



**I.4                    2009 – PB Ltd – Phase 2 Intrusive Site Investigation**

SCOTTISH POWER

**ENVIRONMENTAL ASSESSMENT,  
UNITS 2B & 3 AT DAMHEAD CREEK  
POWER STATION, KINGSNORTH  
ROCHESTER, KENT**

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**COMMERCIAL IN CONFIDENCE**

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## **EXECUTIVE SUMMARY**



Scottish Power has commissioned Parsons Brinckerhoff Ltd to undertake a site investigation and risk assessment of Units 2B & 3 at Damhead Creek Power Station, Kingsnorth, Rochester, Kent. The objectives of the study were to determine the nature and extent of contaminants potentially present at the site in accordance with the procedures set out with the EA report CLR 11.

<b>Preliminary Risk Assessment</b>	<b>Site History</b>	Fuel/product storage tanks were present on the western tip of the site (Unit 3 area) as early as 1914, and by 1966 bulk storage tanks associated with the adjacent oil refinery were present across the rest of Unit 3. The tanks were reportedly demolished following the decommissioning of the oil refinery during the 1980's. Whilst the area of Unit 2B has remained undeveloped, it has been subject to landfilling initially with material dredged from Damhead Creek during the construction of the Kingsnorth Power Station in the mid to late 1960's and latterly with PFA and inert wastes.
	<b>Geology &amp; Hydrogeology</b>	The site is underlain by alluvial drift deposits and the river terrace deposits. These drift deposits are likely to be classified as a minor aquifer and will likely be in hydraulic connection with the adjacent estuary waters. These overlie the London Clay non aquifer and the Chalk Major Aquifer.
	<b>Hydrology</b>	<p>Damhead Creek, a tidal tributary of the River Medway lies approximately 100m to the east of the site, and joins the Medway approximately 2km to the south.</p> <p>Several freshwater and brackish water ponds, originally used for dust suppression during PFA deposition, exist in the eastern and central sections of Unit 2B.</p> <p>Drainage ditches can be found to the south and west of Unit 2B and along the northern border of Unit 3.</p> <p>Berry Wiggins drain flows east to west approximately 200m to the north of the site through a wetland pond and into Damhead Creek.</p>
<b>Site Investigation</b>	<p>The site investigation was undertaken between 17<sup>th</sup> and the 28<sup>th</sup> November 2008, under the full time supervision of a PB Engineer and comprised the following:</p> <p>A total of 31No. trial pits were excavated by a Komatsu 360° PC130 excavator to a maximum depth of 4.7m BGL</p> <p>Excavation and installation of 7No. boreholes to a maximum depth of 15.5m using a Pioneer 2 Rotary Rig. Each borehole was installed into the River Terrace Deposits for ground gas and groundwater monitoring.</p> <p>A total of 2No. rounds of gas and groundwater monitoring were undertaken which resulted in the taking of a total of 12No groundwater samples. All 12 samples were submitted for laboratory analysis.</p> <p>A total of 138 soil samples were taken during the site works with 99No. samples submitted for laboratory analysis including 18No. for leachate analysis.</p> <p>All site works were undertaken in accordance with BS10175: 2001 ('Investigation of Potentially Contaminated Sites'), and were completed without incident.</p>	
<b>Risk Assessment and Recommendations</b>	<b>Human Health</b>	



With the exception of the presence of asbestos the material on site is likely to be suitable for use in terms of potential risk to human health.

The land quality risk assessment involved the comparison of land quality data with risk based guideline values in line with the current land use, (in this instance commercial/industrial land use was adopted). No concentrations were reported in excess of the selected GAC for human health. One soil sample out of the 17No analysed for asbestos returned a positive result for Chrysotile asbestos. The sample was a piece of suspected asbestos cement retrieved from TP130@0.15m bgl. Similar pieces of cement were observed in TP109 and BH205. These were associated with the PFA material in Unit 2B.

Outside of the proposed purchase site potential risks to end users of the proposed commercial development have been identified by ERM within Zone IV North. This zone is to the north of Unit 2B. The PB investigation has not indicated such contamination to be present in the soil or groundwater under Unit 2B and as such it is considered unlikely this impaction will have an effect on this area.

However, one aspect of the construction phase of the proposed development will be the 'cut-and-fill' operations required to achieve the final desired profile necessary for both flood defence measures and providing the development platforms for the various proposed buildings. This will entail the movement of material between and within Unit 2B and Unit 3 only. It is understood that Goodman's are to undertake this operation before handing the site to Scottish Power. Movement of material between the sites should be verified via sampling and analysis to ensure that that any 'cut-and-fill' operations by Goodman render the land suitable for use and able to facilitate the proposed Scottish Power industrial development of the site.

Should Scottish Power have to undertake the works themselves they will also need to ensure the site is suitable for use. A number of remedial solutions are likely to be effective at mitigating potential direct contact risks with any limited additional asbestos containing material that may be found. The most cost effective solution is likely to be the re-use of material beneath hardstanding or at depth.

During PB's site work a small shed was also noted on the site that may contain asbestos containing material. This and any impacted soils will need to be removed by Goodmans during there groundwork. Alternatively Scottish Power will need to make provision for its removal. Assuming this does contain hazardous waste this might cost in the region of £20-40K to remove.

#### **Ground Gas Risk Evaluation**

VOC concentrations were typically recorded with the PID below 5ppm. Elevated peak concentrations were recorded within a number of excavations. However, soil analysis did not indicate a viable source of the volatiles be present in the vadose zone at the site we would expect this to be noted from the soil and groundwater analysis undertaken. Guidance on assessing the risk posed by hazardous ground gases is given within CIRIA Report 665. The worst case conditions have been adopted in order to establish the appropriate protection measures required at the site.

The site has been determined as Characteristic Situation 2 (low risk) and is



consistent with 'typical' Made Ground. Special protection measures will be required to be incorporated in to the build at the site.

ERM's conclude a Characteristic Situation of 3/4 for land inclusive of Unit 2B. This is based on results obtained from ERM-installed boreholes which were not included in the monitoring rounds undertaken for this report. It is also noted that the PB monitoring has been limited to three occasions to date. Whilst it is clear that some gas protection is likely to be required the type and hence cost cannot be defined at present. As a worst case the ERM recommendations could be followed. However at present the type of structure to be constructed by Scottish Power on Units 2B and 3 are not defined. This will be important in defining what protection measures will be required. However it is also suggested that further monitoring of all boreholes on Unit 2B be undertaken for a more accurate Characteristic Situation to be derived over time.

It will be important to ensure that appropriate water supply pipes are installed by Goodman's should they undertake the infrastructure works

### **Controlled Water Risk Evaluation**

Elevated concentrations of contaminants of concern have been observed in groundwater results and soil leachate results.

There were four leachate exceedances of the selected screening criteria, including 3No. exceedances of Selenium at 14mg/kg and 21mg/kg, and 1No. exceedance of Chromium at 19mg/kg. These were associated with the PFA material in Unit 2B.

There were exceedances of the groundwater assessment criteria for Chromium, Copper and Selenium within samples from all four boreholes on Unit 2B, with one sample from BH201 displaying exceedances of five PAHs. These are likely associated with the PFA material in Unit 2B.

BH206 showed exceedances of Nickel, with BH203 and BH205 showing exceedances of heavy end aliphatic and aromatic TPH in Unit 3. These are likely associated with the site's former use as part of an oil refinery.

This suggests that there is a potential pollutant linkage to controlled waters from the site.

However, based on information in the ERM report there is no evidence to indicate that the adjacent surface water has been adversely impacted by existing elevated concentrations within the groundwater, which may indicate that little if any significant off-site migration occurring.

Furthermore, the risk assessment carried out does not allow for dilution by the waters of the underlying Minor Aquifer. It is expected that if considering dilution effects, that the risk assessment would show that contaminant concentrations in the minor aquifer as water enters Damhead Creek are unlikely to exceed environmental water quality standards. Therefore this risk maybe removed following further risk assessment.

A DQRA including full hydraulic modelling would need to be carried out in order to be entirely confident in defining that the contamination noted in the groundwater is not affecting the Damhead Creek. This is likely to be a requirement of any planning permission granted by the local authority.

If Goodman's carry out the infrastructure works at the site it will be important for Scottish Power to ensure that the works undertaken are considered by the



EA as rendering the site suitable for use with respect to the limited source of hydrocarbon contamination found. The works should be supervised and validated by a third party engineer. It is likely that these works will be identified to be necessary by the planning permission and associated planning conditions authorising the development. If however this is the case it will also be important the Scottish Power are not bound to implement parts of these planning conditions on areas of the site that are not to be owned by them.

If Scottish Power end up undertaking the works they will also need to be sure that the site is suitable for use from a Controlled Waters point of view. This could either be through the modelling described above or via limited remediation.

### **Waste Licensing**

It is understood that Goodmans are to obtain a site licence which authorises the excavation, re-deposition and therefore recovery of the waste and this is linked to a planning permission authorising the activity. In the case a site licence will also require surrendering following completion of site works and when waste materials have been re-used and can be demonstrated to have been fully recovered. The most appropriate way forward with respect to the implementation of the waste management licensing regime will be determined following consultation and agreement with the Environment Agency. It will be important to note that this license will likely cover land to be owned by Scottish Power. The legal ramification of this need to be fully understood by Scottish Power.

In summary it is considered that provided Goodmans undertake the works as per the specification or Scottish Power make appropriate provision to undertake the works outlined it is likely this site can be made to be suitable for its intended use.

All conclusions are based upon the development of the site for commercial end use comprising the construction of an electricity sub station on Unit 3 and the use of Unit 2B as a welfare and construction lay down area during the construction, with a view to the installation of a carbon capture plant in the future. Should design changes to this proposal occur, re-examination of the data will be necessary.

SECTION 1

**PRELIMINARY RISK ASSESSMENT**

## 1 INTRODUCTION

### 1.1 Context and Objectives

- 1.1.1 Scottish Power has commissioned Parsons Brinckerhoff Ltd (PB) to undertake a site investigation and risk assessment at Units 2B & 3 at Damhead Creek Power Station, Kingsnorth, Rochester, Kent.
- 1.1.2 The objectives of the study were to obtain and to determine the chemical composition of the soil and groundwater in regard to soil and dissolved phase contamination, in accordance with the procedures set out within the EA report CLR 11.
- 1.1.3 All work has been undertaken in accordance with PB's email dated 12 November 2008 to Scottish Power and, to the extent possible, the Environment Agency document CLR11 'Model Procedures for the Management of Land Contamination'.

### 1.2 Limitations

- 1.2.1 PB has prepared this report for the sole use of Scottish Power (the Client) in accordance with generally accepted consulting practices and for the intended purposes as stated in the agreement under which this work was completed. This report may not be relied upon by any other party without the explicit written agreement of PB. No other third party warranty, expressed or implied, is made as to the professional advice included in this report. This report must be used in its entirety.
- 1.2.2 Unless otherwise stated in this report, the assessments made assume that the site and facilities will relate to current site use and no account has been taken for change of use requirements that may be required by the freeholder or any planning authority.
- 1.2.3 The records search was limited to information available in a confidential manner from Scottish Power, the Landmark<sup>®</sup> Information Group and public sources regulatory authority have been contacted regarding this work. Information provided to Landmark is changing continually and frequently incomplete. Unless PB has actual knowledge to the contrary, information obtained from interviews or provided to PB by site personnel and other information sources has been assumed to be correct. PB does not assume any liability for misrepresentation of information or for items not visible, accessible, or present on the subject property at the time of the site reconnaissance or site investigation.

### 1.3 Integrated Management System Control

- 1.3.1 PB operates under an Integrated Management System. The Management System comprises the processes necessary for effective operation of the business and is designed to meet the requirements of BS EN ISO 9001:2000, BS EN ISO 14001:2004 and HSG65 for Health and Safety.

#### Safety Management

- 1.3.2 Site works/visits, as well as office based work has been undertaken in accordance with PB's Integrated Management System – Safety Management Series which operates within the standard outlined in HSG65.

### Quality Control

- 1.3.3 The preparation of this report has been undertaken in accordance with PB's Integrated Management System – Quality Control Series which operates within the standard outlined in ISO 9001 (UL Certificate and File No. A9384).

### Environment Management

- 1.3.4 The design and implementation of this project has been undertaken in accordance with PB's Integrated Management System - Environmental Management System Series that has been developed in line with ISO 14001 (UL Certificate and File No. A12283).

## **1.4 Site Referencing Information**

- 1.4.1 Site referencing information is provided within Table 1.1, and the site location is shown on Figure 1.

**Table 1.1: Site Referencing Information**

<b>Name of Site</b>	Units 2B & 3
<b>Address of Site</b>	Damhead Creek Power Station, Kingsnorth, Rochester, Kent
<b>Size of Site</b>	Approximately 20.07 Ha
<b>NGR</b>	581210, 173050
<b>Site Ownership</b>	The site is owned by Goodman
<b>Site Occupation</b>	Vacant land which is currently non-operational. An application for outline planning permission was submitted in December 2007 by Goodman for the future development of large commercial units/warehouses on the site and surrounding area.
<b>Proposed Site Use</b>	Construction of an electricity sub station on Unit 3. Use of Unit 2B as a working welfare and construction lay down site for use during construction of electricity sub station on Unit 3 and Damhead Creek II Power Station, with a view to potentially constructing a carbon capture plant at some point in the future.

## **1.5 Previous Prepared Reports by PB**

- 1.5.1 A previously prepared report has been compiled for the site:
- Phase 1 Environmental Desk Study –Goodman Land (Units 2B & 3), December 2008, PB Ltd.
- 1.5.2 The reports were commissioned by Scottish Power in order to establish the preliminary environmental status of the site, and to identify any potential environmental risks and liabilities associated with current or historical activities.
- 1.5.3 Please refer to the Phase 1 Environmental Desk Study report for a complete preliminary risk assessment.

## 1.6 Previous Prepared Reports by third parties

### 1.6.1 Kingsnorth – Environmental Investigation & Risk Assessment

1.6.2 The above mentioned report was produced by Environmental Resources Management (ERM) in February 2008 for Goodman Ltd and details site works undertaken by ERM during September 2007. The report addresses an area which, although encompasses the majority of the subject site of this report (~21 Ha), extends northwards covering a total area of 82ha (including 14ha of non-developable ecological mitigation land)

1.6.3 As part of the site work undertaken by ERM, 18No. deep boreholes reaching depths of between 13.8m and 17.0m 13No. shallow boreholes reaching depths of between 3.7m and 5.0m and 42No. trial pits reaching depths of between 1.6m and 5.0m were advanced across the site. Of these, 4No. deep boreholes, 5No. shallow boreholes and 10No trial pits were excavated within the boundaries of the subject site of this report.

1.6.4 Strata encountered in Zone I (incorporating Unit 3) during the investigation comprised Made Ground of silts and gravels to depths of up to 3.7m below ground level (bgl) with some areas displaying visual and olfactory evidence of contamination in the form of hydrocarbon odours and tar deposits. Underlying this were natural superficial alluvial and salt marsh deposits and river terrace deposits to depths of 9.0m bgl.

1.6.5 Strata encountered in Zone IV (incorporating Unit 2B) during the investigation comprised Made Ground of Pulverised Fuel Ash (PFA) to depths of up to 3.0m bgl underlain by river dredgings to depths of up to 6m bgl. London Clay was encountered across the site at depths greater than 13.0m bgl.

### Conclusions

1.6.6 Samples from three boreholes in Zone I (outside of the subject site of this report) showed elevated concentrations of lighter end Aliphatics and lower end Aromatics. One location within the boundary of Unit 3 (TP29) showed elevated concentrations of Total Petroleum Hydrocarbons (TPH) in the carbon chain length (C) C21 – C40, the highest concentration being 21080 mg/kg. However, further statistical analysis using the mean and maximum value tests suggested that long term exposure to site soils was likely to be significantly below the assessment criteria and therefore acceptable.

1.6.7 Poly Chlorinated Biphenyl (PCB) congener 28 were encountered across Zone IV at relatively low concentrations between 0.053 ug/kg and 1.87ug/kg, although no assessment criteria were available to compare against. All other contaminants of concern to human health were recorded at concentrations below their relevant screening values or below laboratory detection limits.

1.6.8 Concrete bound asbestos samples were encountered in a trial pit in the northern section of Zone IV

1.6.9 Samples from Zones I and IV returned a few isolated, slightly elevated organics within leachate, perched water and groundwater. Free product was encountered in one borehole in the north of Zone IV (outside of the subject site of this report). Elevated metal and ammoniacal nitrogen concentrations were detected within leachate, perched water and groundwater in Zones I and IV, but not in surface waters. All determinands were run through the ConSim probabilistic model based on the Environment Agency's P20 methodology and the results compared to Environmental Quality Standards (EQS) Marine standards, World Health Organisation (WHO)

Drinking water standards, or to background water quality from a borehole at the highest gradient.

- 1.6.10 It was concluded that infiltration rates would be significantly diminished due to the high proportion of hard standing proposed as part of the development (distribution warehouses). Additionally, it was concluded that migration of contaminants and adverse impact on adjacent surface waters was unlikely to be occurring.
- 1.6.11 Ground gas monitoring was undertaken on one occasion and identified potentially significant concentrations of methane (>1%) originating from boreholes with response zones located in the alluvial deposits in Zone I and IV, carbon dioxide (>5%) in Zone IV and relatively low flow rates excepting one borehole each in Zone I and IV. The results when considered with guidance in the CIRIA Report C659 show that Zones I and IV are within Characteristic Situations 2 and 3 respectively. However, the guidance also states that a low sensitivity development on a low gas generation potential site such as the subject site would require data from six monitoring visits over a 2 month period and as such, further rounds of monitoring would be required in order to accurately characterise the gas regime of the site.

