl)
BH101	12.111	9.053
BH102A	12.210	8.997
BH103	11.617	8.872

Levellogger data which has been processed to correct for atmospheric pressure influence and corrected to mAOD is presented in Appendix VIII. The data shows a relatively stable groundwater level over the assessed periods. However, relatively small fluctuations have been detected within the dataset which roughly correspond to the tidal cycle, and it is therefore possible that these fluctuations could be attributed to tidal influence from Langstone Harbour, located approximately 3.0km away. However, a detailed analysis of the relationship between groundwater level and the tidal cycle is outside of the scope of this report.

Groundwater data has been corrected to Ordnance Datum using x, y, and z data obtained for the purpose of this report in order to obtain an average groundwater level for each location to remove the effect of local differences in ground level across the site.

The groundwater flow direction has been calculated using the triangulation method and indicates that groundwater flow is towards the south-west with a hydraulic gradient (i) of 0.0041 based on a change in groundwater level of 0.08m over a horizontal distance of 20m. The groundwater triangulation plot is presented as Figure 4 in Appendix III and graphical representations of the levellogger data are presented in Appendix VIII.

10.0 TIER 1 QUALITATIVE GROUNDWATER RISK ASSESSMENT

OEC has undertaken a Tier 1 qualitative risk assessment to determine if any potential contaminants within groundwater and soil pose an unacceptable level of risk to the identified receptors.

10.1 Controlled Waters

For the purpose of the Tier 1 assessment, laboratory data from all phases of investigation has been compared directly to the UK Drinking Water Standards (UK DWS). In cases where a determinant does not have a UK DWS screening value, the measured concentrations have also been compared to the World Health Organisation Drinking Water Standard (WHO DWS) screening values in order to adopt a conservative approach. The origin of the Tier 1 screening values are presented in Appendix VI.

Groundwater results from the first phase of sampling (July 2016) has not been included in this assessment as the results were not considered to be representative due to high levels of suspended solids within the samples analysed. A high suspended solid percentage within samples can skew the results to reflect concentrations sorbed to fine particles of silt, clay and organic matter and does not therefore accurately reflect dissolved phase determinants in the underlying aquifer.

All subsequent groundwater sampling has utilised the low-flow (micro-purging) methodology of groundwater sampling as preferred by the Environment Agency. This technique allows for a sample to be collected directly from formation water without overt agitation of the water column present within the monitoring pipe and therefore minimises the mobilisation of either product residue adhered to the well casing, or of suspended fines with sorbed contaminants and therefore provides a reliable estimate of dissolved-phase contaminants.

It was noted that during the monitoring round dated 15th June 2017, that water was actually collected from a historic well (WS9) installed during the previous site investigation undertaken by Soils Ltd. The results have been included in the assessment, but WS9 was not sampled on subsequent monitoring visits.

Table 10.1 Tier 1 Risk Assessment for Controlled Waters

Determinand	Units	UK Drinking Water Threshold	WHO DWS	FW EQS	n	MC	No of Ex	Loc of Ex	Assessment
Inorganics									
Arsenic	µg/l	10.0	-	50	31	12.1 29.6 17.9 441.2	8	BH101 BH102A WS104 WS108	Further Assessment Required
Cadmium	µg/l	5.0	-	2000	31	<0.5	-	-	No Further Assessment
Chromium	µg/l	50.0	-	4.7	31	62.7 502.6	4	BH102A WS108	Further Assessment Required

