14.0 SOILS, GEOLOGY AND CONTAMINATION

14.1 INTRODUCTION

This section of the assessment discusses the historical and current use of the proposed development site in relation to the issue of contaminated land and the underlying geology and hydrogeology. It details the objectives, methodology and findings of a Phase 1 Desk Based review including a review of previous site investigation data, a Phase II intrusive site investigation, conducted by ENVIRON in 2004, and also considers the potential impacts of disturbance of the soils on the site associated with the redevelopment proposals.

In particular the site is known to have had a long potentially contaminative history and there are polluted soils, surface waters and groundwater on the site. Most notably, there is known to be a widespread presence of galligu contamination on the site (chemical waste from the alkali industry and in particular the *Le Blanc* Process). As such the client is conscious of the potential for these materials to be disturbed during the redevelopment programme and have thus developed a strategy for managing these materials. This necessitated a comprehensive site investigation across the proposed development area, which is discussed in detail later in this section of the report.

14.2 ASSESSMENT METHODOLOGY

The study involved a combination of desk-based studies, consultations with interested parties and regulators and site based investigation and sampling. The 2004 site investigation was designed based upon known site conditions from earlier investigations, geotechnical requirements for the previous development and the need to characterise those materials most likely to be disturbed during the proposed redevelopment of the site.

14.2.1 Desk Based Review

The methodology employed in completing the desk-based review of the site and surroundings involved the following:

- a review of historical maps of the site and surrounding area to determine any historical potential for contamination at or within the vicinity of the site;
- consultation with Halton Borough Council and the Environment Agency regarding contaminated land issues associated with the site and surroundings, including the presence of licensed landfills and other sites that may have been identified under Part IIA of the *Environmental Protection Act 1990*;
- a search of the Environment Agency website (www.environment-agency.co.uk), regarding the ground condition of the site and immediate vicinity (landfill and waste sites, pollution incidents) and groundwater and surface water information;
- a review of records held on an environmental database (Envirocheck), including records of landfills, water abstractions, pollution incidents, enforcements and prosecution actions;
- interpretation of the British Geological Survey (BGS) map of the area (BGS Sheet 97, Runcorn, Scale 1:50,000);
- consultation of the Radon Atlas of England and Wales, published by the National Radiological Protection Board (2002) and Radon: guidance on protective measures for new dwellings, published by the Department of the Environment, Transport and the Regions (1999);
- interpretation of the Environment Agency Groundwater Vulnerability Map of the area (Sheet 16, West Cheshire, 1:100,000) and the Policy and Practice for the Protection of Groundwater Regional Appendix;
- a review of previous intrusive investigations of the proposed development site. Some of these facilitated the assessment of chemical conditions across the site but some were restricted to geotechnical testing and were thus of limited value to this study; and
- numerous site visits and interviews with current site personnel to assess current site activities and environmental setting.

Information from the desk-based review and earlier site investigations identified potential pollution sources on the site and provided some limited quantification of these and identified potential pathways for pollutants to migrate from the source areas to potential receptors (humans, ecosystems, buildings, etc). Based upon the preliminary desk based risk assessment it was then possible to identify likely risk scenarios and design a comprehensive site wide investigation that could be used to characterise the site, assess the risks and develop appropriate mitigation measures.

The site investigation methodology undertaken for the previous application in 2004 is described below, with the findings and interpretation presented later in this report section.

14.2.2 Site Investigation Methodology – ENVIRON 2004

ENVIRON was commissioned in 2004 to undertake a site wide comprehensive site investigation to support the design of the development proposals at that time and provide a more comprehensive characterisation of the site for the previous planning application and EIA submission.