#### Recommendations

- 1.6.12 The report recommendation for areas within the subject site of this report were that further gas monitoring should be undertaken in order to fully characterise the gas regime on site.
- 1.6.13 With reference to the effect of contaminants on potable water supply pipes, elevated concentrations of largely arsenic and chromium were observed across the site, along with elevated concentrations of petroleum hydrocarbons. As such, the report recommends special consideration to be taken when selecting bedding materials for new service pipes.
- 'Kingsnorth, Land Contamination Further Investigation and Risk Assessment Works'
- 1.6.14 This report, also by ERM, was produced as an addendum to the February 2008 report and details further investigation and assessment works carried out between April and August 2008. These works were undertaken in order to address the outstanding issues identified by the February 2008 report.
- 1.6.15 A total of 42 trial pits were excavated along with the installation of 27 further monitoring wells. Only 2No. of the further boreholes were installed within the area of Unit 3 and 1No. in the area of Unit 2B. None of the further trial pits were installed within the subject site of this report. A further five monthly rounds of gas monitoring were undertaken from all available installed boreholes.
- 1.6.16 Soil samples from the further investigation were analysed for TPH, metals and Poly Aromatic Hydrocarbons (PAH). The analysis results were compared against published Soil Guideline Values for commercial land use, irrespective of depth or location. This conservative approach was adopted with the knowledge that significant cut and fill operations were likely to take place prior to any planned development and that as a result, it could not be known at that stage what material would ultimately form the upper horizon of the site. All samples taken from the subject site showed all analysed contaminants to be at concentrations either below relevant screening values or below laboratory detection limits.
- 1.6.17 The ground gas regime of the site was analysed further with the results of five further rounds of monitoring undertaken between April and August 2008. Using the CIRIA

guidance, Zone I and IV were calculated as having gas characteristic situations 2 and 3/4 (depending on future foundation plans), respectively. The high classification for Zone IV results, partly, from the high methane levels associated with product degradation in the north of the zone which is outside of the area of Unit 2B. However, methane concentrations greater than 1% were consistently recorded in three boreholes in Zone IV, one of which (DBH17) lies within the south eastern section of Unit 2B.

### Recommendations

- 1.6.18 The areas of Unit 3 and 2B within Zone I and IV respectively are subject to recommendations in response to the gas regime classifications and comprising the installation of BS8485 Level 1 gas protection measures in an industrial building for Zone I and the installation of BS8485 Level 3 gas protection measures in an industrial building for Zone IV.

## **1.7 Geological and Hydrogeological Information**

- 1.7.1 The geology and hydrogeology of the site can be found in Table 1.2 below:

**Table 1.2: Geology & Hydrogeology**

Formation	Aquifer Classification	Flow Mechanism (if applicable)
Made Ground	Non Aquifer	-
Alluvial / River Terrace Deposits	Minor Aquifer	Intergranular
London Clay Formation	Non Aquifer	-

- 1.7.2 The geological succession identified during the site investigation works undertaken by PB is summarised within Section 2.

## **1.8 Hydrological and Drainage Information**

- 1.8.1 The site lies approximately 10m to the east of Damhead Creek. Groundwater below the site will be relatively shallow and is likely to be hydraulically connected with the adjacent Damhead Creek and Medway Estuary.
- 1.8.2 Ponds exist on the central and eastern areas of Unit 2B.
- 1.8.3 Man made drainage ditches features occupy mitigation land to the south and west of Unit 2B with a drainage ditch running along the northern boundary of Unit 3
- 1.8.4 The Barry Wiggins drain flows from west to east into a wetland pond area to northeast of site (Unit 2B) and then via gravity sluice gates (tide locked) into Damhead Creek
- 1.8.5 Service plans obtained indicate that no water mains run across the site.

## **1.9 Conceptual Site Model**

- 1.9.1 On the basis of the information summarised above, a conceptual site model (CSM) has been developed for the site. The CSM is used to guide the investigation activities at the site and identifies potential contaminants, receptors (both on and off-site) and exposure pathways that may be present. The identification of such potential "pollutant linkages" is a key aspect of the evaluation of potentially contaminated land.

1.9.2 Potential pollutant linkages identified at the site are detailed within Table 1.3.

**Table 1.3: Potential Pollutant Linkages**

Contaminant(s)	Pathway(s)	Receptor(s)
<b>Landfilled material on Unit 2B</b>	Ingestion, inhalation and/or dermal contact with contaminated materials in soils, surface water or windblown	Site workers during future site development
	Dissolution and leaching into groundwater and surface water of mobile soil contaminants	Controlled waters (shallow and perched groundwater and ponds)
	Migration of contaminated groundwater and surface water	Controlled waters (surface waters such as ponds, ditches and Damhead Creek)
	Chemical attack of foundations (e.g. piles) and services through direct contact with aggressive ground conditions	Property (i.e. foundations) and services on-site
<b>Made Ground on Units 2B and 3</b>	Ingestion, inhalation and/or dermal contact with contaminated materials in soils, surface water or windblown	Site workers during future site development
	Dissolution and leaching into groundwater and surface water of mobile soil contaminants	Controlled waters (shallow and perched groundwater)
	Migration of contaminated groundwater and surface water	Controlled waters (surface waters such as drainage ditches and ultimately Damhead Creek)
<b>Natural alluvial deposits</b>	Migration of soil gas (Methane and Carbon Dioxide) into buildings and voids from underlying alluvial deposits	Property and buildings (explosive risk)
	Migration of soil gas (Methane and Carbon Dioxide) into buildings and voids from underlying alluvial deposits	Site workers and future site occupants
<b>Off-site contamination</b>	Ingestion, inhalation and/or dermal contact with windblown contaminated materials (principally from adjacent areas of PFA)	Site workers and future site occupants
	Dissolution and leaching into groundwater and surface water of mobile soil contaminants	Controlled waters (shallow and perched groundwater)
	Migration of contaminated groundwater and surface water	Controlled waters (surface waters such as ponds, ditches and Damhead Creek)

1.9.3 It should be noted that the identification of potential pollutant linkages does not indicate that they are significant in any way or that the site is unsuitable for its current use. It does however act as a way of focusing data collection at the site, as explained in Section 2.

SECTION 2

**SITE INVESTIGATION**

## 2 SITE INVESTIGATION

### 2.1 Rationale for Site Investigation and Specific Objectives

2.1.1 The site investigation has been undertaken in accordance with CLR11 and associated statutory guidance, incorporating a desk study (also completed by PB) followed by an intrusive investigation. Recommendations for further investigation and/or remedial options would be dependant on the findings of this study.

2.1.2 It is understood that the site will be developed for commercial/industrial use. Consequently, Scottish Power require PB to provide an appropriately detailed site investigation and quantitative risk assessment to define the nature and extent of any contamination at the site.

2.1.3 The site investigation has been designed to test the validity of the conceptual site model and all the potential pollutant linkages previously identified. The key drivers for the site being:

- The risk to human health (particularly construction workers);
- The risk to controlled waters surrounding (ponds, ditches and Damhead Creek) and beneath the site; and
- The risk to property and buildings.

2.1.4 The investigation will, therefore, focus on collecting data on the following:

- Quality of Made Ground/natural ground within the site boundaries;
- Presence of anthropogenic ground gas and vapours at the site;
- Presence and quality of perched groundwater beneath the site; and
- Leachability of contaminants into the underlying Minor Aquifer.

2.1.5 Our soil sampling rationale for the site investigation has been developed with reference to the Environment Agency (EA) guidance 'Secondary Model Procedures for the Development of Appropriate Soil Sampling Strategies for Land Contamination' (Technical Report P5-066/TR). Using this guidance, an approximate grid size of 75m was selected for the non-targeted sampling of soils giving an 80% confidence in detecting a circular area of interest (hotspot) of 500m<sup>2</sup>. Sample locations were also selected with regard to the previous exploratory hole locations undertaken by ERM in February 2008, to ensure comprehensive site coverage and minimal duplication of investigated areas. Borehole locations were selected to enable investigation of groundwater, ground gas and vapours across Units 2B and 3.

### 2.2 Methods of Site Investigation

2.2.1 The site investigation was undertaken between the 17<sup>th</sup> and 28<sup>th</sup> November 2008, under the full time supervision of PB Engineers. The scope of the works are detailed within Table 2.1.

**Table 2.1: Scope of Site Investigation**

Works	Rationale
Up to 7 No. boreholes to be excavated (to approximately 15.0m BGL) across the site.	Unit 2B has historically been used to fill material dredged from Damhead Creek and later with the placement of PFA and inert wastes. Unit 3 has historically been used for fuel/product/bulk oil refinery storage. As a result of these

**Table 2.1: Scope of Site Investigation**

Works	Rationale
<p>A minimum of two soil samples to be collected and analysed from each borehole.</p> <p>Where visual and/or olfactory evidence of contamination is detected above the water table, leachate preparation and analysis will be carried out.</p>	<p>historical activities and results of previous investigations, it is possible that elevated concentrations of contaminants are present within shallow and deep soils.</p> <p>As a minimum, one soil sample will be taken from the top 1.0m BGL and further samples taken within each change of stratum thereafter. This will enable PB to determine the chemical composition of the soil. Chemical analysis of soil samples will be determined based upon visual and olfactory evidence of contamination, in-situ tests and to enable characterisation of soil strata across the site.</p> <p>The analysis of leachate will enable PB to assess any risks posed from contaminants in soil of the unsaturated zone to the underlying Minor Aquifer.</p>
<p>Installation of up to 7 No. boreholes for ground gas and vapour monitoring.</p> <p>Up to four rounds of groundwater monitoring and sampling to be undertaken.</p> <p>Up to four rounds of ground gas and vapour monitoring to be undertaken.</p>	<p>The installation of boreholes for groundwater monitoring and sampling will enable PB to assess the direction and quality of groundwater underlying the site (Minor Aquifer).</p> <p>The monitoring of boreholes will enable PB to assess any risks to human health arising from elevated ground gas and vapour concentrations.</p>
<p>Up to 35 No. trial pits to be excavated (maximum depth 5.0m BGL) across the site.</p> <p>A minimum of two soil samples to be collected from each trial pit.</p> <p>Where visual and/or olfactory evidence of contamination is detected above the water table, leachate preparation and analysis will be carried out.</p>	<p>As a result of the historical site activities, and results of previous investigations it is possible that elevated concentrations of contaminants are present within shallow soils.</p> <p>As a minimum, one soil sample will be taken from the top 1.0m BGL and further samples taken within each change of stratum thereafter. This will enable PB to determine the chemical composition of the soil. Chemical analysis of soil samples will be determined based upon visual and olfactory evidence of contamination, in-situ tests and to enable characterisation of soil strata across the site.</p> <p>The analysis of leachate will enable PB to assess any risks posed from contaminants in soil of the unsaturated zone to the underlying Minor Aquifer.</p>

- 2.2.2 All site works were undertaken in accordance with BS10175: 2001 ('Investigation of Potentially Contaminated Sites') and were completed without incident.
- 2.2.3 All works were carried out by experienced personnel under the supervision of a PB Engineer. In addition, an Engineer from BACTEC was present on-site during the intrusive works to provide the necessary mitigation measures for a high risk UXO site. This included a comprehensive UXO induction for all personnel, electromagnetic surveys and a watching brief during the progression of each excavation.
- 2.2.4 A minimum of 2 persons were in attendance when an excavation was in progress (e.g. the PB Engineer and JCB/drill rig operator). When the PB Engineer was called away from the excavation area, the JCB/drill rig operator ceased work until the PB Engineer returned. Before excavation commenced, the proximal area was cleared of all non-essential personnel.

- 2.2.5 Suitable personal protective equipment was worn at all times during the works. Eating, drinking and smoking were not permitted on-site except in designated messing areas.
- 2.2.6 Prior to any intrusive works, site services were located by Amethyst Surveys Ltd. This included examination of record drawings provided by the relevant utility companies and an on-site utility survey using a cable avoidance tool (RD4000) and transmitter. As an additional precaution, all locations were re-scanned by PB personnel prior to excavation and all boreholes were hand dug to 1.2m BGL.
- 2.2.7 A PB Ecologist was on-site during the marking of exploratory hole locations to ensure that ecological constraints were not present.
- 2.2.8 All arisings were placed upon heavy-duty plastic sheeting to avoid surface contamination. Excess soil arisings required disposal and were located in a lockable skip which was accessible by all site staff for the safe storage of site soils. At the end of the work, the skip was removed by a licensed waste contractor for off-site disposal, once the required European Waste Code had been determined.
- 2.2.9 All works complied with PB's Environmental Monitoring System (ISO 14001 accredited).

#### Boreholes

- 2.2.10 Boreholes were excavated using a track-mounted Pioneer Rig. The Pioneer Rig has the advantage of recovering soil cores within a semi-rigid polycarbonate liner which permitted the accurate logging of subsurface ground conditions and negated the risk of cross contaminating the ground surface. In addition, it provided sufficient material for sampling purposes, which meant that we were able to sample from discrete depths accurately. This type of drilling technique is extremely clean and resulted in minimal disruption to the site.
- 2.2.11 The rigs were securely positioned over borehole locations prior to commencement of sampling. On uneven ground, the rigs were levelled prior to sampling.
- 2.2.12 When sampling was in progress, an area of 2.0m around the sampling rig was clear wherever possible.
- 2.2.13 Seven boreholes were excavated during the site works to a maximum depth of 15.5m BGL. A total of 48 No. soil samples were collected with 30 No. submitted for laboratory analysis.

#### Trial Pits

- 2.2.14 Trial Pits were excavated using a Komatsu 360° PC130.
- 2.2.15 Before anyone entered an excavation the stability of the walls of the excavation were assessed by PB staff, and under no circumstances did anyone enter an excavation greater than 1.2m deep. At depths greater than 1.2m samples were collected from excavation arisings only.
- 2.2.16 Where significant instability of the pit was apparent at any stage of the excavation, following an assessment by the site engineer, the pit was immediately backfilled. Trial pits were additionally backfilled immediately upon completion, with the arisings placed back in reverse order of excavation. No trial pits were left open overnight.

2.2.17 A total of 31 No. trial pits were excavated during site works to a maximum depth of 4.7m BGL. A total of 90 No. soil samples were collected with 69 No. soil samples submitted for laboratory analysis (including six duplicates).

## 2.3 Laboratory Analysis

2.3.1 A total of 99 No. soil samples (including six duplicates) were submitted for laboratory analysis of the following determinands:

- Metals and metalloids (Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc, Boron);
- pH Value;
- Total Sulphate;
- Total Cyanide;
- Polycyclic aromatic hydrocarbons (PAH) (Speciated EPA 16); and
- Total petroleum hydrocarbons (TPH) (C<sub>6</sub>-C<sub>40</sub>).

2.3.2 In addition, a total of 17 No. selected shallow soil samples were submitted for an asbestos screen and one potential asbestos cement fragment for an asbestos identification. Furthermore, 18 No. soil samples were submitted for TPH CWG (based upon visual/olfactory evidence and elevated PID readings). To support the derivation of appropriate tier 1 screening values, a total of 18 No. soil samples were analysed for total organic carbon (TOC).

2.3.3 A total of 18 No. soil samples were subject to leachate preparation. Samples were selected where visual and/or olfactory evidence of contamination was noted within the unsaturated zone and to provide coverage of the site. The leachate preparations were analysis for the following determinands:

- Metal and Metalloids (Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc, Boron);
- pH Value;
- Sulphate;
- Total Cyanide;
- Sulphide;
- Speciated PAH; and
- TPH (C<sub>6</sub>-C<sub>40</sub>).

2.3.4 A total of twelve groundwater samples were also submitted for laboratory analysis of the above suite of determinands. In addition, four groundwater samples taken from Unit 3 were subject to speciated TPH analysis.

2.3.5 All soil samples were stored in accordance with laboratory guidance and couriered to the laboratory within 24 hours of sampling. The samples were analysed by Chemtest, Newmarket, a UKAS and MCERTS accredited laboratory. Full schedules of sample analysis are provided in Appendix F.

2.3.6 Analytical results for soil, leachate and groundwater are provided within Appendices B and C, and summarised in Tables 3.4 to 3.22.

## 2.4 General Ground Conditions

2.4.1 Ground conditions have been logged in accordance with the requirements of BS5930:1999. Detailed logs for the trial pits and boreholes are provided in Appendix A along with photographs of exploratory locations.

2.4.2 A summary of the ground conditions identified during the investigation is given below.

### Unit 3

#### Made Ground – Unit 3

2.4.3 Made Ground was encountered within all exploratory locations across Unit 3 with thicknesses ranging from 0.5m (TP108) to 3.2m (BH206). Made Ground encountered typically comprised, with progressive depth:

- Surface cover of gravel and moss with sparse ruderal vegetation;
- A relatively thin layer of orange-brown moderately clayey gravelly sand. The gravel typically comprised flint and chert suggesting local origin;
- Gravel, cobbles and boulders of aerated blocks with coarse sand, often including occasional metal packing wire. A geotextile membrane was evident at the base of this stratum; and
- Orange-brown or grey-brown sandy clay with a minor gravel component of flint and occasional anthropogenic inclusions comprising red brick, red clay tile and concrete.

2.4.4 Within trial pits TP103 and TP106, located in the north westernmost tip of Unit 3, Made Ground conditions were different to those encountered throughout the bulk of Unit 3, potentially associated with the differing historical use of this area for fuel/product storage tanks and their later removal. Underlying the surface cover of angular gravel was gravelly sand and gravelly sandy clay. The gravel component typically comprised flint and shell fragments suggesting this material is of local origin. Rubbery tar product was also noted in TP106. Of particular note was the absence of aerated blocks within the geotextile membrane in this area of Unit 3.

2.4.5 Trial pits TP109 and TP130 were located on the grass verge aligning the Damhead Creek Power Station access road. Within this area, the Made Ground typically comprised dark brown slightly clayey sand and gravel. The gravel typically comprised coarse angular basalt, limestone, quartz, flint, granite, mudstone and glass, with a geotextile membrane at the base. This was underlain by a gravelly silty/clayey sand. The gravel comprised quartz, flint, limestone and sandstone with various anthropogenic components including partial and whole bricks, coal/solidified bitumen, various metal objects, rubber hose and glass fragments. This evident fill material aligns with anecdotal evidence that this area of Unit 3 was recently raised as a flood protection measure for the temporary placement of welfare facilities.