Iron	µg/l								
Lead	µg/l	10.0	-	7.2	31	95 10	2	BH102A WS104	Further Assessment Required
Mercury	µg/l	100		1,000	2	1,140. 93		WS108	Further Assessment Required
Nickel	µg/l	20.0	-	20	31	138 431	4	BH102A WS108	Further Assessment Required
Selenium	µg/l	10.0	-	20	31	<3	-	-	No Further Assessment
Copper	µg/l	2000.0	-	1	31	729	-	-	No Further Assessment
Zinc	µg/l	-	-	50	31	335 1481 129	5	BH102A WS108 TANK	Further Assessment Required
PAH									
Cyanide	µg/l	50.0	-	50	31	130 130 570 170 150 250	12	BH101 BH102A BH103 WS104 WS108 WS9	Further Assessment Required
Napthalene	µg/l	-	-	2.4	31	10.1	5	BH102A	Further Assessment Required
Anthracene	µg/l	-	-	0.1	31	0.77 0.24	8	WS104 TANK	Further Assessment Required
Fluoranthene	µg/l	-	-	0.1	31	5.49 2.48	7	BH103 WS104	Further Assessment Required
Benzo(a)Pyrene	µg/l	-	0.7	0.05	31	0.02	-	-	No Further Assessment
Indeno(123- α)Pyrene	µg/l	-	-	0.2	31	<0.10	-	-	No Further Assessment
Benzo(ghi)Perylene	µg/l	-	-	0.2	31	<0.10	-	-	No Further Assessment
PAHs (sum of 4) ^(*)	µg/l	0.1	-	-	31	0.26 6.86	-	WS104 BH103	Further Assessment Required
TPH Aliphatics									
TPH C ₅ -C ₆	µg/l	-	15,000	20	31	<10	-	-	No Further Assessment
TPH C ₆ -C ₈	µg/l	-	15,000	-	31	46	-	-	No Further Assessment
TPH C ₈ -C ₁₀	µg/l	-	300	-	31	32	-	-	No Further Assessment
TPH C ₁₀ -C ₁₂	µg/l	-	300	-	31	<5	-	-	No Further Assessment
TPH C ₁₂ -C ₁₆	µg/l	-	300	-	31	<10	-	-	No Further Assessment
TPH C ₁₆ -C ₂₁ **	µg/l	-	300	-	31	170	-	-	No Further Assessment
TPH C ₂₁ -C ₆₅ **	µg/l	-	300	-	31	50	-	-	No Further Assessment
TPH Aromatics									
TPH C ₅ -C ₇	µg/l	-	10	-	31	92 12 19	3	BH102A BH102A WS104	Further Assessment Required
TPH C ₇ -C ₈	µg/l	-	50	-	31	<10		-	No Further Assessment

TPH C ₆ -C ₁₀	µg/l	-	300	20	31	12	-	-	No Further Assessment
TPH C ₁₀ -C ₁₂	µg/l	-	100	-	31	58	-	-	No Further Assessment
TPH C ₁₂ -C ₁₆	µg/l	-	100	-	31	60	-	-	No Further Assessment
TPH C ₁₆ -C ₂₁	µg/l	-	90	-	31	210	1	TANK	Further Assessment Required
TPH C ₂₁ -C ₃₅	µg/l	-	90	-	31	40	-	-	No Further Assessment

Notes

(*) Sum of 4 PAH is the summation of Benzo(b)Fluoranthene, Benzo(k)Fluoranthene, Benzo(ghi)Perylene and Indeno(123-Od)pyrene. The LOD is utilises as an indicative value to adopt the most conservative approach when calculating the total PAH values.

(**) WHO Guidance on Petroleum Products in Drinking Water does not provide target values for TPH Aliphatic C₁₆-C₂₁ or C₂₁-C₃₅ and so the target value of 300 µg/l for C₁₂-C₁₆ has been used to adopt a conservative approach.

With reference to Table 10.1, it can be seen that the UK DWS and FW EQS has been exceeded for the following determinants:

- Metals (Arsenic, Chromium, Lead, Nickel & Zinc);
- Cyanide;
- PAHs (Naphthalene, Anthracene & Fluoranthene & Sum of Four PAHs);
- TPH (Aromatic C₆-C₆ & C₁₆-C₂₁)

The ground investigation works undertaken to date have identified two discrete water bodies; a localised and laterally discontinuous perched water body within near surface Made Ground, as identified by groundwater strikes and seepages within locations WS104, WS106, WS107, WS108 and TP101. No water was encountered within the remaining window sample locations (WS101, WS102, WS103, WS105, WS109, WS109A and WS110) further indicating that the water body within Made Ground is laterally discontinuous and locally perched in nature.