Sampling locations were positioned to provide a representative spatial assessment of the ground conditions, to target identified areas of potential contamination (e.g. current storage tanks) and to provide preliminary geotechnical information. The intrusive investigation was carried by ENVIRON over a period of five weeks, from the 8th November 2004 to the 16th December 2004 with subsequent periods of sample analysis, monitoring and assessment of results. The field investigation comprised the following:

- the drilling of twelve boreholes by cable percussion/rotary drilling methods;
- the drilling of sixteen shallow window sample holes by hydraulic sampling equipment;
- the excavation of twenty three trial pits using a machine excavator;
- the excavation of two spoil mounds using a machine excavator;
- field examination and sampling of soil and groundwater;
- chemical analysis of selected soils, surface water and groundwater samples for a range of contaminants, which are likely to be associated with current and historical activities on the site;
- submission of selected soil samples for geotechnical testing; and
- sampling and monitoring of installed locations for land gases.

The sampling locations associated with this investigation are presented in *Figure 14.1*.

Boreholes

The first phase of the investigation involved the excavation of twelve boreholes (BH8, BH9, BH11, BH12, BH14, BH15, BH23, BH31, BH34, BH43, BH51 and BH55) to depths of between 11.00 m below ground level (bgl) and 40.00 m bgl using cable percussion drilling techniques. These were designed to establish the characteristics of the underlying strata at depth and to facilitate gas and groundwater sampling. All of the boreholes, with the exception of BH51 and BH55 (which were terminated due to ground conditions), were progressed to the interface of the sandstone bedrock, with three of the boreholes (BH12, BH23 and BH31) then further advanced into the sandstone bedrock to a maximum depth of 45.50 m bgl by rotary drilling methods. This was for geotechnical purposes.

The Foundry Lane site investigation comprised five boreholes (BH8, BH9, BH11, BH12 and BH15), one of which (BH12), was advanced into the sandstone bedrock for geotechnical purposes, to a depth of 18.8 m by rotary drilling methods. Two boreholes (BH14 and BH23) were located on the unsurfaced area to the north of the reclamation mound, one of which (BH23), was also advanced into the sandstone bedrock for geotechnical purposes, to a depth of 36.0 m by rotary drilling methods. The West Bank Dock site investigation comprised five boreholes (BH31, BH34, BH43, BH51 and BH55), one of which (BH31) was advanced into the sandstone bedrock for geotechnical purposes, to a depth of 45.5 m by rotary drilling methods. Upon completion of the geotechnical testing, the sandstone stratum within the three rotary boreholes was grouted back up with cement/bentonite to the base of the glacial till in order to prevent any mobile contaminants (if present), to migrate laterally or downwards to the sandstone aquifer.

The cable percussion drilling rigs used temporary steel casing to prevent the hole from collapsing and prevent influx of contaminated soils and groundwater. No fluids or foams were used during the drilling operations, other than small amounts of clean water to assist the driving of the casing. The drilling tools and casing were cleaned by washing down with mains water after completion of each borehole to prevent possible cross contamination between borehole locations. Decontamination of the equipment was undertaken at a designated location assigned by ENVIRON field personnel.

The boreholes were completed as gas and groundwater monitoring wells using 50mm diameter High Density Polyethene (HDPE) standpipes with a combination of solid casing and slotted well screen, set within a 2-5mm gravel filter pack. The wells were completed with steel monitoring well covers. Illustrations of the well design are provided in Volume 3 of the ES (*Appendix 14.2)*.

Window Sample Holes

In addition to the deep boreholes the excavation of sixteen window sample holes was undertaken (WS1-WS16) to depths of up to 5.00 m bgl using hydraulically-powered sampling equipment to enable the visual assessment and logging of shallow ground conditions in hard-surfaced or difficult to access areas of the site. The rationale for the location of the window sample positions was to target identified potential on-site sources of contamination within the West Bank Dock site.