2.4.6 Visual and olfactory evidence of contamination noted within the Made Ground of Unit 3 is presented in Table 2.2.

**Table 2.2: Visual and Olfactory Evidence of Potential Contamination within the Made Ground – Unit 3**

Location	Depth (m BGL)	Visual Evidence	Olfactory Evidence
TP101	2.45	Black staining of soil and sheen.	Moderate hydrocarbon odour.
TP103	1.18 – 1.7	Lens of black hydrocarbon stained gravel between 1.54m to 1.7m BGL.	Moderate to strong hydrocarbon odour (lube oil).
TP104	0.97	Wet tarry product.	Strong hydrocarbon odour (lube oil).
	1.05 – 2.3	-	Moderate to strong hydrocarbon odour (lube oil).
TP106	0.35 – 1.2	Rare coarse rubbery tar.	Moderate hydrocarbon odour. Slight medical odour from 0.5m BGL.
TP130	0.23 – 1.7	Occasional coarse coal/solidified bitumen.	-
BH203	0.5 – 0.8	-	Metallic/alluvial odour.
BH206	1.5 – 2.0	Black staining of soil.	Strong hydrocarbon and metallic odour.
	2.0 – 2.2	-	Very strong hydrocarbon odour.

**Natural Ground – Unit 3**

- 2.4.7 Natural ground across Unit 3 was encountered as orange-brown coarse sand and gravel of flint (River Terrace Deposits). This was interbedded by various layers of firm to stiff orange-brown and light blue-grey mottled sandy clay, which was often closely sheared with light blue polished surfaces (Alluvium).
- 2.4.8 Underlying the interbedded River Terrace Deposits and Alluvial clays was stiff to very stiff dark blue-grey clay with occasional white fissures and brown plant remains (London Clay). The London Clay was encountered at depths between 7.0m (BH206) and 12.0m BGL (BH203) within Unit 3.
- 2.4.9 Visual and olfactory evidence of contamination noted within the natural ground of Unit 3 is presented in Table 2.3.

**Table 2.3: Visual and Olfactory Evidence of Potential Contamination within the Natural Ground – Unit 3**

Location	Depth (m BGL)	Visual Evidence	Olfactory Evidence
TP101	2.45 – 2.9	Dark grey hydrocarbon staining and sheen on soil.	Moderate hydrocarbon odour.
TP103	1.7 – 3.6	-	Moderate hydrocarbon odour.
TP106	1.2 – 3.5	Abundant black product in pores (approx. 2mm-5mm)	Moderate hydrocarbon odour from 1.8m BGL (lube

		diameter).	oil/diesel).
TP131	2.0 – 2.2	-	Strong hydrocarbon odour.
BH203	4.1 – 6.0	-	Metallic odour.
BH206	2.2 -3.2	Sheen on soil.	Hydrocarbon odour.

## **Unit 2B**

### **Made Ground**

2.4.10 Made Ground was encountered within all exploratory locations across Unit 2B with thicknesses ranging from 0.08m (TP117 and TP120) to 7.4m (BH202). The Made Ground was variable across this area as described below.

### **Western and Central Area of Unit 2B**

2.4.11 Surface cover across the western and central area of Unit 2B and the roadways consisted of PFA and aerated blocks. A layer of PFA was then present between depths of 0.58m BGL (TP122) and up to 4.2m BGL (TP127 – on mound of PFA). Towards the base of this stratum, the PFA became clayey and wet.

2.4.12 The PFA was frequently underlain by black decaying grass (indicating the former ground level prior to PFA placement) and associated topsoil of dark brown silty sand (0.07m – 0.40m thick).

2.4.13 The former topsoil was typically underlain by light orange-brown and occasionally light blue-grey mottled sand clay.

### **Eastern Area of Unit 2B**

2.4.14 Surface cover across the eastern area of Unit 2B typically consisted of long grass, beneath which was a topsoil of brown silty sand (0.08m – 0.2m thick). The extent of Made Ground was minimal in this area (excluding roadways).

2.4.15 No visual evidence of contamination was noted within the Made Ground during excavation work in Unit 2B. Olfactory evidence of contamination is presented in Table 2.4.

**Table 2.4: Olfactory Evidence of Potential Contamination within the Made Ground – Unit 2B**

<b>Location</b>	<b>Depth (m BGL)</b>	<b>Olfactory Evidence</b>
BH201	5.0 – 6.7	Slight medical/disinfectant odour.
BH202	6.5 – 7.4	Moderate hydrocarbon odour. Includes metallic odour from 6.75m.
BH207	3.2 – 3.4	Hydrocarbon odour.

## Natural Ground

### Western and Central Area of Unit 2B

- 2.4.16 Natural ground in the western area of Unit 2B was very soft dark blue-grey clay with rare pockets of black decaying plant material and associated organic odour. This stratum was absent in the central areas of the site, being replaced by a light grey, dark grey and grey-brown thickly laminated sandy clay/clayey sand.
- 2.4.17 This was underlain by orange-brown coarse sand and gravel of flint (River Terrace Deposits) interbedded by various layers of firm to stiff orange-brown and light blue-grey mottled sandy clay, which was often closely sheared with light blue polished surfaces (Alluvium).
- 2.4.18 Underlying the interbedded River Terrace Deposits and Alluvial clays was stiff to very stiff dark blue-grey clay with occasional white granular deposits (London Clay). The London Clay was encountered at a depth of 13.7m BGL in BH201 (western area) and 15.3m BGL (with 4.2m of PFA mound atop) in BH202 (central area).

### Eastern Area of Unit 2B

- 2.4.19 Natural ground in the eastern area of Unit 2B was encountered at shallow depths of 0.08m BGL as orange-brown coarse sand and gravel of flint (River Terrace Deposits) interbedded by various layers of firm to stiff orange-brown and light blue-grey mottled sandy clay, which was often closely sheared with light blue polished surfaces (Alluvium).
- 2.4.20 Underlying the interbedded River Terrace Deposits and Alluvial clays was stiff to very stiff dark blue-grey clay with occasional white granular deposits (London Clay). The London Clay was encountered at a depth of 12.0m BGL in BH207.
- 2.4.21 No visual evidence of contamination was noted within the natural ground during excavation work in Unit 2B. Olfactory evidence of contamination is presented in Table 2.5.

**Table 2.5: Olfactory Evidence of Potential Contamination within the Natural Ground – Unit 2B**

Location	Depth (m BGL)	Olfactory Evidence
TP118	2.5 – 4.3	Slight hydrocarbon/organic odour.
TP121	1.7 – 1.8	Slight hydrocarbon odour.
BH207	3.4 – 4.8	Hydrocarbon odour. Includes metallic odour from 3.8m BGL.

- 2.4.22 Where encountered across the site, the sandy flint gravels had minimal cohesion and were therefore notably unstable during excavation.

## **2.5 Buried Structures**

- 2.5.1 No buried structures were encountered during excavations at the site with the exception of a concrete platform 0.28m thick in TP103 (in the north westernmost tip of Unit 3).

## 2.6 Ground Vapour Emissions

- 2.6.1 A Photo Ionisation Detector (PID) was used on-site during the works to screen soil samples for the presence of volatile organic compounds (VOCs). Soil samples were bagged and screened for a minimum period of 60 seconds.
- 2.6.2 In addition, all installed boreholes were monitored with a PID on two occasions to detect the presence of VOCs within the ground, and to account for any interference this may cause to gas monitoring undertaken.
- 2.6.3 Both average and peak readings were recorded (PID calibrated to isobutylene). Screening results are summarised within Appendix D.

## 2.7 Ground Gas Emissions

- 2.7.1 Seven boreholes were installed in the sand and gravel for ground gas monitoring. Each borehole was gas monitored with an infra-red gas analyser (GA2000), calibrated by the manufacturer and checked in the field against calibration gas. Flow rate from the borehole was measured using a flow pod, followed by peak and steady state concentrations of methane, carbon dioxide, oxygen, carbon monoxide and hydrogen sulphide. Barometric pressure was also recorded. Monitoring was undertaken on two occasions to assess the potential risks to human health from ground gas.
- 2.7.2 CIRIA guidance (CIRIA 665) suggests that 24 hours to seven days is required for air within boreholes to equilibrate with the soil environment, with the lower durations required for more porous soils. The monitoring visits were undertaken biweekly for one week, commencing four days after the installation of the last borehole, which is more than sufficient for the establishment of equilibrium.
- 2.7.3 Results of ground gas measurements taken from installed boreholes during the monitoring visit are given within Appendix D.

## 2.8 Groundwater Observations

- 2.8.1 Following ground gas monitoring, the water level in each standpipe was measured using an electronic interface probe. Depths to the groundwater surface within the boreholes are given within Table 2.6.

**Table 2.6: Depth to Groundwater**

Location	02/12/08		04/12/08	
	(m BGL)	(m AOD)	(m BGL)	(m AOD)
BH201	5.035	-1.055	4.85	-0.87
BH202	- <sup>A</sup>	- <sup>A</sup>	7.05	-0.21
BH203	3.087	-0.867	- <sup>A</sup>	- <sup>A</sup>
BH204	2.995	1.055	3.27	0.78
BH205	2.573	- <sup>B</sup>	2.58	- <sup>B</sup>
BH206	1.731	0.989	1.62	1.1
BH207	5.313	-2.003	5.23	-1.92

<sup>A</sup> Unable to monitor boreholes

<sup>B</sup> No AOD data available.

2.8.2 Groundwater was encountered within all monitored boreholes on both monitoring visits. No product was detected with the interface probe within any boreholes. No visual evidence of contamination was observed during sampling and olfactory evidence of potential contamination was limited to BH206 on round 1 where a slight sweet chemical odour was noted.

2.8.3 During intrusive works, visual and olfactory evidence of contamination was noted in groundwater as follows:

- TP101 Slow influx of perched groundwater at 2.5m BGL with visible brown product;
- TP106 Moderate groundwater influx at 0.35m BGL of visibly darker colour and with sheen; and
- TP131 Rapid influx of groundwater at 1.9m BGL with sheen and brown oil.

## 2.9 Quality Assurance / Quality Control

2.9.1 A total of 99 No. soil samples were scheduled for analysis following exploratory works at the site. This included the analysis of a total of 6 No. duplicate soil samples.

2.9.2 The duplicates and corresponding samples are outlined in Table 2.7.

**Table 2.7: Duplicate and Corresponding Samples**

Duplicate Sample ID	Corresponding Soil Sample	
	Sample ID	Depth (m BGL)
DUP A	TP103	0.4
DUP B	TP104	2.0
DUP C	TP109	0.5
DUP D	TP116	0.3
DUP E	TP124	2.8
DUP F	TP126	0.1

2.9.3 Examination of the duplicate data indicates that all duplicate samples support their corresponding soil sample.

2.9.4 The data collection, storage and preparation of this report has been undertaken in accordance with PB's Integrated Management System which operates within the standards outlined in ISO 9001 (BSI Certificate No. Q06143) and ISO 14001 (BSI Certificate No. A12283).

SECTION 3

**GENERIC QUANTITATIVE RISK ASSESSMENT**

**3 SOIL GENERIC QUANTITATIVE RISK ASSESSMENT**

This section makes use of the site investigation findings, as described in the previous section, to evaluate further the potential pollutant linkages identified in Section 1. A combination of qualitative and quantitative techniques is used, as described below. The purpose of generic quantitative risk assessment, utilised by PB, is to establish whether generic assessment criteria and assumptions are appropriate for assessing the risks and, if so, to apply them to establish whether there are actual or potential unacceptable risks. It also determines whether further detailed assessment is required. The approaches detailed all broadly fit within a tiered assessment structure in line with the framework set out in the DETR, Environment Agency and Institute for Environment and Health Publication Guidelines for Environmental Risk Assessment and Management.

**3.1 Numerical Assessment Criteria - Soils**

3.1.1 Various numerical assessment criteria have been used to interpret the chemical testing results, as described in this section. These criteria are generally set to be highly conservative and in the event that they are exceeded a further level of analysis is typically required.

Soils

3.1.2 The commercial/industrial land use scenario has been selected from those available within the Soil Guideline Value (SGV) Reports and CLEA v1.03 model for the development of Generic Assessment Criteria (GAC).

3.1.3 It is recognised that the standard commercial/industrial land use represents a range of generic site conditions and is not intended to accurately reflect the site specific conditions or the behaviour of a particular individual at the site. Should exceedances of the generic assessment criteria be identified, site specific refinements to the model can be made at a later stage in the assessment process.

3.1.4 The assessment criteria used for the screening of determinands within soils are identified within Table 3.1.

**Table 3.1: Selected Assessment Criteria – Contaminants in Soils**

Substance Group	Determinand(s)	Assessment Criteria Selected
<i>Organic Substances</i>		
Non-halogenated hydrocarbons.	Total Petroleum Hydrocarbons (TPHCWG banded)	CLEA v1.03 model
Polycyclic Aromatic Hydrocarbons (PAH's).	Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benz(a)anthracene, Chrysene, Benz(b)fluoranthene, Benz(k)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Dibenz(a,h)anthracene, Benzo(ghi)perylene	CLEA v1.03 model

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**Table 3.1: Selected Assessment Criteria – Contaminants in Soils**

Substance Group	Determinand(s)	Assessment Criteria Selected
<i>Inorganic Substances</i>		
Heavy metals and metalloids.	Arsenic, Cadmium, Chromium, Mercury, Nickel, Selenium	CLEA v1.03 model
	Lead	SGV (Report 10)
	Copper, Zinc	CLEA v1.03 model

CLEA v1.03

- 3.1.5 An updated version of the CLEA framework was released by the Environment Agency (EA) on 12<sup>th</sup> August 2008. This updated guidance partly addressed the issues raised by the DEFRA 'Way Forward' document, and resulted in the publication of two updated reports – "Human health toxicological assessment of contaminants in soil" and "Updated technical background to the CLEA model". The existing CLR 7-10 documents, SGV reports and CLEA UK (beta) model were all withdrawn by the EA and DEFRA.
- 3.1.6 Operation of the new CLEA software (v1.03 beta) requires the input of a number of parameters with only a limited number currently published by the EA – their report 'Compilation of Organic Chemical Data for the Derivation of Soil Guideline Values, Report SC050021/SR7' was published on 7th November 2008 and consequently, the new CLEA software (v1.03 beta) can be used for development of organic and inorganic generic assessment criteria.
- 3.1.7 Due to the ongoing development of appropriate exposure and intake parameters, generic assessment criteria for Lead have been derived using the SGV reports, as these methods are still considered to be scientifically robust and justifiable, until all associated documentation is published.
- 3.1.8 All model assumptions and input parameters (both toxicological and fate & transport), in addition to full CLEA UK report summaries, are provided within Appendix E

CLEA v1.03 Input Criteria

- 3.1.9 The input criteria used for the development of GACs within CLEA v1.03, and where appropriate, those required for selection of the correct screening criteria from SGV reports, are provided within Tables 3.2.

**Table 3.2: CLEA UK Input Criteria – Residential with Plant Uptake**

Input Details	Value
Land Use	Commercial
Building Type	Office (post 1970s)
Receptor	Female
Age Class	17
Exposure Duration	49 years
Averaging Time	17885 days
Oral	Direct Soil and Dust Ingestion
Dermal	Skin Contact with Soil Derived Indoor Dust

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**Table 3.2: CLEA UK Input Criteria – Residential with Plant Uptake**

Input Details	Value
	Skin Contact with Soil
Inhalation	Inhalation of Soil Derived Indoor Dust
	Inhalation of Soil Dust
	Inhalation of Soil Vapours Indoors
	Inhalation of Soil Vapours Outdoors
Soil Type	Sandy Loam
pH	8.317 (PFA), 7.385 (Made Ground), 8.002 (Natural), 7.989 (London Clay)
Soil Organic Matter	9.09% (PFA), 2.977% (Made Ground), 0.500% (Natural), 1.00% (London Clay)

3.1.10 Soil samples obtained from the site were grouped by geology and an average pH and soil organic matter was calculated for each group for the derivation of GACs. An average pH value was obtained by converting all pH values of the soil samples in each group, to hydrogen ion concentrations, averaging them, and then using the product to complete the average pH. Full calculations are provided within Appendix E.

**3.2 Numerical Assessment Criteria – Leachate and Groundwater**

3.2.1 The assessment criteria used for the screening of determinands within leachate and groundwater are detailed within Table 3.3.

**Table 3.3: Selected Assessment Criteria – Contaminants in Groundwater**

Substance Group	Determinand(s)	Assessment Criteria Selected
<i>Organic Substances</i>		
Volatile Organic Compounds (VOCs)	Benzene, Toluene, Xylenes	EQS
	Ethylbenzene	WHO Health
Non-halogenated hydrocarbons	Total Phenols	EQS
Polycyclic Aromatic Hydrocarbons (PAH's)	Naphthalene	EQS
	Acenaphthylene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benz(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenz(a,h)anthracene, Benzo(ghi)perylene	LEC
<i>Inorganic Substances</i>		
Heavy metals and metalloids	Arsenic, Cadmium, Lead, Nickel, Mercury, Chromium, Copper, Zinc, Boron	EQS
Heavy metals and metalloids	Selenium	UK DWS
Cyanides	Total Cyanide	EQS (MAC)

### SECTION 3 GENERIC QUANTITATIVE RISK ASSESSMENT

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3.2.2 A brief discussion of each source of criteria is provided below.