A laterally continuous piezometric surface was encountered within the deep cable percussive boreholes, which were advanced through a confining clay horizon, with groundwater strikes encountered at depths ranging from 7.60-10.50m bgl. As such, the risk assessment below makes a distinction between the two water bodies.

Given the site history and the fact that the above determinants were found to exceed the adopted Tier I groundwater screening values, OEC have also undertaken an assessment of the concentrations detected within soils using a direct comparison to the current Tier I human health screening values for a residential end use with homegrown produce for comparative purposes.

10.2 Assessment of Soil Concentrations

A soil assessment has been undertaken as it was considered that any widespread impact which could migrate to the groundwater table would be anticipated to be present at elevated concentrations within near surface and deeper soils, if originating from the site. Data has also been extracted from the previous Soils Limited report (ref. 15214/DS) for the Qualitative Risk

Assessment. Absence of elevated concentrations within the soil profile would support the assessment that the source of impact was off-site and not directly attributed to the subject site.

At a Tier 1 stage the long term (chronic) human health toxicity of the soil has been assessed by comparing the on-site concentrations of organic and inorganic compounds with reference values published by the EA (Contaminated Land Exposure Assessment (CLEA) Soil Guideline Values (SGV)) and where absent, Generic Assessment Criteria (GACs) published by LQM/ CIEH Suitable for Use Levels (S4UL) 2015. Based on the proposed residential end use with landscaped areas across the site, OEC has adopted screening values for a residential end use with homegrown produce. The origin of the GAC values are presented within Appendix VI.

Table 10.2 Tier 1 Risk Assessment for exceedances of soils for Residential End Use without Home Grown Produce

Determinand	Units	GAC	n	MC	No. of ex	Loc. of Ex	Pathway	Assessment
Inorganics								
Arsenic	mg/ kg	40	28	48.2 46.9 109.2 76	4	WS108 (4.50m bgl) WS109A (0.60m bgl) WS109A (1.50m bgl) WS3 (6.50m bgl)	1	Further Assessment Required
Chromium (III)	mg/ kg	910	28	127.7	-	N/A	1	No Further Action
Chromium (VI)	mg/ kg	6	28	<2	-	N/A	1	No Further Action
Lead	mg/ kg	310	28	356 7552 403 713 361	5	WS106 (3.0m bgl) TP101 (1.60m bgl) WS3 (0.50m bgl) WS6 (0.80m bgl) WS4 (2.40m bgl)	1	Further Assessment Required
Nickel	mg/ kg	180	28	41.6	-	N/A	1	No Further Action
Zinc	mg/ kg	40000	28	1291	-	N/A	1	No Further Action
PAH								
Cyanide	mg/ kg	791	28	2502.6	1	WS109A (0.60m bgl)	2	Further Assessment Required
Naphthalene	mg/ kg	2.3	28	3.32 5.35 6270 2.59	4	WS105 (0.30m bgl) WS109A (0.60m bgl) WS1 (4.80m bgl) WS3 (0.50m bgl)	2	Further Assessment Required
Anthracene	mg/ kg	3100	28	22.01	-	N/A	3	No Further Action
Fluoranthene	mg/ kg	1500	28	1550	1	WS1 (4.80m bgl)	3	Further Assessment Required
Benzo(b/k)Fluoranthene	mg/ kg	110	28	112.68 184.6 632	3	WS105 (0.30m bgl) WS109A (0.60m bgl) WS1 (4.80m bgl)	3	Further Assessment Required