Four of the window sample holes (WS4, WS6, WS11 and WS16) were installed with 35mm monitoring wells, to facilitate gas and shallow groundwater monitoring. The locations at which wells were installed were selected where perched groundwater was encountered and field evidence suggested possible contamination. The wells comprised slotted well screen set within a gravel filter pack with the upper sections of the wells comprising plain pipe set within a bentonite clay seal to the surface to prevent the ingress of surface water. The wells were completed with steel monitoring well covers. All remaining window sample locations were reinstated (grouted).

Trial Pit Sampling locations

The excavation of twenty three trial pits (TP1-TP23) to depths of up to 5.30 m bgl using a machine excavator was undertaken to permit the sampling of soils and to enable a wider visual assessment of shallow ground conditions within the unsurfaced areas of the site. This element of the investigation mainly comprised the southern area of the West Bank Dock site (TP1-TP7), the area of land to the north of the Reclamation site (TP8-TP14) and the southern section of the Reclamation site (TP15-TP23). Trial pit sampling locations were positioned to provide a reasonable spatial coverage of each of these areas, rather than targeting specific strata or suspected contamination hot spots.

Surface Mound Sampling

In addition to potentially contaminated materials present in the ground, there is also the potential for surface deposits of material to be contaminated. In particular there were the two mounds present on site that were investigated. The excavation of trial pits / trenches into the mounds located on the Foundry Lane site (adjacent Ditton Brook) and on the southern area of the West Bank Dock site (separating AHC from Granox (PDM)) was undertaken using the machine excavator. The sampling of soils/spoil material in these mounds enabled an assessment of the material for possible re-use at the site during redevelopment or for classification for off-site disposal, if required.

It should be noted that the positioning of excavations was restricted due to the presence of the current buildings, the presence of live services and by on-going operational activities at the site. In accordance with ENVIRON's Health and Safety protocol, each sampling location was confirmed as safe for excavation and free from buried services by a specialist independent contractor (RGI) using available utility drawings, visual methods and cable avoidance equipment.

In addition to the above, surface soil samples were also taken in several proposed landscaping areas and subjected to nutrient and growth suitability analysis to support the landscaping design (see *Section 10 - Landscape and Visual Character*).

14.2.3 Sample Acquisition and on-site analysis

Soil

Soil samples were obtained from the boreholes, window sample holes and trial pit locations at regular intervals, on changes in strata or horizons of observed potential contamination. The samples were collected using clean instruments, and examined for visual and olfactory evidence of contamination; observations were recorded on logs, which are presented in *Appendix 14.2*. The samples were then subjected to headspace testing for volatile hydrocarbons (VOCs) on site using a Photovac 2020 photoionisation detector (PID) fitted with a 10.6eV lamp.

Headspace testing involves analysing the sealed atmosphere of a soil sample for volatile hydrocarbons. The presence of hydrocarbon vapours acts as an indication of contamination in the soil, although not an absolute measurement of the concentration of volatile hydrocarbons. A wide spectrum of organic vapours including aromatics, amines, alkanes (>C_4), certain chlorinated solvents, alkenes and heterocyclics can be detected by the PID. The limit of detection for most species is 0.2ppmv (parts per million by volume) and the operating range is 0.1-2000ppmv. The results of the headspace testing are presented in graphical format on the lithological logs in *Appendix 14.2* and the analytical results are presented in *Section 14.4*.

Groundwater

Groundwater samples were obtained from the boreholes/window sample locations after completion of the well installations. Prior to sampling the groundwater in each well, the depth to groundwater was first measured and the well developed by the removal of at least three well volumes. The groundwater levels were then allowed to recover before sampling to ensure that the samples were of "fresh" groundwater, representative of the surrounding water bearing strata. Samples were obtained using a disposable HDPE bailer or waterra tubing, which were specifically dedicated to each well to avoid cross-contamination between sampling locations. These were disposed of following use. The groundwater samples were assessed in the field for sheens, colour and odours and particularly examined for the presence of free-phase product (*i.e.* a distinct layer of contaminated liquid). The groundwater monitoring data and the analytical results are presented in *Section 14.4*.