#### EQS

3.2.3 Environmental Quality Standards (EQS) have been released by the EA for dangerous substances, as identified by the EC Dangerous Substances Directive. EQS can vary for each substance, for the hardness of the water and can be different for fresh, estuarine or coastal waters. The laboratory analyses results have been compared to values for estuarine / coastal waters

#### Lowest Effect Concentration (LEC)

3.2.4 In the absence of EQS for PAHs (except naphthalene), screening criteria have been taken from the Environment Agency R&D Technical Report P45 'Polycyclic Aromatic Hydrocarbons (PAH): Priorities for Environmental Quality Standard Development' (2001). Lowest Effect Concentration (LEC) values have been used as screening criteria.

#### UK Drinking Water Standards

3.2.5 In the absence of EQS, UK Drinking Water Standards (UK DWS) have been used for screening purposes, taken from 'Water Supply (Water Quality) Regulations 1989 (SI 1989/1147) (as amended)' and 'Water Supply (Water Quality) Regulations 2000 (SI 2000/3184) (as amended)'.

#### WHO Health

3.2.6 In the absence of EQS and UK DWS, World Health Organisation guideline values (WHO Health) have been used for screening purposes, taken from 'Guidelines for Drinking-water Quality, First Addendum to Third Edition, Volume 1, Recommendations' (2006). The health value is a guideline value representing the concentration of a contaminant that does not result in any significant risk to the receptor over a lifetime of exposure.

#### Dutch Intervention Values

3.2.7 In the absence of EQS, UK DWS and WHO Health, the Dutch Institute and Human Toxicology data values (DUTCH) are used for speciated TPH. These screening criteria have been taken from 'RIVM Report 711701 023, Technical Evaluation of the Intervention Values for Soil/sediment and Groundwater' (2001). Whilst they do not have force of law in the UK, they are recognised as a valid source of information by the EA. For example, they are recommended in the EA document 'Biological Test Methods for Assessing Contaminated Land'.

### **3.3 Identification of Potential Risks – Human Health**

3.3.1 The aim of this section is to determine which pollutant linkages represent potentially unacceptable risks, and thereby require further investigation, further risk assessment and/or remedial action.

#### Soils

3.3.2 Soil samples were collected through non-targeted sampling, which aims to provide information to characterise the site conditions. Samples were then grouped according to geology (PFA, Made Ground, Natural and London Clay) and screened against generic assessment criteria derived for commercial land use and have been summarised within Tables 3.4 to 3.7. Full analytical results for groundwater samples are provided in Appendix C.

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3.3.3 The input criteria used for the development of Generic Assessment Criteria (GAC) within CLEA v1.03, and where appropriate, those required for selection of the correct screening criteria from SGV reports, are provided within Table 3.2.

Pulverised Fuel Ash

3.3.4 Samples in this group were collected from across the site at depths of between 0.50m and 3.50m bgl, and were screened for metals and PAHs. They generally consisted of dark blue-grey, gravelly, fine-grained sand or very soft, black-grey clay. The average pH value of the PFA samples was 8.317 and the average soil organic matter was 17.070%.

**Table 3.4: Pulverised Fuel Ash Laboratory Analysis Results – Metals and Metalloids**

Determinand	Unit	No. sample tested	Screening Criteria		Min	Max	No Exceed
Arsenic	mg/kg	18	311.6	CLEA v.103	<2	100	0
Cadmium	mg/kg	18	270.6	CLEA v.103	<0.1	0.73	0
Chromium	mg/kg	18	292.1	CLEA v.103	16	73	0
Copper	mg/kg	18	148423	CLEA v.103	16	170	0
Lead	mg/kg	18	450	SGV 10	6	120	0
Mercury	mg/kg	18	490.1	CLEA v.103	<0.1	0.36	0
Nickel	mg/kg	18	874.1	CLEA v.103	29	120	0
Selenium	mg/kg	18	8095.9	CLEA v.103	<0.2	6.4	0
Zinc	mg/kg	18	558247.9	CLEA v.103	19	160	0
Boron Water Soluble	mg/kg	18	-	-	3.2	49	-

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**Table 3.5: Pulverised Fuel Ash Laboratory Analysis Results – Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. sample tested	Screening Criteria		Min	Max	No. Exceed
Naphthalene	mg/kg	18	2091.2	CLEA v.103	<0.1	1.5	0
Acenaphthylene	mg/kg	18	158.4	CLEA v.103	<0.1	0.2	0
Acenaphthene	mg/kg	18	2194.1	CLEA v.103	<0.1	1.1	0
Fluorene	mg/kg	18	69954.2	CLEA v.103	<0.1	0.4	0
Phenanthrene	mg/kg	18	7400.5	CLEA v.103	<0.1	1.5	0
Anthracene	mg/kg	18	527792	CLEA v.103	<0.1	<0.1	0
Fluoranthene	mg/kg	18	12402.9	CLEA v.103	<0.1	0.1	0
Pyrene	mg/kg	18	12363.4	CLEA v.103	<0.1	0.2	0
Benzo(a) anthracene	mg/kg	18	131.6	CLEA v.103	<0.1	<0.1	0
Chrysene	mg/kg	18	132.1	CLEA v.103	<0.1	<0.1	0
Benzo(b) fluoranthene	mg/kg	18	132.8	CLEA v.103	<0.1	<0.1	0
Benzo(k) fluoranthene	mg/kg	18	133.1	CLEA v.103	<0.1	<0.1	0
Benzo(a) pyrene	mg/kg	18	13.3	CLEA v.103	<0.1	<0.1	0
Dibenz(ah) anthracene	mg/kg	18	132.7	CLEA v.103	<0.1	<0.1	0
Indeno(123-cd) pyrene	mg/kg	18	13.3	CLEA v.103	<0.1	0.8	0
Benzo(ghi) perylene	mg/kg	18	133.6	CLEA v.103	<0.1	<0.1	0
Total PAH	mg/kg	18	-	-	<2	2.7	-

3.3.5 All determinands were either at non-detectable concentrations or at concentrations below the relevant screening criteria.

Made Ground

3.3.6 Samples in this group were obtained from across the site at depths of between 0.10m and 7.00m bgl and generally consisted of orange-brown, clayey, gravelly sand with brick, clinker, flint, quartz and granite fragments. All samples were screened for metals and PAHs with a proportion screened for TPH (CWG) based on historical and/or visual and olfactory evidence.

3.3.7 The input criteria used for the development of Generic Assessment Criteria (GAC) within CLEA UK, and where appropriate, those required for selection of the correct

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screening criteria from SGV reports, are provided within Tables 3.2. The average pH value of the Made Ground samples was 7.385 and the average soil organic matter was 8.620%.

**Table 3.6: Made Ground Laboratory Analysis Results – Metals and Metalloids**

Determinand	Unit	No. sample tested	Screening Criteria		Min	Max	No Exceed
Arsenic	mg/kg	36	311.62	CLEA v.103	<2	53	0
Cadmium	mg/kg	36	270.58	CLEA v.103	<0.1	1	0
Chromium	mg/kg	36	292.09	CLEA v.103	10	71	0
Copper	mg/kg	36	148423.02	CLEA v.103	170	<5	0
Lead	mg/kg	36	450.00	SGV 10	5.4	260	0
Mercury	mg/kg	36	490.05	CLEA v.103	<0.1	6.2	0
Nickel	mg/kg	36	874.12	CLEA v.103	8	150	0
Selenium	mg/kg	36	8095.86	CLEA v.103	<0.2	3.8	0
Zinc	mg/kg	36	558247.87	CLEA v.103	17	520	0
Boron Water Soluble	mg/kg	36	-	-	<0.4	19	-

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**Table 3.7: Made Ground Laboratory Analysis Results – Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. sample Tested	Screening Criteria		Min	Max	No. Exceed
Naphthalene	mg/kg	36	1839.73	CLEA v.103	<0.1	470	0
Acenaphthylene	mg/kg	36	138.20	CLEA v.103	<0.1	57	0
Acenaphthene	mg/kg	36	1955.43	CLEA v.103	<0.1	200	0
Fluorene	mg/kg	36	69847.27	CLEA v.103	<0.1	170	0
Phenanthrene	mg/kg	36	6959.33	CLEA v.103	<0.1	400	0
Anthracene	mg/kg	36	527424.36	CLEA v.103	<0.1	120	0
Fluoranthene	mg/kg	36	12288.83	CLEA v.103	<0.1	200	0
Pyrene	mg/kg	36	12245.72	CLEA v.103	<0.1	150	0
Benzo(a) anthracene	mg/kg	36	131.37	CLEA v.103	<0.1	51	0
Chrysene	mg/kg	36	131.98	CLEA v.103	<0.1	59	0
Benzo(b) fluoranthene	mg/kg	36	132.71	CLEA v.103	<0.1	29	0
Benzo(k) fluoranthene	mg/kg	36	132.97	CLEA v.103	<0.1	30	0
Benzo(a) pyrene	mg/kg	36	13.29	CLEA v.103	<0.1	18	0
Dibenz(ah) anthracene	mg/kg	36	13.31	CLEA v.103	<0.1	4.4	0
Indeno(123-cd) pyrene	mg/kg	36	132.58	CLEA v.103	<0.1	8.5	0
Benzo(ghi) perylene	mg/kg	36	133.51	CLEA v.103	<0.1	7.8	0
Total PAH	mg/kg	36	-	-	<2	2000	-

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**Table 3.8: Made Ground Laboratory Analysis Results – TPH**

Determinand	Unit	No. Sample Tested	Screening Criteria		Min	Max	No Exceed
Aliphatic EC 5-6	mg/kg	12	2679.70	CLEA UK	<0.1	<0.1	0
Aliphatic EC 6-8	mg/kg	12	8056.63	CLEA UK	<0.1	<0.1	0
Aliphatic EC 8-10	mg/kg	12	2069.23	CLEA UK	<0.1	42	0
Aliphatic EC 10-12	mg/kg	12	10413.21	CLEA UK	<0.1	500	0
Aliphatic EC 12-16	mg/kg	12	39804.89	CLEA UK	<0.1	3500	0
Aliphatic EC 16-35 <sup>B</sup>	mg/kg	12	2069175.05	CLEA UK	<0.1	3640	0
Aromatic EC 5-7	mg/kg	12	1153.76	CLEA UK	<0.1	<0.1	0
Aromatic EC 7-8	mg/kg	12	1251.12	CLEA UK	<0.1	<0.1	0
Aromatic EC 8-10	mg/kg	12	3329.96	CLEA UK	<0.1	66	0
Aromatic EC 10-12 <sup>B</sup>	mg/kg	12	14999.72	CLEA UK	<0.1	330	0
Aromatic EC 12-16	mg/kg	12	42200.81	CLEA UK	<0.1	450	0
Aromatic EC 16-21	mg/kg	12	55925.38	CLEA UK	<0.1	500	0
Aromatic EC 21-35	mg/kg	12	55925.38	CLEA UK	<0.1	200	0
TPH (C <sub>5</sub> -C <sub>38</sub> )	mg/kg	35	-	-	<10	9300	-

3.3.8 All determinands were at concentrations below the relevant screening criteria.

River Deposits

3.3.9 Samples in this group were obtained from across the site at depths of between 0.15m and 15.30m bgl and generally consisted of orange-yellow clays, sands and gravels of flint, quartz and occasional shells. This group includes both undisturbed and dredged river deposits. All samples were screened for metals and PAHs with a proportion screened for TPH (CWG) based on historical and/or visual and olfactory evidence.

3.3.10 The input criteria used for the development of Generic Assessment Criteria (GAC) within CLEA UK, and where appropriate, those required for selection of the correct screening criteria from SGV reports, are provided within Tables 3.2. The average pH value of the Made Ground samples was 8.002 and the average soil organic matter was 1.030%.

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**Table 3.9: River Deposits Laboratory Analysis Results – Metals and Metalloids**

Determinand	Unit	No. sample tested	Screening Criteria		Min	Max	No Exceed
Arsenic	mg/kg	41	311.6	CLEA v.103	<2	51	0
Cadmium	mg/kg	41	270.6	CLEA v.103	<0.1	0.6	0
Chromium	mg/kg	41	292.1	CLEA v.103	8.4	61	0
Copper	mg/kg	41	148423.0	CLEA v.103	<5	64	0
Lead	mg/kg	41	450.0	SGV 10	<5	77	0
Mercury	mg/kg	41	490.1	CLEA v.103	<0.1	0.92	0
Nickel	mg/kg	41	874.1	CLEA v.103	11	97	0
Selenium	mg/kg	41	8095.9	CLEA v.103	<0.2	1.9	0
Zinc	mg/kg	41	558247.9	CLEA v.103	<10	130	0
Boron Water Soluble	mg/kg	41	-	-	<0.4	15	-

**Table 3.10: River Deposits Laboratory Analysis Results – Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. sample Tested	Screening Criteria		Min	Max	No. Exceed
Naphthalene	mg/kg	41	247.58	CLEA v.103	<0.1	1	0
Acenaphthylene	mg/kg	41	16.92	CLEA v.103	<0.1	2.3	0
Acenaphthene	mg/kg	41	274.88	CLEA v.103	<0.1	3.5	0
Fluorene	mg/kg	41	64352.32	CLEA v.103	<0.1	1	0
Phenanthrene	mg/kg	41	1614.89	CLEA v.103	<0.1	5.2	0
Anthracene	mg/kg	41	507785.68	CLEA v.103	<0.1	3.3	0
Fluoranthene	mg/kg	41	8368.58	CLEA v.103	<0.1	4.2	0
Pyrene	mg/kg	41	8253.74	CLEA v.103	<0.1	3.8	0
Benzo(a) anthracene	mg/kg	41	121.08	CLEA v.103	<0.1	0.9	0
Chrysene	mg/kg	41	126.92	CLEA v.103	<0.1	1.2	0
Benzo(b) fluoranthene	mg/kg	41	129.51	CLEA v.103	<0.1	1.8	0

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**Table 3.10: River Deposits Laboratory Analysis Results – Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. sample Tested	Screening Criteria		Min	Max	No. Exceed
Benzo(k) fluoranthene	mg/kg	41	130.36	CLEA v.103	<0.1	0.8	0
Benzo(a) pyrene	mg/kg	41	13.00	CLEA v.103	<0.1	6.7	0
Dibenz(ah) anthracene	mg/kg	41	13.04	CLEA v.103	<0.1	1.6	0
Indeno(123-cd) pyrene	mg/kg	41	129.08	CLEA v.103	<0.1	2.4	0
Benzo(ghi) perylene	mg/kg	41	131.97	CLEA v.103	<0.1	1.4	0

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**Table 3.11: River Deposits Laboratory Analysis Results – TPH**

Determinand	Unit	No. Sample Tested	Screening Criteria		Min	Max	No Exceed
Aliphatic EC 5-6	mg/kg	6	630.84	CLEA UK	<0.1	<0.1	0
Aliphatic EC 6-8	mg/kg	6	1269.29	CLEA UK	<0.1	<0.1	0
Aliphatic EC 8-10	mg/kg	6	266.17	CLEA UK	<0.1	<0.1	0
Aliphatic EC 10-12	mg/kg	6	1325.89	CLEA UK	<0.1	2.9	0
Aliphatic EC 12-16	mg/kg	6	5885.08	CLEA UK	<0.1	120	0
Aliphatic EC 16-35	mg/kg	6	489004.03	CLEA UK	<0.1	155	0
Aromatic EC 5-7	mg/kg	6	182.22	CLEA UK	<0.1	<0.1	0
Aromatic EC 7-8	mg/kg	6	187.30	CLEA UK	<0.1	<0.1	0
Aromatic EC 8-10	mg/kg	6	428.24	CLEA UK	<0.1	<0.1	0
Aromatic EC 10-12	mg/kg	6	2221.76	CLEA UK	<0.1	0.8	0
Aromatic EC 12-16	mg/kg	6	10211.70	CLEA UK	<0.1	12	0
Aromatic EC 16-21	mg/kg	6	55925.38	CLEA UK	<0.1	14	0
Aromatic EC 21-35	mg/kg	6	55925.38	CLEA UK	<0.1	9.5	0
TPH (C <sub>5</sub> -C <sub>38</sub> )	mg/kg	43	-	-	<10	300	-

3.3.11 All determinands were either at non-detectable concentrations or at concentrations below the relevant screening criteria.

London Clay

3.3.12 Samples in this group were obtained from across the site at depths of between 12.02m and 14.00m bgl and generally consisted of stiff blue-grey clay. All samples were screened for metals and PAHs.

3.3.13 The input criteria used for the development of Generic Assessment Criteria (GAC) within CLEA UK, and where appropriate, those required for selection of the correct screening criteria from SGV reports, are provided within Tables 3.2. The average pH

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value of the London Clay samples was 7.989. No soil organic matter values were obtained for the results, therefore a conservative value of 1% was assumed.