Benzo(ghi)Perylene	mg/kg	360	28	142	-	N/A	3	No Further Action
Indo(123-cd)Pyrene	mg/kg	45	28	45.59 64.33 211		WS105 (0.30m bgl) WS109A (0.60m bgl) WS1 (4.80m bgl)	3	Further Assessment Required
TPH Aromatic								
TPH C ₅ -C ₇	mg/kg	370	10	621	1	WS1 (4.80m bgl)	2	Further Assessment Required
TPH C ₁₆ -C ₂₁ *	mg/kg	1900	10	7293	1	WS1 (4.80m bgl)	2	Further Assessment Required
Notes Main Exposure Pathways: 1 = Soil Ingestion, 2 = Vapour Inhalation (indoor), 3 = Dermal Contact & Ingestion, 4 = Dust Inhalation. Abbreviations: GAC= General Assessment Criteria, n = number of samples, MC= Maximum Concentration; Loc of Ex = Location of Exceedance. * The Tier 1 GAC for the hydrocarbon fraction is derived from the OEHV S4UL assessment for petroleum hydrocarbons Criteria Working Group (CWG) for both aliphatic and aromatic compounds. OEHV has utilised the lowest of the aliphatic and aromatic chain lengths in order to adopt a conservative approach, which is considered satisfactory for the protection of human health. (i) Benzo (b) Fluoranthene (2.6mg/kg) Benzo (k) Fluoranthene (77mg/kg)								

With reference to Table 10.2, the results of this direct comparison demonstrate that the Tier 1 screening criteria have been marginally exceeded for the following determinands:

- Metals (Arsenic & Lead);
- Cyanide;
- PAH (Naphthalene, Fluoranthene, Benzo(b/k)Fluoranthene, Indeno(123-cd)Pyrene, Benzo(ghi)Perylene);
- TPH Aromatic C₅-C₇ and C₂₁-C₄₀.

10.3 Assessment of Perched Water

Perched water was encountered as strikes and seepages within Made Ground within locations WS104, WS106, WS107, WS108 and TP101 (Section 9.2). However, during the most recent phase of groundwater sampling, water was only encountered within locations WS104 and WS108 located slightly west of site centre. Groundwater monitoring did not identify any groundwater within locations WS101, WS102, WS103, WS105, WS109, WS109A and WS110 indicating that the water body is discontinuous.

Elevated concentrations of arsenic were found to exceed the UK DWS in perched waters in locations WS104 and WS108. It was found to exceed marginally in location WS104 with concentrations ranging from 12.0 µg/l to 17.9 µg/l compared to a screening value of 10 µg/l. However, at location WS108 concentrations were considerably higher, ranging from 155.1 µg/l to 441.2 µg/l.

Elevated concentrations of chromium, ferric iron (Fe III), nickel and zinc were also identified within location WS108 but no further exceedances for heavy metals were identified within location WS104.

An exceedance of Cyanide was identified in locations WS104 and WS108 and WS9 previously installed by Soils Limited.

Water samples from location WS108 exhibited a very low pH with values ranging from pH 1.75 to pH 1.99. These results are in contrast to location WS104, located approximately 15m to the south-east, which yielded almost neutral pH results ranging from pH 7.40 – pH 7.53.

Additional analyses were scheduled on samples from WS104 and WS108 in order to determine the cause of the low pH values. These additional analyses comprised the following anions; total dissolved sulphur (S), chloride (Cl), nitrate (NO₃) and ortho-phosphate (PO₄). The results indicated a very high concentration of dissolved sulphur (3,149mg/l) compared to location WS104 (5.61mg/l). It is therefore considered that given the concentration of total dissolved sulphur that the low pH concentrations within location WS108 are likely due to the presence of sulphuric acid (H₂SO₄) in the subsurface. The high concentrations of heavy metals within WS108 are therefore likely to be associated with acidic (low pH) conditions due to the increase in solubility of heavy metals with low pH. However, the absence of low pH conditions at location WS104 suggests that the cause of low pH conditions is localised to the vicinity of WS108.