Gas Monitoring Survey

Soil gas concentrations were recorded in each of the boreholes and the four installed window sample holes on several occasions. Measurements were taken using a fully calibrated portable infra-red gas analyser (Geotechnical Instruments Gas analyser GA2000) and soil gas was monitored for the presence of flammable gas (calibrated as methane), carbon dioxide, oxygen, hydrogen sulphide, carbon monoxide and atmospheric pressure. Gas flow rates were additionally monitored using an integrated gas flow pod. In addition, several gas samples were collected in the field and analysed for bulk gas composition at an accredited laboratory. The results of the gas monitoring are discussed in *Section 14.4*.

QA/QC Sample Handling Procedures

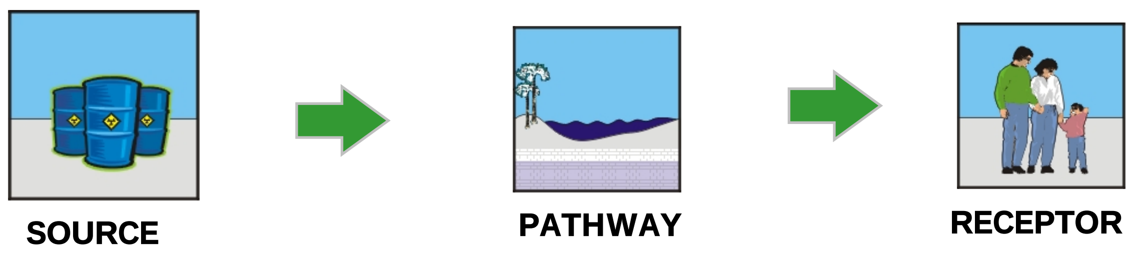
Selected soil samples and all groundwater samples were placed in sealed glass jars (appropriate to the type of analysis to be undertaken) and labelled with site-specific sample identification information. Samples were stored and transported to an independent UKAS accredited analytical laboratory in cool boxes maintained at a low temperature with chain of custody documentation.

These issues are discussed in more detail in the remainder of this report section.

14.2.4 Data Interpretation and Risk Assessment

As well as having a systematic approach to collecting the data it is also necessary to adopt recognised techniques and standards in assessing them and particularly with regard to environmental risk assessment.

The information gathered during the desk-based review and site investigation was utilised to develop a conceptual site model based on the risk assessment principles of:



Soil Guidelines

As an initial **screening method**, and to assist with putting the results into context, the following guideline criteria were used for screening the analytical results.

- the Contaminated Land Exposure Assessment Model (CLEA), developed by the Department of Environment Transport and Regions (DETR)/Environment Agency (EA) to derive risk based soil assessment criteria that are protective of human health; and

- in the absence of generic criteria in the UK, the Dutch Ministry of Housing, Planning and the Environment guidelines for soil and groundwater contamination (Soil Protection Act 2000).

These are described in more detail below.

Risk based screening levels (soil guideline values) for certain contaminants in soil that are designed to be protective of human health have recently been published in the UK. The CLEA (Contaminated Land Exposure Assessment) guidelines have been referenced where relevant during the interpretation of the analytical results. Given that the future site development is proposed to remain industrial/commercial, the results have therefore been screened against the appropriate soil guideline values (SGV's) for an industrial/commercial end use.

It is also recognised, however, that there are wider issues than just human health. The Dutch Ministry for the Environment has published a comprehensive set of assessment criteria for both soil and groundwater, covering a wide range of compounds. The Dutch guidelines, commonly referred to as STI values, were developed taking into account eco-toxicological factors (*i.e.* in addition to human health) and the chemical availability of the constituents of concern. They have no legal basis in the UK but provide a useful initial reference point in the absence of any such promulgated standards in the UK. The "S–value" (Target Value) generally indicates the quality of natural or background soil. At the other end of the scale, the "I–value" (Intervention Value), is considered to present sufficient risk to require remediation. The intermediate "T-value", equivalent to the arithmetic mean of the S- and I- values, indicates the need to consider further investigation. Comparison of the analytical data from this Phase II has been made with 'uncorrected' Intervention values, (*i.e.* the values have not been corrected for the organic content of the soil at the site).