**Table 3.12: London Clay Laboratory Analysis Results – Metals and Metalloids**

Determinand	Unit	No. sample tested	Screening Criteria		Min	Max	No Exceed
Arsenic	mg/kg	2	311.6	CLEA v.103	5.2	5.7	0
Cadmium	mg/kg	2	270.6	CLEA v.103	0.49	0.52	0
Chromium	mg/kg	2	292.1	CLEA v.103	18	36	0
Copper	mg/kg	2	148423.0	CLEA v.103	33	34	0
Lead	mg/kg	2	450.0	SGV 10	15	17	0
Mercury	mg/kg	2	490.1	CLEA v.103	<0.1	<0.1	0
Nickel	mg/kg	2	874.1	CLEA v.103	42	54	0
Selenium	mg/kg	2	8095.9	CLEA v.103	1.5	1.9	0
Zinc	mg/kg	2	558247.9	CLEA v.103	68	86	0
Boron Water Soluble	mg/kg	2	-	-	<0.4	0.8	-

**Table 3.13: London Clay Laboratory Analysis Results – Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. sample Tested	Screening Criteria		Min	Max	No. Exceed
Naphthalene	mg/kg	2	400.10	CLEA v.103	<0.1	0.1	0
Acenaphthylene	mg/kg	2	28.09	CLEA v.103	<0.1	<0.1	0
Acenaphthene	mg/kg	2	450.31	CLEA v.103	<0.1	<0.1	0
Fluorene	mg/kg	2	66730.51	CLEA v.103	<0.1	<0.1	0
Phenanthrene	mg/kg	2	2474.89	CLEA v.103	<0.1	<0.1	0
Anthracene	mg/kg	2	516488.24	CLEA v.103	<0.1	<0.1	0
Fluoranthene	mg/kg	2	9743.95	CLEA v.103	<0.1	<0.1	0
Pyrene	mg/kg	2	9643.77	CLEA v.103	<0.1	<0.1	0

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**Table 3.13: London Clay Laboratory Analysis Results – Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. sample Tested	Screening Criteria		Min	Max	No. Exceed
Benzo(a) anthracene	mg/kg	2	125.22	CLEA v.103	<0.1	<0.1	0
Chrysene	mg/kg	2	128.76	CLEA v.103	<0.1	<0.1	0
Benzo(b) fluoranthene	mg/kg	2	130.64	CLEA v.103	<0.1	<0.1	0
Benzo(k) fluoranthene	mg/kg	2	131.28	CLEA v.103	<0.1	<0.1	0
Benzo(a) pyrene	mg/kg	2	13.10	CLEA v.103	<0.1	<0.1	0
Dibenz(ah) anthracene	mg/kg	2	13.14	CLEA v.103	<0.1	<0.1	0
Indeno(123-cd) pyrene	mg/kg	2	130.33	CLEA v.103	<0.1	<0.1	0
Benzo(ghi) perylene	mg/kg	2	132.51	CLEA v.103	<0.1	<0.1	0

3.3.14 All determinands were either at non-detectable concentrations or at concentrations below the relevant screening criteria.

**Asbestos**

3.3.15 One soil sample out of the 17No. analysed for asbestos returned a positive result for Chrysotile. The sample was a piece of suspected asbestos cement retrieved from TP130@0.15m bgl. Similar pieces of cement were observed in TP109 and BH205 along with various other brick and granite cobbles in a sandy matrix. Underlying this material was a woven membrane

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**Ground Gas and Vapour**

Soil Sample Vapour Monitoring

- 3.3.16 91No. soil samples collected at 3.70m bgl and above were subject to an on-site screen with a PID to detect the presence of volatile organic compounds (VOCs) and determine the requirement for additional scheduling of such compounds.
- 3.3.17 VOC concentrations were typically recorded with the PID below 5ppm. Elevated peak concentrations were recorded within a number of excavations as indicated in Table 3.14.

**Table 3.14: Maximum Measured PID Values**

Excavation ID	Depth (m)	PID average (ppm)	PID Maximum (ppm)
TP103	1.45-1.7	48.8	66.7
TP104	1.4	38.5	63.4
TP106	2.7	100.0	117.0

- 3.3.18 These concentrations are elevated relative to those typically measured at the site and exceed 50ppm where a potential risk to human health through the inhalation of vapours may be considered feasible.
- 3.3.19 Full results are included within Appendix D.

Borehole Vapour Monitoring

- 3.3.20 The 7No. boreholes excavated and installed during the ground investigation were monitored with a PID on two occasions (BH202 and BH203 one occasion) to detect the presence of VOCs within the ground at the site. PID readings ranged from 0.0ppm to 7.3ppm.
- 3.3.21 Full results are included within Appendix D.

Ground Gas Monitoring

- 3.3.22 Ground gas measurements were recorded from the 7No. boreholes excavated and installed during the ground investigation. A total of two monitoring rounds (BH202 and BH203 on one occasion) were undertaken, recording concentrations of methane, carbon dioxide, oxygen and hydrogen sulphide. Note was also made of the rainfall, surface air temperature and atmospheric pressure which may influence ground gas behaviour and will therefore be considered during the ground gas risk assessment.
- 3.3.23 Full monitoring results are provided within Appendix D

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**3.4 Identification of Potential Risks – Controlled Waters**

Leachate Analysis Results

3.4.1 Selected soil samples were scheduled for leachability testing. Laboratory analysis for leachates are summarised in Tables 3.15 and 3.16. Raw laboratory data is included as Appendix C. Exceedances in respect to location are summarised in Figure 3 in the Figures Section.

**Table 3.15: Leachate Laboratory Analysis Results – Metals and Metalloids**

Determinand	Unit	No. Samples Tested	Screening Criteria		Min	Max	No. Exceed
Arsenic	ug/l	18	25	EQS Marine	<1	21	0
Boron	ug/l	18	7000	EQS Marine	<20	660	0
Cadmium	ug/l	18	2.5	EQS Marine	<0.5	<0.5	0
Chromium	ug/l	18	15	EQS Marine	<1	19	1
Copper	ug/l	18	5	EQS Marine	<1	2.8	0
Lead	ug/l	18	25	EQS Marine	<1	3.4	0
Mercury	ug/l	18	0.3	EQS Marine	<0.5	<0.5	0
Nickel	ug/l	18	30	EQS Marine	<1	2.5	0
Selenium	ug/l	18	10	WHO	<1	21	3
Zinc	ug/l	18	40	EQS Marine	<1	7.4	0

**Table 3.16: Leachate Laboratory Analysis Results – Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. Samples Tested	Selected Screening Criteria		Min	Max	No. Exceeded
Naphthalene	ug/l	18	10	EQS	<0.1	<0.1	0
Acenaphthylene	ug/l	18	580	LEC	<0.1	<0.1	0
Acenaphthene	ug/l	18	-	-	<0.1	<0.1	-
Fluorene	ug/l	18	210	LEC	<0.1	<0.1	0
Phenanthrene	ug/l	18	300	LEC	<0.1	<0.1	0
Anthracene	ug/l	18	1.2	LEC	<0.1	<0.1	0
Fluoranthene	ug/l	18	0.9	LEC	<0.1	<0.1	0
Pyrene	ug/l	18	4	LEC	<0.1	<0.1	0
Benz(a)anthracene	ug/l	18	1.8	LEC	<0.1	<0.1	0

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**Table 3.16: Leachate Laboratory Analysis Results – Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. Samples Tested	Selected Screening Criteria		Min	Max	No. Exceeded
Chrysene	ug/l	18	0.7	LEC	<0.1	<0.1	0
Benzo(b)fluoranthene	ug/l	18	1.4	LEC	<0.1	<0.1	0
Benzo(k)fluoranthene	ug/l	18	1.4	LEC	<0.1	<0.1	0
Benzo(a)pyrene	ug/l	18	1.5	LEC	<0.1	<0.1	0
Dibenz(ah)anthracene	ug/l	18	0.4	LEC	<0.1	<0.1	0
Indeno(123-cd)pyrene	ug/l	18	0.9	EQS	<0.1	<0.1	-
Benzo(ghi)perylene	ug/l	18	2	LEC	<0.1	<0.1	0
Total PAH	ug/l	18	-	-	<2	<2	-

3.4.2 Two contaminants analysed for in the leachate samples exceeded their relevant screening values:

- 1No. exceedance of Chromium in TP124@0.50m bgl (PFA) on Unit 2B at 19mg/l.
- 3No. exceedances of Selenium in TP110@0.60m bgl, TP112@0.40m bgl and TP124@05.0m bgl (all in PFA) on Unit 2B, the highest concentration being 21mg/l in TP124.

3.4.3 PAH results were found to be below the detection limit in leachate samples.

3.4.4 TPH results were found to be below the detection limit in leachate samples. However, it is noted that during ground investigation visual and olfactory evidence of TPH contamination was noted.

### 3.5 Groundwater

3.5.1 Two rounds of groundwater monitoring were undertaken, sampling groundwater from the new installed boreholes. Six boreholes were monitored on each occasion, with BH202 and BH203 only monitored on one occasion each.

3.5.2 A comparison of the results from the sampled boreholes against the assessment criteria outlined in Table 3.3 is presented in Tables 3.17 to 3.20. Full analytical results for groundwater samples are provided in Appendix C. Exceedances in respect to location are summarised in Figure 3 in the Figures Section.

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**Table 3.17: Groundwater Laboratory Analysis Results – Metals and Metalloids**

Determinand	Unit	No. Samples Tested	Screening Criteria		Min	Max	No. Exceeded
Arsenic	ug/l	12	25	EQS Marine	1.2	16	0
Boron	ug/l	12	7000	EQS Marine	130	2800	0
Cadmium	ug/l	12	2.5	EQS Marine	<0.5	<0.5	0
Chromium	ug/l	12	15	EQS Marine	5.5	53	<b>3</b>
Copper	ug/l	12	5	EQS Marine	2.6	49	<b>3</b>
Lead	ug/l	12	25	EQS Marine	<1	2.1	0
Mercury	ug/l	12	0.3	EQS Marine	<0.5	1.7	<b>1</b>
Nickel	ug/l	12	30	EQS Marine	7	46	<b>1</b>
Selenium	ug/l	12	10	WHO	2	64	<b>3</b>
Zinc	ug/l	12	40	EQS Marine	9.4	25	0

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**Table 3.18: Groundwater Laboratory Analysis Results – Petroleum Hydrocarbons**

Determinand	Unit	No. Samples Tested	Screening Criteria		Min	Max	No. Exceeded
Aliphatic EC 5-6	ug/l	4	613	DIV	<0.1	<0.1	0
Aliphatic EC 6-8	ug/l	4	444	DIV	<0.1	<0.1	0
Aliphatic EC 8-10	ug/l	4	15	DIV	<0.1	<0.1	0
Aliphatic EC 10-12	ug/l	4	10	DIV	<0.1	<0.1	0
Aliphatic EC 12-16	ug/l	4	0.59	DIV	<0.1	<0.1	0
Aliphatic EC 16-21	ug/l	4	0.001	DIV	54	64	<b>2</b>
Aliphatic EC 21-35	ug/l	4	-	-	500	1200	-
Aromatic EC 6-7	ug/l	4	492	DIV	<0.1	<0.1	0
Aromatic EC 7-8	ug/l	4	850	DIV	<0.1	<0.1	0
Aromatic EC 8-10	ug/l	4	640	DIV	<0.1	<0.1	0
Aromatic EC 10-12	ug/l	4	1331	DIV	<0.1	<0.1	0
Aromatic EC 12-16	ug/l	4	1331	DIV	<0.1	<0.1	0
Aromatic EC 16-21	ug/l	4	543	DIV	<0.1	<0.1	0
Aromatic EC 21-35	ug/l	4	7	DIV	19	26	<b>2</b>
TPH (C <sub>5</sub> -C <sub>38</sub> )	ug/l	4	10	DWS	640	1300	<b>2</b>

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**Table 3.19 Groundwater Laboratory Analysis Results - Polycyclic Aromatic Hydrocarbons (PAHs)**

Determinand	Unit	No. Samples Tested	Selected Screening Criteria		Min	Max	No. Exceeded
Naphthalene	ug/l	12	10	EQS	<0.1	<0.1	0
Acenaphthylene	ug/l	12	580	LEC	<0.1	<0.1	0
Acenaphthene	ug/l	12	-	-	<0.1	<0.1	-
Fluorene	ug/l	12	210	LEC	<0.1	<0.1	0
Phenanthrene	ug/l	12	300	LEC	<0.1	4.5	0
Anthracene	ug/l	12	1.2	LEC	<0.1	0.4	0
Fluoranthene	ug/l	12	0.9	LEC	<0.1	2.5	1
Pyrene	ug/l	12	4	LEC	<0.1	7.1	1
Benzo(a)anthracene	ug/l	12	1.8	LEC	<0.1	3.4	1
Chrysene	ug/l	12	0.7	LEC	<0.1	2.8	1
Benzo(b)fluoranthene	ug/l	12	1.4	LEC	<0.1	<0.1	0
Benzo(k)fluoranthene	ug/l	12	1.4	LEC	<0.1	<0.1	0
Benzo(a)pyrene	ug/l	12	1.5	LEC	<0.1	6.4	1
Dibenz(ah)anthracene	ug/l	12	0.4	LEC	<0.1	<0.1	0
Indeno(123-cd)pyrene	ug/l	12	0.9	EGS	<0.1	<0.1	0
Benzo(ghi)perylene	ug/l	12	2	LEC	<0.1	<0.1	0
Total PAH	ug/l	12	-	-	<2	27	-

3.5.3 Several contaminants analysed for in the groundwater samples exceeded their relevant screening values:

- 7No. exceedances of both Chromium and Copper, 2No. each in BH201, BH204 and BH207 and 1No. in BH202 (all in Unit 2B), the highest exceedances being 67mg/l in BH207, and 100mg/l again in BH207, respectively.
- 1No. exceedance of Mercury in BH 204 in Unit 2B at 1.7mg/l.
- 2No exceedances of Nickel both in BH206 in Unit 3 at 46mg/l and 31mg/kg.

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- 2No. exceedances of both TPH in the Aliphatic band C16 – C21 and TPH in the Aromatic band C21 – C35 within BH203 and BH205 in Unit 3, the highest exceedances being 64mg/l in BH203 and 26mg/l in BH205, respectively.

3.5.4 Concentrations of TPH in the Aliphatic band C21 – C35 were elevated in two samples. However, no screening values currently exist for this band.

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**3.6 Risk Assessment**

**Human Health**

3.6.2 All soil samples taken from trial pits and boreholes across site areas Unit 2B and 3 showed concentrations of contaminants either below their relevant screening values or below laboratory detection limits. This suggests that with respect to the soils and the potential risk these may pose to human health the site is likely to be considered suitable for its proposed use.

3.6.3 However it is noted that one soil sample out of the 17No. analysed for asbestos returned a positive result for Chrysotile. The sample was a piece of suspected asbestos cement retrieved from TP130@0.15m bgl. Similar pieces of cement were observed in TP109 and BH205 along with various other brick and granite cobbles in a sandy matrix.

**Ground Gas and Vapour**

Soil Sample Vapour Monitoring

3.6.4 91No. soil samples collected at 3.70m bgl and above were subject to an on-site screen with a PID to detect the presence of volatile organic compounds (VOCs) and determine the requirement for additional scheduling of such compounds.

3.6.5 VOC concentrations were typically recorded with the PID below 5ppm. Elevated peak concentrations were recorded within a number of excavations. These concentrations are elevated relative to those typically measured at the site and exceed 50ppm where a potential risk to human health through the inhalation of vapours may be considered feasible. These results can be related to mid and heavy end aliphatic and aromatic TPH concentrations highlighted in laboratory results of these samples and visual/olfactory evidence of free product witnessed during the site works. Additionally, all locations are found within Unit 3 which is known to have been subject to oil refinery operations.

Borehole Vapour Monitoring

3.6.6 The 7No. boreholes excavated and installed during the ground investigation were monitored with a PID on two occasions (BH202 and BH203 one occasion) to detect the presence of VOCs within the ground at the site. PID readings ranged from 0.0ppm to 7.3ppm. These concentrations are unlikely to present a risk to human health through the inhalation of vapours and therefore no further action to investigate this data has been taken.

Ground Gas Monitoring

3.6.7 Ground gas measurements were recorded from the 7No. boreholes excavated and installed during the ground investigation. A total of two monitoring rounds (BH202 and BH203 on one occasion) were undertaken, recording concentrations of methane, carbon dioxide, oxygen and hydrogen sulphide. Note was also made of the rainfall, surface air temperature and atmospheric pressure which may influence ground gas behaviour and will therefore be considered during the ground gas risk assessment. Full monitoring results are provided within Appendix D.

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3.6.8 Groundwater was detected in all boreholes which remained relatively constant between the two monitoring visits. Alterations in the level of the water table are therefore considered unlikely to have exerted an influence on the gas monitoring undertaken at the site.

3.6.9 The surface air temperature ranged between 3°C (round 1) and 7°C (round 2).

**Table 3.20: Characterisation of Site Gassing Regime**

	Methane		Carbon Dioxide		Characteristic Situation
	Typical Maximum Concentration (%)	Gas Screening Value <sup>A</sup> (l/h)	Typical Maximum Concentration (%)	Gas Screening Value (l/h) <sup>A</sup>	
<b>Measured Concentration</b>	28.0	<b>0.476</b>	3.0	0.051	2

<sup>A</sup> Worst case flow rate of 1.7 l/h

3.6.10 The barometric pressure was constant during each gas monitoring round with the exception of round 2 which indicated a slight increase (of 2 millibars). Barometric pressure was seen to reduce between monitoring rounds. Where reductions in barometric pressure were recorded there is the potential for increased gas emission rates resulting from expansion of the gas though this was not reflected within the measured flow rates from each borehole.

3.6.11 Guidance on assessing the risk posed by hazardous ground gases is given within CIRIA Report 665. Given that the proposed future use for the site is commercial, Situation A (all development types except low rise housing with gardens) has been selected from this guidance to represent the future exposure scenario at Units 2B and 3. Typical Maximum Concentrations and Gas Screening Values have been calculated to define the gas regime at the site, and are presented in Table 3.20. The worst case conditions have been adopted in order to establish the appropriate protection measures required at the site.

3.6.12 The site has been determined as Characteristic Situation 2 (low risk) and is consistent with 'typical' Made Ground. Special protection requirements are listed below:

- a) Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) with at least 1200 g DPM2.
- b) Beam and block or pre cast concrete slab and minimum 2000 g DPM/reinforced gas membrane.
- c) Possibly under floor venting or pressurisation in combination with a) and b) depending on use.
- All joints and penetrations sealed.

3.6.13 However, reference to the ERM report 'Kingsnorth, Land Contamination Further Investigation and Risk Assessment Works' suggests that while the Characteristic

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Situation of 2 agrees with ERM's conclusion for Unit 3, it differs to their assignment of a Characteristic Situation of 3/4 for land inclusive of Unit 2B. This is based on results obtained from ERM-installed boreholes which were not included in the monitoring rounds undertaken for this report. It is suggested that further monitoring of all boreholes on Unit 2B be undertaken for a more accurate Characteristic Situation to be derived.