During the monitoring visit undertaken on 20th July 2017, it was noted that the decommissioned AST adjacent to location WS108 was continuously leaking an orange coloured fluid. Anecdotal evidence from an operative on site suggested that the tank is open topped and collects rainwater, and in order to provide further information a water sample was collected from the AST for comparison purposes. The water sample from the tank exhibited elevated concentrations of zinc, anthracene (PAH) and TPH C₁₆-C₂₁, which is consistent with its former use as a fuel storage tank. The concentration of zinc is considered likely to be due to the galvanisation of the tank, which has solubilised into the collected water over time. The liquid sampled was orange in colour, which was considered to be due to the presence of suspended ferric iron oxide (Fe III). The sample was filtered on-site, which removed the majority of the orange colouration with the laboratory result yielding a dissolved Fe III concentration of 0.07µg/l.

Elevated concentrations of total dissolved chromium were recorded within perched water samples from location WS108 with a maximum concentration of 502.6µg/l.

It was noted that concentrations of total dissolved chromium did not exceed the adopted screening value (50µg/l) nor did they exceed the laboratory limit of detection of 1.5µg/l at any other locations analysed during any of the four monitoring rounds. This suggests that chromium exceedances are localised to the perched waters in the vicinity of WS108.

Elevated concentrations of PAH were identified within the perched water taken from location WS104. Anthracene showed an exceedance of the Freshwater EQS with a maximum concentration of 0.53µg/l, and an exceedance of Fluoranthene with a maximum concentration of 1.36µg/l. Anthracene and Fluoranthene are compared to a Freshwater EQS of 0.1 µg/l due to there being no UK DWS or WHO DWS screening value. It is therefore considered whilst the elevated concentrations of the PAH exceed the adopted screening

levels that do not have the potential to present a significant risk to off-site receptors as the concentrations are isolated to perched water within Made Ground at location WS108.

10.4 Assessment of Groundwater

Groundwater was encountered within the three deep cable percussive boreholes, BH101, BH102A and BH103. Elevated concentrations of heavy metals including arsenic, chromium, lead, nickel and zinc were found to exceed the UK DWS in groundwater samples from BH102A, with a single marginal exceedance of arsenic ($12.1\mu\text{g/l}$ compared to a UK DWS value of $10.0\mu\text{g/l}$) identified within BH101. Given the marginal nature of the exceedance of arsenic at location BH101, together with the absence of exceedances in the remaining five (5no) monitoring visits, this is not considered to present a significant risk to controlled waters.

Elevated concentrations of heavy metals exceeding the adopted screening criteria within location BH102A were restricted to a single sample taken on 19th October 2016 with no concentrations exceeding the screening criteria detected prior to or after this date. Given the absence of elevated concentrations of heavy metals in five out of six groundwater samples analysed, it is considered that these results are not representative of groundwater conditions present within location BH102A.

Six (6no.) exceedances were recorded for cyanide, one within BH101, two within BH103 with the remaining three (3no.) exceedances occurring within location BH102A. However, it should be noted that the exceedance of cyanide ($576\mu\text{g/l}$) detected at location BH103 on 19th October 2016 is considered to be anomalous as a repeat test undertaken subsequently yielded a concentration of $40\mu\text{g/l}$.

Elevated concentrations of PAH were identified within groundwater at locations BH102A and BH103. Location BH102A yielded two exceedances of Naphthalene with maximum recorded concentrations of $10.1\mu\text{g/l}$ and $10.9\mu\text{g/l}$ compared to an adopted screening value of $2.4\mu\text{g/l}$ (FW EQS).

Exceedances of the UK DWS sum of 4 PAHs, which comprises Benzo(b)Fluoranthene, Benzo(k)Fluoranthene, Indeno(123-cd)Pyrene and Dibenzo(a,h)Anthracene, PAHs of Anthracene and Fluoranthene were identified at location BH103 only.