Neither of these guidelines referred to have any legal status in the UK, they merely provide a useful screening guide to help identify where more site specific risk assessment may be required. Where known contamination exists above guideline values and this presents a significant risk to potential receptors then more sophisticated site specific Quantitative Risk Assessment (QRA) can be undertaken to better define the risks and identify appropriate remediation target values for the substances of concern.

Groundwater Guidelines

There are no statutory UK guidelines for chemical contamination of groundwater at present. In order to provide an initial assessment of the analytical data, therefore, the results were compared with the Dutch Reference Values for groundwater. The Dutch values were developed using a risk-based approach for multi-functional land use. However, the Dutch values relate to the situation in the Netherlands where there is a heavy reliance on groundwater for public and private use, and may therefore be considered conservative in many applications in the UK.

In addition, in the absence of dedicated UK groundwater standards, the UK Water Supply (Water Quality) Regulations 2000 are often used to assess the results of groundwater investigations. However, since they are drinking water standards, they generally represent conservative reference values and they should not be applied prescriptively for all situations, particularly where water is not abstracted for drinking water supplies as is the case on this site.

Where Environmental Quality Standards (EQS) exist these have also been considered.

14.2.5 Reclamation Mound Investigation - 2007

Given that the previous application in 2004 did not involve the large scale disturbance of material (soils and galligu) entrained within the Reclamation Mound, only limited investigation was undertaken at the periphery of this area. The current proposals for the site will involve the excavation and stabilisation of material within the mound, and therefore the contractors involved with the project undertook an investigation in August 2007 and October 2007 to assess the ground characteristics. Samples were obtained by Earthworks Testing Solutions Ltd at the request of Beach Soil Stabilisation Ltd and subjected to testing to ascertain the soil strength capabilities and leachability testing for potential stabilisation treatment. The investigation and testing identified that the site comprised approximately 3-4m of topsoil and clay, overlying galligu. The galligu was white and dark grey, friable and in some places solidified. The results of the preliminary testing indicate that it is suitable for stabilisation with the addition of lime, although further tests are currently underway to refine the treatment process.

14.3 BASELINE ENVIRONMENTAL CONDITIONS

14.3.1 Current Activities on Site

The site is primarily used for road and rail haulage logistics with current activities on site including warehousing distribution, excise warehousing, a rail head, packing and blending for a range of industries including, for example, food and drink, clothing, textile, lube oil, chemical and construction engineering. These activities are conducted within two main areas consisting of the Foundry Lane site and the West Bank Dock site. The activities undertaken within each of these areas, as identified from the site walkover in 2004 and from discussions with the site personnel including the Estates Manager, Logistics Manager and Packing Manager, are discussed below. An updated walkover was undertaken in 2007 and discussions with John Hodgson (former Estates Manager) confirmed that no substantive changes had taken place. A site layout plan showing the current site uses is also presented in *Section 2 – Existing Site Description*.

Foundry Lane Site

The Foundry Lane site comprises a railhead, which was constructed in 1998 and occupies the northern and western sections of the site. The railhead consists of two lines running parallel with the northern boundary, with a third line running adjacent to the Ditton Brook. The rail lines meet in the north-western corner of the site prior to converging with the main Widnes railway line located to the north. Reportedly, there is an oil interceptor associated with the rail head, which was installed circa 2002, however, according to site personnel there is no regular inspection/maintenance programme for the interceptor and the chamber associated with the interceptor has never been emptied as there have been no known incidents.