**Controlled Waters**

**Leachate**

3.6.14 A total of 18No. soil samples were subject to leachate preparation and analysis, and were screened against the selected assessment criteria given within appended Table 3.3

3.6.15 There were four leachate exceedances of the selected screening criteria, including 3No. exceedances of Selenium at 14mg/kg and 21mg/kg, and 1No. exceedance of Chromium at 19mg/kg.

3.6.16 **Groundwater**

3.6.17 A total of 12No. groundwater samples were subject to laboratory analysis and were screened against the selected assessment criteria given within Table 3.3.

3.6.18 There were exceedances of Chromium, Copper and Selenium within samples from all four boreholes on Unit 2B, with one sample from BH201 displaying exceedances of five PAHs.

3.6.19 BH206 showed exceedances of Nickel, with BH203 and BH205 showing exceedances of heavy end aliphatic and aromatic TPH.

3.6.20 During intrusive works, visual and olfactory evidence of contamination was noted in groundwater as follows:

- TP101 Slow influx of perched groundwater at 2.5m BGL with visible brown product;
- TP106 Moderate groundwater influx at 0.35m BGL of visibly darker colour and with sheen; and
- TP131 Rapid influx of groundwater at 1.9m BGL with sheen and brown oil.

3.6.21 It was additionally noted that the London Clay was proved to a minimum thickness of 5.00m. Groundwater was found to be within the River Terrace Deposits above the London Clay. It is unlikely that any mobile contamination would penetrate this impermeable layer, which would also prevent the migration of contaminants from the Made Ground to the Chalk at depth

**Buildings and Building Foundations**

- 3.6.22 Sulphate attack on building foundations occurs where sulphate solutions react with the various products of hydration in Ordinary Portland Cement (OPC) or converted High-Alumina Cement (HAC). The reaction is expansive, and therefore disruptive, not only due to the formation of minute cracks, but also due to loss of cohesion in the matrix.
- 3.6.23 The proposals for Unit 3 will involve the construction of building foundations at the site, potentially through the PFA, Made Ground, River Deposits and into the London Clay. The presence of sulphate in soil, leachate and groundwater has therefore been considered through the assessment detailed within BRE Special Digest 1:2005.
- 3.6.24 A characteristic sulphate value from soil has been devised based upon the recommendation that for datasets of more than 10 results, the mean of the highest 20% of the results (rounded to 100mg/l) should be taken as the characteristic value.
- 3.6.25 A characteristic sulphate value from groundwater and for leachate has been devised based upon the recommendation that the single highest determined sulphate concentration of the results should be taken as the respective characteristic value.
- 3.6.26 Consideration of pH is also necessary in selecting a Design Sulphate Class. As the dataset for groundwater had more than 10 results, the mean of the lowest 20% of the results was taken as the characteristic value. The Design Sulphate Class was subsequently selected based upon the lower pH determination resulting from these reviews.

**Table 3.21: Determination of Characteristic Sulphate and pH Values**

	Measured Concentrations	
	Sulphate	pH
<b>Soil</b>	-	7.91
<b>Leachate</b>	140 mg/l	7.7
<b>Groundwater</b>	640mg/l	7.0

- 3.6.27 Although there has been the deposition of waste in the form of river dredgings and pulverised fuel ash, all classifications have been based upon a Natural Site. A mobile groundwater regime has been selected to represent the groundwater perched above the London Clay at the site as there was visible seepage into trial pits and boreholes during the site work.
- 3.6.28 The soils on Unit 2B and 3 (with a characteristic sulphate value of 640 mg/l and a characteristic pH of 6.9) have been given a Design Sulphate Class of DS-2 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-2.
- 3.6.29 This is a provisional review of the ACEC at the site and the dataset upon which the assessments are made may not be representative, particularly of the environment at depth within the London Clay (due to limited sampling). It is additionally noted that the concentration of some chemicals in groundwater (e.g. sulphate) may vary seasonally, probably being greatest in late summer when groundwater is reduced in volume. The sampling forming the basis of this study was undertaken in winter.

**Selection of Materials for Water Supply Pipes**

- 3.6.30 The installation of water supply pipes in contaminated land can lead to the permeation and accelerated deterioration of the pipe material due to chemical reaction between the pipe and the contaminants in the ground in which it is laid. This can lead to premature failures, resulting in leakage and loss of water quality. The Water Supply (Water Fittings) Regulations 1999 (England and Wales) include the requirement that no water fitting shall be installed, connected, arranged or used in such a manner that it causes or is likely to cause contamination of water supplied by a water undertaker. Therefore, suitable materials are necessary when laying water pipes and the laying of water supply pipes in contaminated land is not permitted.
- 3.6.31 In order to assess the risks to conventional pipe material from the contaminants found at the site, criteria are required for concentrations that would be of significance. However, there is a shortage of relevant data which directly relates to the effects of contaminants on pipeline material upon which to base these criteria.
- 3.6.32 The Foundation for Water Research guidance notes (FR 0448: Laying Potable Water Supply Pipelines in Contaminated Ground) have been used by the Water Regulations Advisory Scheme (WRAS) to devise 'threshold' values for various contaminants (WRAS, 2002). Where concentrations are measured in excess of these 'threshold' values it is likely that special consideration of material selection would be required. The guidance however also includes stipulations that:
- The list is not comprehensive, with other potential contaminants known but without information on their critical concentrations;
  - Soil sampling may not be the most appropriate method for establishing concentrations; and
  - Some organic concentrations are known to have a greater effect on polyethylene pipes when present in mixtures rather than singly.
- 3.6.33 The comparison of measured soil concentrations from the site with the 'threshold' levels is presented in appended Table 4.23 with the exceedances summarised within Table 3.22. This also includes the type of contaminant which aids the determination of suitable pipe material.

**Table 3.22: Soil Exceedances of WRAS 'Threshold' Values**

Determinand	Type of Contaminant	WRAS 'Threshold' Value (mg/kg)	No. of Exceedances
Arsenic	Toxic	10	76 of 96
Mercury	Toxic	1.0	2 of 96
Selenium	Organic	3.0	14 of 96
pH	Organic	<5 or >8	62 of 96
Total Petroleum Hydrocarbons	Organic	50	9 of 98
Total Polycyclic Aromatic Hydrocarbons	Corrosive	50	2 of 96

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3.6.34 As toxic, organic and corrosive contaminants are present at the site, a compound pipe would be necessary consisting of polythene-aluminium-polythene. This structure relies upon the aluminium forming an impermeable barrier to prevent organic contaminants from permeating through it, whilst the outer polythene protects the aluminium from corrosive environments. Special attention is required for joints (which may need to be over wrapped with aluminium foil protected by Densoclad tape) and curved ducts to bring the compounds pipes into buildings (to allow for the reduced flexibility of compound pipes).

3.6.35 It is however noted that following the recommendations of the Foundation for Water Research guidance notes, the laying of water pipes across any land where arsenic has been identified is unacceptable without site remediation. It is therefore suggested that as an additional protective measure, all water pipes are laid within trenches lined with impermeable clay barriers to prevent contact of arsenic with the water pipes.

**3.7 Identification of Pollutant Linkages not to be Considered Further**

3.7.1 On the basis of the comparison of the detected chemical concentrations with the criteria described above, Table 3.23 lists the pollutant linkages, with justifications, that are considered insignificant within the context of this risk assessment:

**Table 3.23: Potential Pollutant Linkages**

Contaminant(s)	Pathway(s)	Receptor(s)	Justification
<b>Landfilled material on Unit 2B</b>	Ingestion, inhalation and/or dermal contact with contaminated materials in soils, surface water or windblown	Site workers during future site development	No exceedances of relevant screening values were observed in soil analysis results
<b>Made Ground on Units 2B and 3</b>	Ingestion, inhalation and/or dermal contact with contaminated materials in soils, surface water or windblown	Site workers during future site development	No exceedances of relevant screening values were observed in soil analysis results

**3.8 Remaining Pollutant Linkages**

3.8.1 Following the generic quantitative risk assessment detailed above, Table 3.24 details the remaining pollutant linkages identified as requiring further action.

**Table 3.24: Potential Pollutant Linkages**

Contaminant(s)	Pathway(s)	Receptor(s)	Justification
<b>Made Ground on Unit 2B</b>	Dissolution and leaching into groundwater and surface water of mobile soil contaminants (metals)	Controlled waters (shallow and perched groundwater and ponds)	Elevated concentrations detected in leachate results.

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**Table 3.24: Potential Pollutant Linkages**

Contaminant(s)	Pathway(s)	Receptor(s)	Justification
<b>Made Ground on Unit 2B</b>	Migration of contaminated groundwater (metals and PAHs)	Controlled waters (surface waters such as ponds, ditches and Damhead Creek)	Elevated concentrations detected in groundwater results.
<b>All strata down to London Clay on Unit 2B and 3.</b>	Chemical attack of foundations (e.g. piles) and services through direct contact with aggressive ground conditions	Property (i.e. foundations) and services on-site	DS-2 and AC-2 classifications derived from Sulphate and pH results.
<b>Made Ground on Unit 3</b>	Migration of contaminated groundwater (metals and TPH)	Controlled waters (surface waters such as drainage ditches and ultimately Damhead Creek)	Elevated concentrations detected in groundwater results.
<b>Natural alluvial deposits</b>	Migration of soil gas (Methane and Carbon Dioxide) into buildings and voids from underlying alluvial deposits	Property and buildings (explosive risk)	CIRIA C665 derived Characteristic Situation 2 and higher classifications from previous investigations.
<b>Off-site contamination</b>	Ingestion, inhalation and/or dermal contact with contaminated materials	Site workers and future site occupants	Potential risks to end users of the proposed commercial development have been identified by ERM within Zone IV North from the product and also 8 soil samples associated with the product. Furthermore a number of fragments of cement bound asbestos sheeting were also found in Zone IV North. The identified risks may arise as a result of elevated concentrations of several TPH fractions and Benzo(a)Pyrene predominantly as result of ingestion from soils but as a result of both ingestion and dermal contact with product.
	Dissolution and leaching into groundwater and surface water of mobile soil contaminants	Controlled waters (shallow and perched groundwater)	Potential risks to controlled waters have been identified within the ERM report in Zone IV North from the product, which represents an ongoing source of mobile dissolved phase hydrocarbon contamination. In the PB investigation BH205 showed exceedances of heavy end aliphatic and aromatic TPH.

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**Table 3.24: Potential Pollutant Linkages**

Contaminant(s)	Pathway(s)	Receptor(s)	Justification
<b>Off-site contamination</b>	Migration of contaminated groundwater and surface water	Controlled waters (surface waters such as ponds, ditches and Damhead Creek)	See above

**3.9 Human Health Risk Evaluation**

- 3.9.1 The land quality risk assessment involved the comparison of land quality data with risk based guideline values in line with the current land use (in this instance commercial/industrial land use was adopted).
- 3.9.2 No concentrations were reported in excess of the selected GAC for human health. One soil sample out of the 17No analysed for asbestos returned a positive result for Chrysotile asbestos. The sample was a piece of suspected asbestos cement retrieved from TP130@0.15m bgl. Similar pieces of cement were observed in TP109 and BH205. These were associated with the PFA material in Unit 2B.
- 3.9.3 Outside of the proposed purchase site potential risks to end users of the proposed commercial development have been identified by ERM within Zone IV North. This zone is to the north of Unit 2B. The risks noted by ERM are from both product and also 8 soil samples associated with the product. Furthermore a number of fragments of cement bound asbestos sheeting were also found in this zone. The identified risks may arise as a result of elevated concentrations of several TPH fractions and Benzo(a)Pyrene predominantly as result of ingestion from soils but as a result of both ingestion and dermal contact with product. The PB investigation has not indicated such contamination to be present in the soil or groundwater under Unit 2B and as such it is considered unlikely this impactation will have an effect on this area.
- 3.9.4 However, one aspect of the construction phase of the proposed development will be the 'cut-and-fill' operations required to achieve the final desired profile necessary for both flood defence measures and providing the development platforms for the various proposed buildings. This will entail the movement of material between and within Unit 2B and Unit 3 only. It is understood that Goodman's are to undertake this operation before handing the site to Scottish Power.
- 3.9.5 Consequently it will be important to ensure that any 'cut-and-fill' operations by Goodman renders the land suitable for use and facilitate the proposed Scottish Power industrial development of the site. i.e. material shown by ERM not be to suitable for use from outside of the land to be purchased by Scottish Power such as that in Zone IV north should not be relocated onto land to be purchased. This issue will need to be formalised during the drafting of the purchase agreement.
- 3.9.6 Should Scottish Power have to undertake the works themselves they will also need to ensure the site is suitable for use. As it stands the material on site is likely to be suitable for use in terms of potential risk to human health.
- 3.9.7 However, one soil sample out of the 17No. analysed for asbestos returned a positive result for Chrysotile asbestos. Similar pieces of cement were observed in TP109 and BH205 thus the need for limited removal or placement of such material during future earthworks cannot be ruled out.

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- 3.9.8 A number of remedial solutions are likely to be effective at mitigating potential direct contact risks with any limited additional asbestos containing material that may be found. The most cost effective solution is likely to be the re-use of material beneath hardstanding or at depth. Thus in levelling and regrading the site any asbestos containing material found could be encapsulated at depth. These would not likely be outside the normal works undertaken as part of the levelling and regrading of the site.
- 3.9.9 In addition it is understood that for construction laydown the site will likely be covered by a layer of hardcore. Such a system would provide a capping layer and will provide a barrier between end users and contaminated soils.
- 3.9.10 It is understood that Goodman's are budgeting approximately £800,000 to £1M for the groundwork over the whole of there development site.
- 3.9.11 During PB's site work a small shed was also noted on the site that may contain asbestos containing material. This and any impacted soils will need to be removed by Goodmans during there groundwork. Alternatively Scottish Power will need to make provision for its removal. Assuming this does contain hazardous waste this might cost in the region of £20-40K to remove.
- 3.10 Controlled Water Risk Evaluation**
- 3.10.1 There were four leachate exceedances of the selected screening criteria, including 3No. exceedances of Selenium at 14mg/kg and 21mg/kg, and 1No. exceedance of Chromium at 19mg/kg. These were associated with the PFA material in Unit 2B.
- 3.10.2 There were exceedances of the groundwater assessment criteria for Chromium, Copper and Selenium within samples from all four boreholes on Unit 2B, with one sample from BH201 displaying exceedances of five PAHs.
- 3.10.3 BH206 showed exceedances of Nickel, with BH203 and BH205 showing exceedances of heavy end aliphatic and aromatic TPH in Unit 3, the site of the former oil refinery in Unit 3.
- 3.10.4 The risk posed by the contaminants relates as a result of the dissolution of these substances into pore water, migration through the unsaturated zone into alluvial groundwaters and subsequent migration towards Damhead Creek which would be considered to be the most sensitive receptor as the presence of the London Clay would prevent the downward migration of contaminants to the underlying Chalk Aquifer.
- 3.10.5 The potential risk to groundwater from leaching of contaminated soil is likely to be reduced if the infiltration due to the relatively high proportion of hardstanding associated with proposed development where to be implemented. This is not likely to be the case in the short term on the land to be acquired by Scottish Power as the finalised design of the sites are not yet defined.
- 3.10.6 Based on information in the ERM report there is no evidence to indicate that the adjacent surface water has been adversely impacted by existing elevated concentrations within the groundwater, which may indicate that little if any significant off-site migration occurring.
- 3.10.7 However, with respect to the impaction of the groundwater with TPH in Unit 3. The elevated concentrations of contaminants of concern in groundwater and leachate

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results suggest that there is a potential pollutant linkage to controlled waters from the site. However, this risk does not allow for dilution by the waters of the underlying Minor Aquifer.

- 3.10.8 Preliminary conclusions suggested that local groundwater flow is likely to be towards the closest shoreline at Damhead Creek.
- 3.10.9 Groundwater within the underlying Minor Aquifer deposits is not a utilised resource, and expected dilution effects are likely to prevent contaminant concentrations in Damhead Creek from exceeding environmental water quality standards. Therefore; impacts of any potential discharges are therefore not likely to be measurable.
- 3.10.10 It is understood from meetings with ERM and Goodman's that this is the widely held view of the EA locally however, a DQRA including full hydraulic modelling may need to be carried out in order to be entirely confident in defining that the contamination noted in the groundwater is not affecting the Damhead Creek. The approximate additional cost of this is likely to be £10-15K.
- 3.10.11 If Goodman's carry out the infrastructure works at the site it will be important for Scottish Power to ensure that the works undertaken are considered by the EA as rendering the site suitable for use with respect to the limited source of hydrocarbon contamination found. It is likely that these works will be identified to be necessary by the planning permission and associated planning conditions authorising the development. If however this is the case it will also be important the Scottish Power are not bound to implement parts of these planning conditions on areas of the site that are not to be owned by them.
- 3.10.12 If Scottish Power end up undertaking the works they will also need to be sure that the site is suitable for use from a Controlled Waters point of view.. This could either be through the modelling described above or via limited remediation. If it becomes necessary to remediate this area a number of remedial solutions are likely to be effective at mitigating potential groundwater impacts.
- 3.10.13 These are likely to involve the treatment of the source material to prevent this migrating to the groundwater using methods such as; soil stabilisation (approximate cost £95 per m<sup>3</sup>); bioremediation (approximate cost £50 per m<sup>3</sup>); soil washing (approximate cost £60 per m<sup>3</sup>) or off site disposal (approximate cost £100 per tonne). The amount of material that may need to be treated can only be quantified once remedial targets are calculated and agreed with appropriate regulators. However for budgeting purposes should off site disposal and fill be required a worst case of £3M (excluding transport costs) would be required to excavate contaminated materials from the site. Table 3.25 identifies the likely minimum costs for hotspot removal to a depth of 2m bgl and a bulk density of 2g/cc.