A review of laboratory data indicates that these exceedances occurred during two consecutive visits (25/08/16 and 07/09/16) with concentrations significantly decreasing between the first and second visits and with all subsequent visits yielding results below the laboratory limit of detect of ($<0.01\mu\text{g/l}$) with a concentration marginally above the limit of detect ($0.04\mu\text{g/l}$) occurring on 20/07/2017.

A review of the borehole logs for locations BH101, BH102A and BH103 indicates the presence of between 3.80m and 5.00m of London Clay, which acts as confining layer to the underlying groundwater, encountered as strikes between 7.60 - 11.00m bgl within the Bognor Sand Member of the London Clay Formation. It is considered that the London Clay present

between the near surface geology and groundwater acts as an impermeable barrier which retards the downward migration of contaminants to groundwater.

The groundwater triangulation plot presented as Figure 4.0 indicates that groundwater flow is towards the south-west with a hydraulic gradient (i) of 0.0032.

10.5 Discussion

From the evidence presented above, it is evident that concentrations exceeding the Tier I screening values for groundwater and soils have been identified at the site. Perched water was identified within Made Ground at locations WS104, WS108 and historic location WS9, but was absent from all other window sample locations, indicating that groundwater is locally perched within Made Ground and is laterally discontinuous. OEC have therefore assessed perched water and groundwater separately.

Continuous levellogger data has demonstrated that groundwater flow is towards the south-west which is in agreement with the assessment made within the previous report (A10708v3.0).

Given that the highest perched water concentrations are for heavy metals within location WS108, it is considered likely that these concentrations are attributed with the low pH of perched water at this location (pH1.75-1.99) which would increase the solubility of heavy metals in the soil column. Additional analyses undertaken to identify the cause of low pH conditions (Cl, NO₃, PO₄ and S) indicate that the low pH is likely the result of sulphuric acid (H₂SO₄) as indicated by an extremely high concentration of dissolved sulphur (3,149mg/l) within perched water. However, low pH conditions appear to be localised with perched water at location WS104 returning almost neutral pH values with much lower dissolved sulphur concentrations (5.61mg/l). It is noted that during the previous phase of groundwater sampling in 2016 that location WS108 was dry, and it is considered that the presence of groundwater during the most recent sampling rounds could be attributed to a decommissioned AST (formerly used to store fuel) which is understood to fill with rainwater and overflow. However, during the recent water sampling rounds the tank was observed to have ruptured resulting in a continuous discharge of ferruginous water to a nearby drain. Given that the drain was observed to be in a poor condition, it is possible that the leaking tank could potentially contribute to the presence of perched water within WS108.

It is considered that the presence of elevated concentrations identified in WS104 and WS108 are associated with perched water, which is restricted to Made Ground. Given the depth difference between perched water and groundwater, together with the presence of a layer of London Clay up to 5.00m in thickness, it is considered that perched water is a separate water body which is not in hydraulic continuity with deeper groundwater and therefore does not pose a significant risk to controlled waters.

Up on review of previous monitoring results, elevated concentrations of heavy metals were identified in groundwater within BH102A located close to the eastern boundary of the site, with a single marginal exceedance of arsenic within BH101. All exceedances within location

BH102A were detected in a single sample from 19th October 2016, with both earlier and later monitoring rounds showing no exceedances for metals. These results have tentatively been considered anomalous and not representative of groundwater conditions beneath the site. However, it is noted that BH102A is the closest monitoring point to a neighbouring site which comprises a historic gravel pit, considered to have been formerly part of the gasworks and subsequently infilled, based on historical and GIS data provided by the Local Authority. The nature of infill is unknown and it is considered that the infilled pit remains a potential source of these concentrations, although subsequent monitoring has not reproduced the elevated concentrations detected on 19/10/2016.

Furthermore, the absence of elevated concentrations of heavy metals within neighbouring deep boreholes containing groundwater suggests that the historic on-site use is unlikely to be the source of elevated concentrations of metals present within groundwater.