The central part of the site comprises four large warehousing facilities and an office block. The warehouses are all used for storage purposes and generally house goods for the food and drink industry and the storage of pre-cast aluminium frames for the construction industry. The warehouses are all high bay structures comprised internally of breeze block and externally of metal cladding and have apex corrugated sheeted roofs and concrete floors, with a partially remaining rail track noted within Unit 4. With the exception of the Rehau warehouse located on the eastern section of the site, which was newly constructed in December 2000, the warehouses are the original buildings constructed circa 1970, which appear to have undergone some form of refurbishment in more recent times including new roofing and re-cladding. However, two of the warehouses (Unit 2 and Unit 4) still retain the original roofs, which appeared to be composed of cement based asbestos containing materials (ACMs). The single storey office block appeared to be contemporary to that era.

According to site personnel, there are no underground storage tanks (USTs) located on site. In addition ENVIRON did not identify any evidence of USTs being present on the site (*e.g.* no vent pipes, fill points or covers). However, there are several operational above ground storage tanks (ASTs) located on the Foundry Lane site and are thus, discussed below:

- the office block located in the western section of the site is heated via a gas oil fired boiler, which is served by a 4,300 litre (estimated capacity) above ground storage tank (AST). The AST is sited externally to the south of the office block and is a single skinned, bunded, steel tank, which appeared to be in reasonable condition, however, staining was observed along the bund wall;

- the office accommodation area within the new Rehau building is also heated via a gas oil fired boiler. The AST, which serves the boiler, is located externally is constructed of polyethylene (2,000 litre estimated capacity) with secondary containment and reportedly installed in 2004;

- there is an AST used for fork lift truck refuelling located on the concrete hardstanding to the south of Unit 4. The AST is an unbunded, polyethylene tank comprising approximately 2,500 litres of gas oil;

- there is an AST used for the refuelling of the container lifting trucks, which is located on the tarmac hardstanding in the north-western section of the site and comprises an unbunded steel tank, with an estimated capacity of 7,200 litres of gas oil; and

- there is a gas storage facility (comprising three Flo Gas LPG ASTs) used for propane storage for fork lift truck operation located adjacent to Unit 3 to the east. The installation is used to recharge the gas cylinders, for the fork lift trucks, via a flexible hose charging system. These are not considered to pose a ground contamination risk, however, reportedly this area previously housed a diesel above ground storage, which was removed circa 2000.

The majority of the Foundry Lane site is surfaced in hardstanding comprising tarmac or concrete, however, there is an area of unsurfaced ground located to the north of the warehouses, which is currently utilised for container storage comprising numerous loaded/empty demountable gas/liquid containers together with general shipping containers.

The north-western corner of the site also comprises a small spoil mound, which runs adjacent to the site boundary and was present prior to AHC (Warehouse) Ltd acquiring the site. Reportedly, the spoil mound previously formed part of a railway embankment.

West Bank Dock Site

The West Bank Dock site can be sub-divided into three areas:

- a northern area comprising warehousing activities, including excise warehousing together with liquid packing and solid packing activities;
- a central area, located to the west of the site, comprising liquid blending activities; and
- a southern area used for lorry/trailer parking, with an HGV maintenance workshop area located to the south-east.

The northern section of the site comprises approximately 12 warehousing units (Units 1-10, Unit 10A and Unit 11), office accommodation together with a number of above ground storage tanks and drum store areas. The warehouses are generally used for storage purposes and generally house goods for the food and drink industry (Unit 1 and Unit 9-11, including Unit 10A), the textile industry (Unit 3 and Unit 7), the clothing industry (Unit 8) and the engineering industry (Unit 6). Unit 2 and Unit 5 are associated with the liquid (lube oil) and solid packing undertaken on the site.