**Table 3.25 Estimated Remediation Costs**

	<b>Minimum (1,800m<sup>3</sup>)</b>	<b>Maximum (13,100m<sup>3</sup>)</b>
Stabilisation	£171,000	£1.3M
Bioremediation	£90,000	£655,000
Soil Washing	£108,000	£786,000
Landfill	£360,000	£2.6M
Imported fill	£21,600	£314,400

**SECTION 3  
GENERIC QUANTITATIVE RISK  
ASSESSMENT**

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3.10.14 It is also noted that ERM indicate potential risks to controlled waters within Zone IV North from product, which represents an ongoing source of mobile dissolved phase hydrocarbon contamination. Specifically potential risks have been identified as a result of the presence of naphthalene, 4 -methylphenol, acenaphthene and the aromatic C12-C16 fraction.

3.10.15 With respect to the impaction in area IV north ERM have noted the most cost effective treatment solution is likely to be the stabilisation of the product using appropriate bulking and binding agents. Stabilisation will not substantially reduce the overall concentrations of the contaminants of concern but will mitigate the mobile soluble fraction. As noted previously this is not within the site to be purchased by Scottish Power and modelling undertaken by ERM and monitoring undertaken during this ground investigation do not suggest this source area is impacting the land to be purchased by Scottish Power.

**3.11 Ground Gas Risk Evaluation**

3.11.1 VOC concentrations were typically recorded with the PID below 5ppm. Elevated peak concentrations were recorded within a number of excavations. These concentrations are elevated relative to those typically measured at the site and exceed 50ppm where a potential risk to human health through the inhalation of vapours may be considered feasible. However soil analysis did not indicate a viable source of volatiles present in the vadose zone at the site. We would expect this to be noted from the soil and groundwater analysis undertaken.

3.11.2 Guidance on assessing the risk posed by hazardous ground gases is given within CIRIA Report 665. Given that the proposed future use for the site is commercial, Situation A (all development types except low rise housing with gardens) has been selected from this guidance to represent the future exposure scenario at Units 2B and 3. Typical Maximum Concentrations and Gas Screening Values have been calculated to define the gas regime at the site, and are presented in Table 3.20. The worst case conditions have been adopted in order to establish the appropriate protection measures required at the site.

3.11.3 The site has been determined as Characteristic Situation 2 (low risk) and is consistent with 'typical' Made Ground. Special protection requirements are listed below:

- a) Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) with at least 1200 g DPM2.
- b) Beam and block or pre cast concrete slab and minimum 2000 g DPM/reinforced gas membrane.
- c) Possibly under floor venting or pressurisation in combination with a) and b) depending on use.
- All joints and penetrations sealed.

3.11.4 However, reference to the ERM report 'Kingsnorth, Land Contamination Further Investigation and Risk Assessment Works' suggests that while the Characteristic Situation of 2 agrees with ERM's conclusion for Unit 3, it differs to their assignment of a Characteristic Situation of 3/4 for land inclusive of Unit 2B. This is based on results obtained from ERM-installed boreholes which were not included in the monitoring rounds undertaken for this report. It is also noted that the PB monitoring has been limited to three occasions to date. Whilst it is clear that some gas protection is likely

### SECTION 3 GENERIC QUANTITATIVE RISK ASSESSMENT

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to be required the type and hence cost cannot be defined at present. As a worst case the ERM recommendations could be followed. However at present the type of structure to be constructed by Scottish Power on Units 2B and 3 are not defined. This will be important in defining what protection measures will be required. However it is also suggested that further monitoring of all boreholes on Unit 2B be undertaken for a more accurate Characteristic Situation to be derived over time.

- 3.11.5 Remedial activities identified by the relevant planning conditions to be undertaken during the construction of the built development, such as those arising from the presence of ground gases (for example subfloor vented voids or membranes in floor slabs), are likely to be excluded from the enabling works to be undertaken by Goodmans and as such if required will likely need to be addressed by Scottish Power.

#### **3.12 Other Selection of Materials for Water Supply Pipes**

- 3.12.1 The installation of water supply pipes in contaminated land can lead to the permeation and accelerated deterioration of the pipe material due to chemical reaction between the pipe and the contaminants in the ground in which it is laid.

- 3.12.2 As toxic, organic and corrosive contaminants are present at the site, a compound pipe would be necessary consisting of polythene-aluminium-polythene. This structure relies upon the aluminium forming an impermeable barrier to prevent organic contaminants from permeating through it, whilst the outer polythene protects the aluminium from corrosive environments. Special attention is required for joints (which may need to be over wrapped with aluminium foil protected by Densoclad tape) and curved ducts to bring the compound pipes into buildings (to allow for the reduced flexibility of compound pipes).

- 3.12.3 It is however noted that following the recommendations of the Foundation for Water Research guidance notes, the laying of water pipes across any land where arsenic has been identified is unacceptable without site remediation. It is therefore suggested that as an additional protective measure, all water pipes are laid within trenches lined with impermeable clay barriers to prevent contact of arsenic with the water pipes.

- 3.12.4 It will be important to ensure that appropriate water supply pipes are installed by Goodman's should they undertake the infrastructure works.

#### **3.13 Waste Licensing**

- 3.13.1 One aspect of the construction phase of the proposed development will be the 'cut-and-fill' operations required to achieve the final desired profile necessary for both flood defence measures and providing the development platforms for the various proposed buildings. It is understood that the cut and fill in Units 2B and 3 will be balanced from material within the proposed Units 2A and 2B only. As such material will not be imported from the area covered by the existing Environmental Permit. Consequently, resolution of existing restoration conditions for the licensed landfill are unlikely to be an issue. . These existing licence conditions prevent re-excavation of the deposited PFA material, and require completions of site levels to an agreed profile.

- 3.13.2 However the main issue will be the potential for moving and /or exposing contaminated soils / waste.

- 3.13.3 Without the cut-and-fill, it would be necessary to import fill materials to raise levels in various areas of the Site. The importation of significant amounts of fill and possible

**SECTION 3  
GENERIC QUANTITATIVE RISK  
ASSESSMENT**

---

associated disposal of material off-site may not be particularly cost beneficial or accord with planning aspirations / requirements for sustainability and would lead to adverse environmental effects from additional traffic and associated noise and air quality.

- 3.13.4 It is understood that Goodmans are to obtain a site licence which authorises the excavation, re-deposition and therefore recovery of the waste and this is linked to a planning permission authorising the activity. In the case a site licence will also require surrendering following completion of site works and when waste materials have been re-used and can be demonstrated to have been fully recovered. The most appropriate way forward with respect to the implementation of the waste management licensing regime will be determined following consultation and agreement with the Environment Agency. It will be important to note that this license will likely cover land to be owned by Scottish Power. The legal ramification of this need to be fully understood by Scottish Power and covered in the draft contract.

SECTION 4

## **CONCLUSIONS AND RECOMMENDATIONS**

## **4 CONCLUSIONS AND RECOMMENDATIONS**

### **4.1 Conclusions and Recommendations**

- 4.1.1 Site works were undertaken at Units 2B and 3 at the Damhead Creek Power Station between the 17<sup>th</sup> and the 28<sup>th</sup> November 2008. Works comprised the excavation of 31No. trial pits and 7No. boreholes.
- 4.1.2 The site investigation works were undertaken to determine the chemical composition of the soil and groundwater in regard to soil and dissolved phase contamination, in accordance with the procedures set out within the EA report CLR 11.
- 4.1.3 Following the site investigation and quantitative risk assessment, the following conclusions were drawn:

### **4.2 Human Health**

- 4.2.1 The land quality risk assessment involved the comparison of land quality data with risk based guideline values in line with the current land use, (in this instance commercial/industrial land use was adopted). No concentrations were reported in excess of the selected GAC for human health. One soil sample out of the 17No analysed for asbestos returned a positive result for Chrysotile asbestos. The sample was a piece of suspected asbestos cement retrieved from TP130@0.15m bgl. Similar pieces of cement were observed in TP109 and BH205.
- 4.2.2 Outside of the proposed purchase site potential risks to end users of the proposed commercial development have been identified by ERM within Zone IV North. This zone is to the north of Unit 2B. The PB investigation has not indicated such contamination to be present in the soil or groundwater under Unit 2B and as such it is considered unlikely this impaction will have an effect on this area.
- 4.2.3 However, one aspect of the construction phase of the proposed development will be the 'cut-and-fill' operations required to achieve the final desired profile necessary for both flood defence measures and providing the development platforms for the various proposed buildings. This will entail the movement of material between and within Units 2B and Unit 3 only. It is understood that Goodman's are to undertake this operation before handing the site to Scottish Power. Movement of material between the sites should be verified via sampling and analysis to ensure that that any 'cut-and-fill' operations by Goodman renders the land suitable for use and able to facilitate the proposed Scottish Power industrial development of the site.
- 4.2.4 Should Scottish Power have to undertake the works themselves they will also need to ensure the site is suitable for use. As is stands, with the exception of the presence of asbestos the material on site is likely to be suitable for use in terms of potential risk to human health.
- 4.2.5 One soil sample out of the 17No. analysed for asbestos returned a positive result for Chrysotile asbestos. Similar pieces of cement were observed in TP109 and BH205 thus the need for limited removal or placement of such material during future earthworks cannot be ruled out.
- 4.2.6 A number of remedial solutions are likely to be effective at mitigating potential direct contact risks with any limited additional asbestos containing material that may be found. The most cost effective solution is likely to be the re-use of material beneath hardstanding or at depth. Thus in levelling and regrading the site any asbestos containing material found could be encapsulated at depth. These would not

likely be outside the normal works undertaken as part of the levelling and regarding of the site.

4.2.7 In addition it is understood that for construction laydown the site will likely be covered by a layer of hardcore. Such a system would provide a capping layer and will provide a barrier between end users and contaminated soils.

4.2.8 During PB's site work a small shed was also noted on the site that may contain asbestos containing material. This and any impacted soils will need to be removed by Goodmans during there groundwork. Alternatively Scottish Power will need to make provision for its removal. Assuming this does contain hazardous waste this might cost in the region of £20-40K to remove.

### **4.3 Controlled Water Risk Evaluation**

4.3.1 There were four leachate exceedances of the selected screening criteria, including 3No. exceedances of Selenium at 14mg/kg and 21mg/kg, and 1No. exceedance of Chromium at 19mg/kg. These were associated with the PFA material in Unit 2B.

4.3.2 There were exceedances of the groundwater assessment criteria for Chromium, Copper and Selenium within samples from all four boreholes on Unit 2B, with one sample from BH201 displaying exceedances of five PAHs. These are likely associated with the PFA material in Unit 2B.

4.3.3 BH206 showed exceedances of Nickel, with BH203 and BH205 showing exceedances of heavy end aliphatic and aromatic TPH in Unit 3. These are likely associated with the site's former use as part of an oil refinery.

4.3.4 The risk posed by the contaminants relates as a result of the dissolution of these substances into pore water, migration through the unsaturated zone into alluvial groundwaters and subsequent migration towards Damhead Creek which would be considered to be the most sensitive receptor as the presence of the London Clay would prevent the downward migration of contaminants to the underlying Chalk Aquifer.

4.3.5 Based on information in the ERM report there is no evidence to indicate that the adjacent surface water has been adversely impacted by existing elevated concentrations within the groundwater, which may indicate that little if any significant off-site migration occurring.

4.3.6 However, with respect to the impaction of the groundwater with TPH in Unit 3, the elevated concentrations of contaminants of concern in groundwater results suggest that there is a potential pollutant linkage to controlled waters from the site. However, this risk does not allow for dilution by the waters of the underlying Minor Aquifer.

4.3.7 Groundwater within the underlying Minor Aquifer deposits is not a utilised resource, and expected dilution effects are likely to prevent contaminant concentrations in Damhead Creek from exceeding environmental water quality standards. Therefore; impacts of any potential discharges are therefore not likely to be measurable.

4.3.8 It is understood from meetings with ERM and Goodman's that this is the widely held view of the EA locally however, a DQRA including full hydraulic modelling may need to be carried out in order to be entirely confident in defining that the contamination noted in the groundwater is not affecting the Damhead Creek.

4.3.9 If Goodman's carry out the infrastructure works at the site it will be important for Scottish Power to ensure that the works undertaken are considered by the EA as

rendering the site suitable for use with respect to the limited source of hydrocarbon contamination found. The works should be supervised and validated by a third party engineer. It is likely that these works will be identified to be necessary by the planning permission and associated planning conditions authorising the development. If however this is the case it will also be important the Scottish Power are not bound to implement parts of these planning conditions on areas of the site that are not to be owned by them.

4.3.10 If Scottish Power end up undertaking the works they will also need to be sure that the site is suitable for use from a Controlled Waters point of view. This could either be through the modelling described above or via limited remediation.

#### **4.4 Ground Gas Risk Evaluation**

4.4.1 VOC concentrations were typically recorded with the PID below 5ppm. Elevated peak concentrations were recorded within a number of excavations. However, soil analysis did not indicate a viable source of the volatiles be present in the vadose zone at the site we would expect this to be noted from the soil and groundwater analysis undertaken.

4.4.2 Guidance on assessing the risk posed by hazardous ground gases is given within CIRIA Report 665. The worst case conditions have been adopted in order to establish the appropriate protection measures required at the site.

4.4.3 The site has been determined as Characteristic Situation 2 (low risk) and is consistent with 'typical' Made Ground. Special protection requirements are listed below:

- a) Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) with at least 1200 g DPM2.
- b) Beam and block or pre cast concrete slab and minimum 2000 g DPM/reinforced gas membrane.
- c) Possibly under floor venting or pressurisation in combination with a) and b) depending on use.
- All joints and penetrations sealed.

4.4.4 However, reference to the ERM report 'Kingsnorth, Land Contamination Further Investigation and Risk Assessment Works' suggests that while the Characteristic Situation of 2 agrees with ERM's conclusion for Unit 3, it differs to their assignment of a Characteristic Situation of 3/4 for land inclusive of Unit 2B. This is based on results obtained from ERM-installed boreholes which were not included in the monitoring rounds undertaken for this report. It is also noted that the PB monitoring has been limited to three occasions to date. Whilst it is clear that some gas protection is likely to be required the type and hence cost cannot be defined at present. As a worst case the ERM recommendations could be followed. However at present the type of structure to be constructed by Scottish Power on Units 2B and 3 are not defined. This will be important in defining what protection measures will be required. However it is also suggested that further monitoring of all boreholes on Unit 2B be undertaken for a more accurate Characteristic Situation to be derived over time.

#### **4.5 Other Selection of Materials for Water Supply Pipes**

4.5.1 It will be important to ensure that appropriate water supply pipes are installed by Goodman's should they undertake the infrastructure works.

## **4.6 Waste Licensing**

- 4.6.1 It is understood that Goodmans are to obtain a site licence which authorises the excavation, re-deposition and therefore recovery of the waste and this is linked to a planning permission authorising the activity. In the case a site licence will also require surrendering following completion of site works and when waste materials have been re-used and can be demonstrated to have been fully recovered. The most appropriate way forward with respect to the implementation of the waste management licensing regime will be determined following consultation and agreement with the Environment Agency. It will be important to note that this license will likely cover land to be owned by Scottish Power. The legal ramification of this need to be fully understood by Scottish Power.
- 4.6.2 In summary it is considered that provided Goodmans undertake the works as per the specification or Scottish Power make appropriate provision to undertake the works outlined it is likely this site can be made to be suitable for its intended use.
- 4.6.3 All conclusions are based upon the development of the site for commercial end use comprising the construction of an electricity sub station on Unit 3 and the use of Unit 2B as a welfare and construction lay down area during the construction, with a view to the installation of a carbon capture plant in the future. Should design changes to this proposal occur, re-examination of the data will be necessary.