The Tier I screening values for anthracene, Fluoranthene and Sum of 4 PAHs were exceeded on two occasions within location BH103. However, a review of the data indicates that the highest concentrations were recorded during the first round of low-flow monitoring (25/08/16) with concentrations rapidly decreasing, although still exceeding, on the next visit (07/09/16). All samples taken post-07/09/2017 have yielded results below the laboratory limit of detection. It is therefore considered that the initial elevated concentrations could have been caused by drilling disturbance with concentrations decreasing as equilibrium conditions were reached with negligible concentrations recorded during the most recent sampling rounds.

A concern regarding the risks posed to the deep Principal Aquifer within the Chalk were raised by the EA. However, utilising the BGS hydrogeological map for the area, it is estimated that the top of the Chalk Aquifer which supplies Bedhampton Springs is located approximately 50m below sea level (-50mAOD). Given that the elevation of the site is on average 12m above sea level (12mAOD), the top of the chalk is considered to be located approximately 62m bgl. Given the thickness of London Clay Formation overlying the Chalk, it is considered unlikely that any concentrations within near surface soils, perched water or groundwater, if present, pose a significant risk to the Principal Aquifer.

Location BH103 (located in the south-west of the site) is considered to be most representative of groundwater conditions flowing off-site given the south-westerly groundwater flow direction demonstrated by continuous groundwater monitoring. With the exception of two transient exceedances of PAHs, attributed to disturbance caused by drilling activities, and a single marginal exceedance of cyanide, groundwater samples from location BH103 do not consistently exceed the UK DWS values adopted as screening criteria for the site.

Based on the data presented within this report, OEC therefore do not consider that groundwater concentrations beneath the site pose a significant risk to Controlled Waters.

11.0 REVISED CONCEPTUAL SITE MODEL – CONTROLLED WATERS

Upon completion of the Controlled Waters Risk Assessment, no active pollution pathways have been identified in relation to the risk to Controlled Waters.

12.0 CONCLUSIONS & RECOMMENDATIONS

Revised Conceptual Site Model – Controlled Waters
Upon completion of the Risk Assessment, no active pollution pathways have been identified in relation to the risk to Controlled Waters.
Recommendations
A Remediation Method Statement (RMS) should be prepared for the site to address risks posed to future site users from near surface soils, as set out in OEC Report A10708/ 1.1 and summarised within Section 6.3.1 of this report. It is recommended that a Piling Risk Assessment is prepared to assess the potential risk to Controlled Waters during the piling process. Consideration should be given to the potential for mobilisation of near surface contaminants into the underlying aquifer through potential bridging of the underlying aquitard (London Clay). Depending on pile depth consideration should also be given for the potential for turbidity on the aquifer. Should additional sources or evidence of contamination be encountered during site works, works should be halted and contact made with a suitably qualified Environmental Consultant. At this stage, further investigation and risk assessment should be undertaken, and contact made with the Local Authority.

APPENDIX I
LIMITATIONS

1. This report and its findings should be considered in relation to the terms of reference and objectives agreed between OE Ltd and the Client as indicated in Section 1.2.
 2. For the work, reliance has been placed on publicly available data obtained from the sources identified. The information is not necessarily exhaustive and further information relevant to the site may be available from other sources. When using the information, it has been assumed it is correct. No attempt has been made to verify the information.
 3. This report has been produced in accordance with current UK policy and legislative requirements for land and groundwater contamination, which are enforced, by the local authority and the Environment Agency. Liabilities associated with land contamination are complex and requires advice from legal professionals.
 4. During the site walkover, reasonable effort has been made to obtain an overview of the site conditions. However, during the site walkover no attempt has been made to enter areas of the site that are unsafe or present a risk to health and safety, are locked, barricaded, overgrown, or the location of the area has not been made known or accessible.
 5. Access considerations, the presence of services and the activities being carried out on the site limited the locations where sampling locations could be installed and the techniques that could be used.
 6. Site sensitivity assessments have been made based on available information at the time of writing and are ultimately for the decision of the regulatory authorities.
 7. Where mention has been made to the identification of Japanese Knotweed and other invasive plant species and asbestos or asbestos-containing materials this is for indicative purposes only and do not constitute or replace full and proper surveys.
 8. The executive summary, conclusions and recommendations sections of the report provide an overview and guidance only and should not be specifically relied upon without considering the context of the report in full.
 9. OE cannot be held responsible for any use of the report or its contents for any purpose other than that for which it was prepared. The copyright in this report and other plans and documents prepared by OE is owned by them and no such plans or documents may be reproduced, published or adapted without written consent. Complete copies of this may, however, be made and distributed by the client as is expected in dealing with matters related to its commission. Should the client pass copies of the report to other parties for information, the whole report should be copied, but no professional liability or warranties shall be extended to other parties by OE in this connection without their explicit written agreement there to by OE.
 10. New information, revised practices or changes in legislation may necessitate the re-interpretation of the report, in whole or in part.
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APPENDIX II