The majority of the warehouses are high bay structures comprised internally and externally of brick or a combination of brick and metal cladding, with concrete floors and apex corrugated sheeted roofs, the majority of which appeared to be composed of cement based asbestos containing materials (ACMs). The dates of construction for the warehouses range from pre 1940/1950 (Unit 2, which is in a poor state of repair), circa 1950/1960 (Units 4 and 5), circa 1970 (Unit 3 and Units 6-8), circa 1994/1995 (Units 10, 10A and 11), circa 1998 (Unit 9) and circa 2002/2003 (Unit 1). The two storey office block located in the north-eastern section appeared to have been constructed circa 1960.

Liquid packing is undertaken on the West Bank Dock site, the activities of which, involve the re-packing of lube oil from bulk storage into small containers (2.5 litre and 5 litre containers) for domestic consumer use. Historically, the bulk oil storage facility was a high usage facility following it's installation in circa 1990, however, this operation has reduced to a batch process operating over approximately two days a week. The bulk oil storage facility (tank farm) is located to the east and to the south of Unit 2 and currently comprises several above ground storage tanks, together with an uncontained drum storage area, as detailed below:

- six vertical ASTs, located to the east of Unit 2, which are identical and numbered 1-6. The ASTs previously contained different grades of oil including transmission oil, gear oil, special gear oil plus, diesel and Castrol GTX, notification of which was identified on the individual storage tanks, however, current operational demands only require one or possibly two tanks to be in use at any given time. The ASTs (each with an estimated capacity of 50,000 litres) are steel tanks, noted to be in a relatively poor condition, with inadequate secondary containment. Significant oil staining was noted along the bund wall together with oil spillage inside the bund. The fill points/dispensing points for the ASTs are located outside of the bund wall with significant staining noted on the concrete hardstanding beneath.;
- there are three identical, vertical tanks located to the south of Unit 2, which are known on site as the dump tanks. These tanks (each with an estimated capacity of 20,000 litres) were also used for bulk oil storage in the oil packing operations, however, they are currently non-operational and reportedly empty;
- there are three horizontal ASTs (numbered 7-9) located to the east of Unit 2. Each of the ASTs have an estimated capacity of approximately 40,000 litres and are again, steel tanks noted to be in poor condition with inadequate and damaged bunding;
- there are four old mobile tanks, which are HGV road tankers (each with an estimated capacity of 15,000 litres), which are permanently in situ within the tank farm area. These

mobile tanks, one of which is located to the east of Unit 2, with the others located to the south of Unit 2, were originally operational in small batch productions but are reportedly non operational at present;

- in the area to the east of Unit 2, approximately twenty five, 205 litre drums are stored on wooden pallets, the majority of which appear to be full comprising oil/waste oil; and

- the area to the south of Unit 2, which is generally used for the storage of raw materials, for example, packaging and containers, also houses a considerable number of unidentifiable drums (approximately 70 in total) together with IBCs (approximately 30 in total) and smaller 25 litre containers (approximately 100 in total).

The area to the south of Unit 2 also houses redundant machinery, previously used in the filling operations and approximately eight redundant storage tanks, which are piled high, and reportedly used on site, as and when required. House keeping within this area together with the area to the east of Unit 2 is poor and significant staining was noted on the concrete hardstanding, which is also significantly cracked in places. Furthermore, significant staining was noted on the concrete flooring within Unit 2, which contains the current filling machines.

Reportedly, all of the storage tanks within the tank farm together with other ASTs located on site were purchased second hand, and therefore, the age of the tanks can not be ascertained.

In addition to the ASTs and uncontained drum storage sited within the tank farm area, there are also several other operational and redundant above ground storage tanks located on the West Bank Dock site and are thus, discussed below:

- There is a derv (diesel) AST located within the old transport yard, which comprises approximately 90,000 litres of diesel for the refuelling of heavy goods vehicles. This steel storage tank was noted to be in reasonable condition but was noted to be inadequately bunded. An underground supply line from this tank leads to a supply pump for vehicles, and as with all underground lines, the possibility of accidental leaks going undetected can not be ruled out. Staining was noted along the bund wall;