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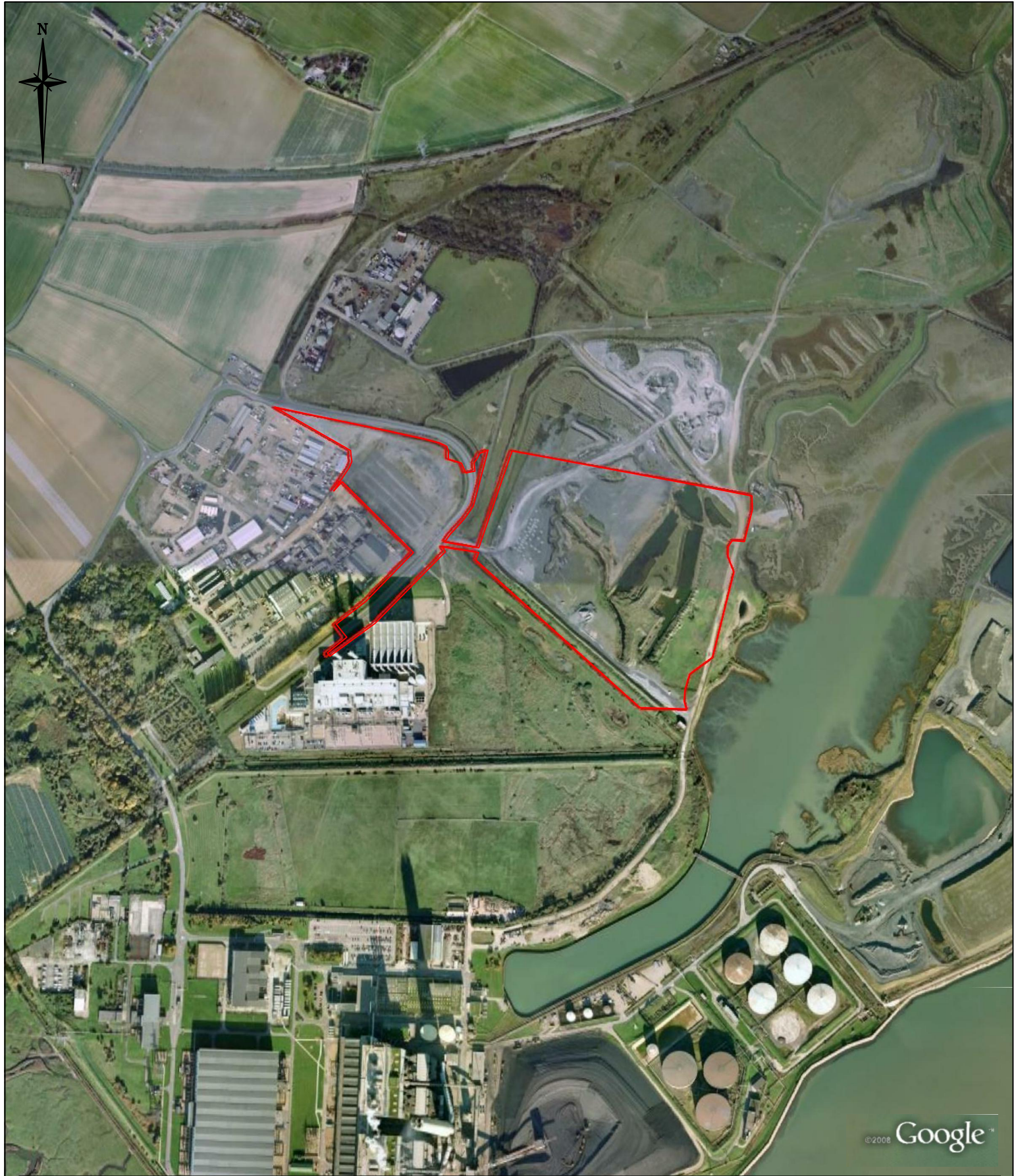
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## FIGURES





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• CLIENT/PROJECT

SCOTTISH POWER  
 ENVIRONMENTAL ASSESSMENT  
 GOODMAN LAND (UNIT 2B &3)  
 KINGSNORTH, ISLE OF GRAIN

• TITLE

SITE LOCATION PLAN

• DATE 17/10/2008

• SCALE Not to Scale

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DRAWN BY JSdS

PRODUCED BY MS

CHECKED DCH

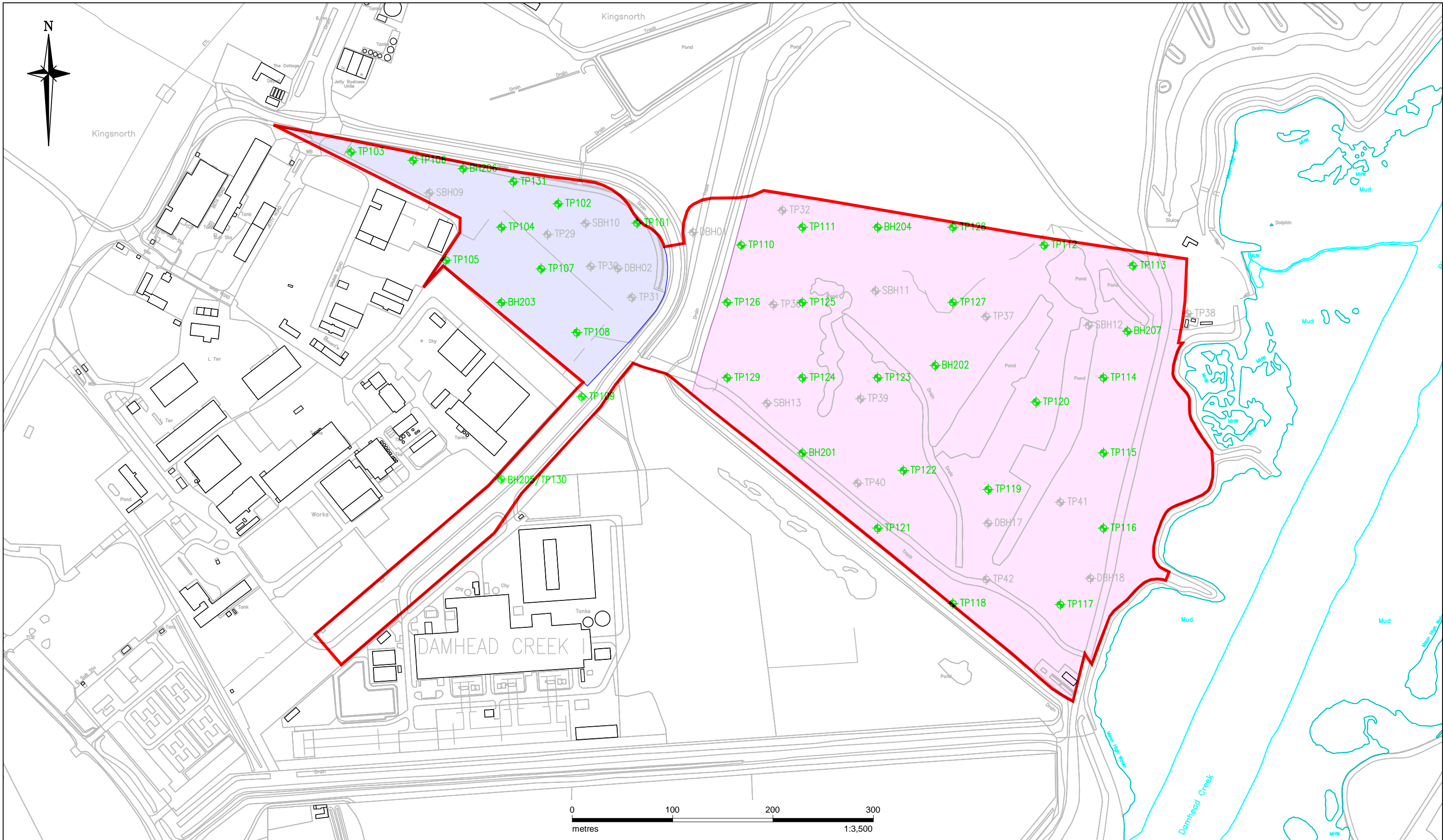
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• DRAWING NUMBER

**FIGURE 1**

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REV	DATE	DESCRIPTION	BY	CHKD	APPD

**NOTES**

- ◊ ERM INVESTIGATION LOCATIONS 2008
- ◆ PB INVESTIGATION LOCATIONS 2008
- UNIT 2B
- UNIT 3
- SITE BOUNDARY

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**CLIENT/PROJECT**  
SCOTTISH POWER  
ENVIRONMENTAL ASSESSMENT  
GOODMAN LAND (UNIT 2B & 3)  
KINGSNORTH, ISLE OF GRAIN

**TITLE**  
EXPLORATORY HOLE LOCATIONS

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		APPROVED	PS

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# FIGURE 2

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TP110	
Depth	Leachate
	0.6m
Selenium	14

BH204		
	Groundwater Round 1	Groundwater Round 2
Chromium	53	57
Copper	49	30
Mercury	1.7	
Selenium	64	66

TP112	
	Leachate
Depth	0.4m
Selenium	14

BH206		
	Groundwater Round 1	Groundwater Round 2
Nickel	46	31

BH207		
	Groundwater Round 1	Groundwater Round 2
Chromium	16	67
Copper	11	100
Selenium	15	63

BH203	
	Groundwater Round 1
TPH aliphatic >C16-C21	64
TPH aromatic >C21-C35	19
Total Petroleum Hydrocarbons	1300

BH202	
	Groundwater Round 2
Chromium	29
Copper	30
Selenium	28

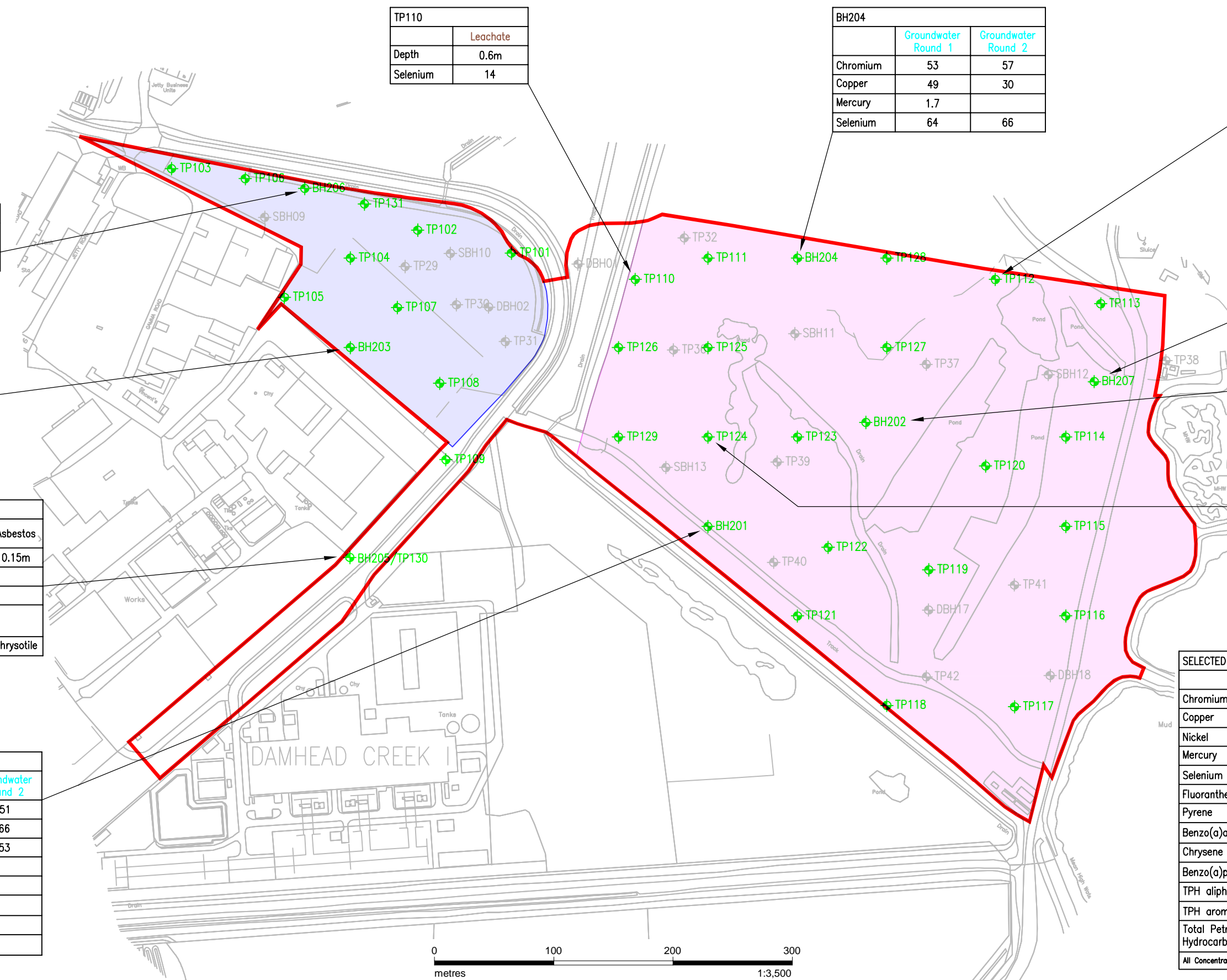
BH205	
	Groundwater Round 1
Depth	Asbestos
	0.15m
TPH aliphatic >C16-C21	54
TPH aromatic >C21-C35	26
Total Petroleum Hydrocarbons	640
Asbestos	Chrysotile

TP124	
	Leachate
Depth	0.5m
Chromium	19
Selenium	21

BH201		
	Groundwater Round 1	Groundwater Round 2
Chromium	46	51
Copper	49	66
Selenium	50	53
Fluoranthene	2.5	
Pyrene	7.1	
Benzo(a)anthracene	3.4	
Chrysene	2.8	
Benzo(a)pyrene	6.4	

SELECTED SCREENING CRITERIA		
	VALUE	SOURCE
Chromium	15	EQS
Copper	5	EQS
Nickel	30	EQS
Mercury	0.3	EQS
Selenium	10	UK DWS
Fluoranthene	0.9	LEC
Pyrene	4	LEC
Benzo(a)anthracene	1.8	LEC
Chrysene	0.7	LEC
Benzo(a)pyrene	1.5	LEC
TPH aliphatic >C16-C21	0.001	DUTCH
TPH aromatic >C21-C35	7	DUTCH
Total Petroleum Hydrocarbons	10	UK DWS

All Concentrations in µg/l



REV	DATE	DESCRIPTION	BY	CHKD	APPD

NOTES

- ERM INVESTIGATION LOCATIONS 2008
- PB INVESTIGATION LOCATIONS 2008
- UNIT 2B
- UNIT 3
- SITE BOUNDARY

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 ENVIRONMENTAL ASSESSMENT  
 GOODMAN LAND (UNIT 2B & 3)  
 KINGSNORTH, ISLE OF GRAIN

TITLE  
 GROUNDWATER AND LEACHATE  
 EXCEEDANCE PLAN

DATE 08/12/08  
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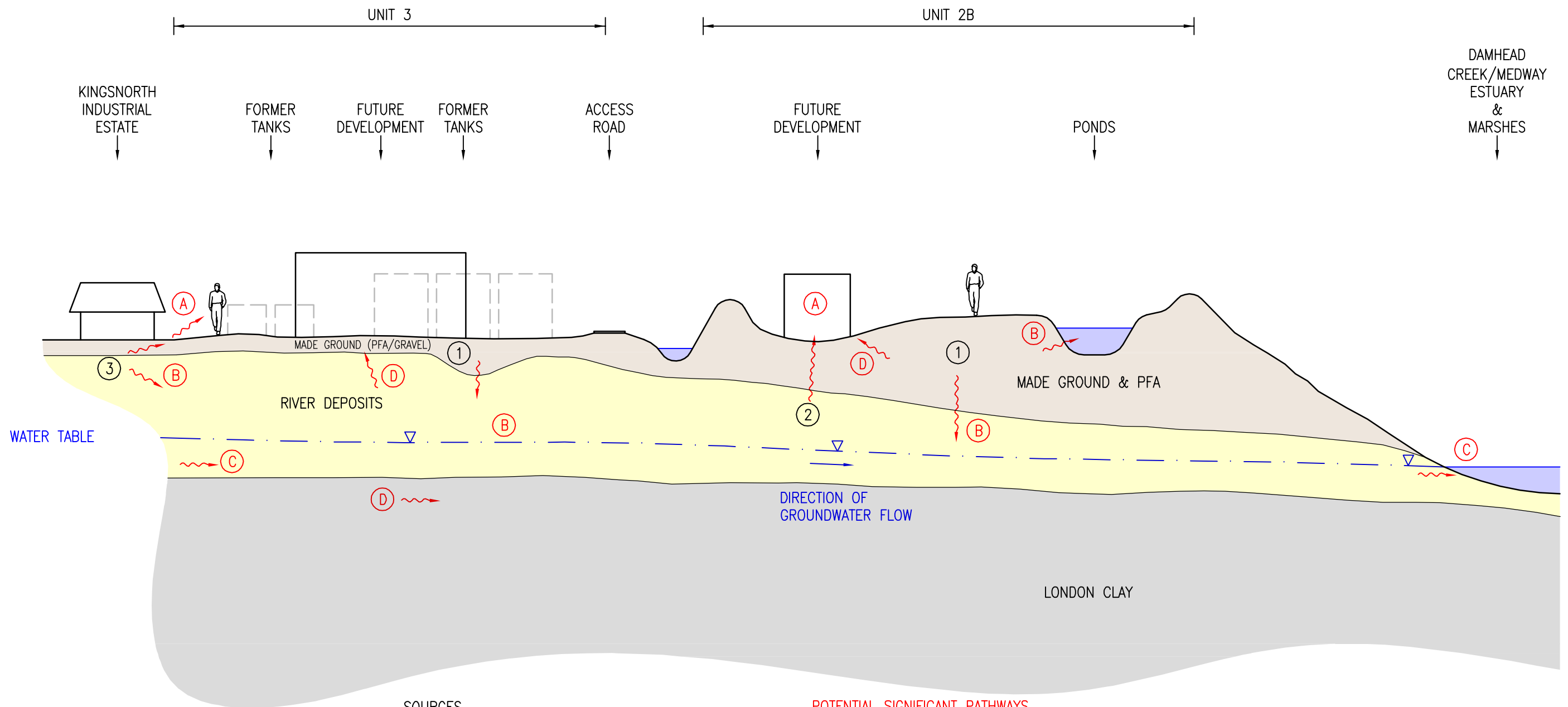
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**FIGURE 3**

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NORTH WEST

SOUTH EAST



**SOURCES**

- ① MADE GROUND ON UNIT 2B & 3
- ② NATURAL ALLUVIAL DEPOSITS
- ③ OFF-SITE CONTAMINATION

**POTENTIAL SIGNIFICANT PATHWAYS**

- Ⓐ INGESTION/INHALATION/DERMAL CONTACT WITH CONTAMINATED MATERIAL IN SOILS, SURFACE WATER OR WINDBLOWN
- Ⓑ DISSOLUTION AND LEACHING INTO GROUNDWATER AND/OR SURFACE WATER
- Ⓒ MIGRATION OF CONTAMINATED GROUNDWATER AND SURFACE WATER
- Ⓓ CHEMICAL ATTACK OF FOUNDATIONS AND SERVICES
- Ⓔ MIGRATION OF SOIL GAS INTO BUILDINGS OR VOIDS

REV	DATE	DESCRIPTION	BY	CHKD	APPD	NOTES

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CLIENT/PROJECT  
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 ENVIRONMENTAL ASSESSMENT  
 GOODMAN LAND (UNIT 2B & 3)  
 KINGSNORTH, ISLE OF GRAIN

TITLE  
 CONCEPTUAL SITE MODEL

• DATE	14/10/08	DRAWN BY	BRG
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• CAD REF	\\PBPow\62725A\SI\Z\1\62725A-F04.dwg	CHECKED	DCH
		APPROVED	PS

• DRAWING NUMBER  
**FIGURE 4**

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