GLOSSARY

AST	ABOVE GROUND STORAGE TANK
BGS	BRITISH GEOLOGICAL SURVEY
BSI	BRITISH STANDARDS INSTITUTE
BTEX	BENZENE, TOLUENE, ETHYLBENZENE, XYLENES
CIEH	CHARTERED INSTITUTE OF ENVIRONMENTAL HEALTH
CIRIA	CONSTRUCTION INDUSTRY RESEARCH ASSOCIATION
CLEA	CONTAMINATED LAND EXPOSURE ASSESSMENT
CSM	CONCEPTUAL SITE MODEL
DNAPL	DENSE NON-AQUEOUS PHASE LIQUID (CHLORINATED SOLVENTS, PCB)
DWS	DRINKING WATER STANDARD
EA	ENVIRONMENT AGENCY
EQS	ENVIRONMENTAL QUALITY STANDARD
GAC	GENERAL ASSESSMENT CRITERIA
GL	GROUND LEVEL
GSV	GAS SCREENING VALUE
HCV	HEALTH CRITERIA VALUE
ICSM	INITIAL CONCEPTUAL SITE MODEL
LNAPL	LIGHT NON-AQUEOUS PHASE LIQUID (PETROL, DIESEL, KEROSENE)
ND	NOT DETECTED
LMFL	LOWER METHOD REPORTING LIMIT
NR	NOT RECORDED
PAH	POLY AROMATIC HYDROCARBON
PCB	POLY-CHLORINATED BIPHENYL
PID	PHOTO IONISATION DETECTOR
QA	QUALITY ASSURANCE
SGV	SOIL GUIDELINE VALUE
SPH	SEPARATE PHASE HYDROCARBON
SP.TPH (CWG)	TOTAL PETROLEUM HYDROCARBON (CRITERIA WORKING GROUP)
SPT	STANDARD PENETRATION TEST
SVOC	SEMI VOLATILE ORGANIC COMPOUND
UST	UNDERGROUND STORAGE TANK
VOCs	VIBRO CONCRETE COLUMNS
VOC	VOLATILE ORGANIC COMPOUND
WTE	WATER TABLE ELEVATION
UNITS	
M	METRES
KM	KILOMETRES
%	PERCENT
%V/V	PERCENT VOLUME IN AIR
MB	MILLI BARS (ATMOSPHERIC PRESSURE)
L/HR	LITRES PER HOUR
µG/L	MICROGRAMS PER LITRE (PARTS PER BILLION)
PPB	PARTS PER BILLION
MG/KG	MILLIGRAMS PER KILOGRAM (PARTS PER MILLION)
PPM	PARTS PER MILLION
MG/M ³	MILLIGRAM PER METRE CUBED
M BGL	METRES BELOW GROUND LEVEL
M BCL	METRE BELOW COVER LEVEL

MAOD	METRES ABOVE ORDNANCE DATUM (SEA LEVEL)
KN/M ²	KILO NEWTONS PER METRE SQUARED
μM	MICRO METRE