- there is an unbunded, polyethylene tank comprising gas oil (2,000 litre estimated capacity), which is located within the liquid blending facility. The gas oil is used within the on-site mobile heaters, which are used to heat various warehouses located on the site;

- there are two gas storage facilities, which comprise propane storage for fork lift truck operation, located adjacent to the derv tank and in the former transport yard, which now comprises the blending area. The installations are used to recharge the gas cylinders, for the fork lift trucks, via a flexible hose charging system;

- for approximately nine months, Unit 11 comprised an incubation unit, which is served by an above ground, unbunded, gas oil storage tank (estimated capacity 1,000 litres), located to the west of the warehouse. Prior to this, the AST was utilised elsewhere on site;

- there is an approximated 6,500 litre capacity, bunded AST, comprising diesel, located in between Unit 1 and Unit 3, which is used for fork lift truck refuelling. Heavy staining was noted along the bund wall;

- there is a redundant nitromethane AST, which is currently sited on metal plinths and located within the former transport yard. The nitromethane AST has been redundant for approximately two years and was previously located, in its operational times, in between Unit 1 and Unit 3, which currently houses an AST used for fork lift truck refuelling. This AST was historically operational when nitromethane or its associated blended product was supplied to the pharmaceutical industry from the site, however, those activities ceased in approximately 2002/2003;

- there are five redundant ASTs located on the unsurfaced/unprotected ground in the southern area of the West Bank Dock site. These ASTs were previously used for the bulk storage of anti-freeze, when anti-freeze packing activities were undertaken on the site. When operational, the ASTs were located externally between Unit 10A and Unit 11, with the anti freeze filling machines located within Unit 10A, however operations ceased around 1995; and

- a waste oil AST (estimated capacity of 1,000 litres) located within the HGV maintenance workshop. The AST appeared to be a single skinned, steel tank, which comprised no secondary containment. Staining was noted on the unsurfaced/unprotected ground, which the AST was sited on.

According to site personnel, there are no oil interceptors located within any of the areas on the West Bank Dock site.

In addition to the liquid packing, solid packing is undertaken on site, which involves the re-packing of powder, received in bulk, into various sized bulk bags for the different consumer industries (reportedly, the powder (dicalite) is used in industrial filtration processes). The bagging unit for this operation is located adjacent to Unit 5, with the various packaged bags which are awaiting distribution stored within Unit 5. Again, this operation has been reduced and now operates over approximately three days a week.

The site also houses a liquid blending facility, which is located within the central section of the West Bank Dock site, towards the west (adjacent to Unit 10). This facility comprises two stainless steel blending tanks, which were acquired second hand and installed in approximately 1995/1996. The blending process involves the mixing and blending of various chemical substances in order to create the final product, which is a de-greasing agent for electrical and mechanical components. The products used in the blending process include n-propyl bromide (which equates to 95% of the total amount), dioxolane, cyclohexene oxide, butylene oxide and dymethyl carbonate, which are all stored in 205 litre drums, prior to use. Drums of Ethyl silicate were also noted in the liquid blending area at the time of the visit in 2004, however, these were reportedly used in a one off decanting job for a customer. There was no designated drum storage area comprising secondary containment.

The main operations of the West Bank Dock site are undertaken within the northern and central sections of the site, however, a HGV maintenance workshop is located in the south-eastern corner of the site. Reportedly, this piece of land together with the workshop was only acquired by AHC (Warehousing) Ltd in circa 2004. The workshop comprises a maintenance pit located internally and an inspection pit externally to the east. Activities generally include low level maintenance and repair work and therefore, contained with the workshop area were various pieces of vehicle maintenance equipment together with various lubricants and oils, however, these were not noted to be in significant quantities.

The remainder of the southern area comprises undeveloped/unsurfaced land, which is utilised for lorry/trailer parking and storage of metal components for large cranes. Storage of drums are located at the northern end of Ronan Road , located in the south-western corner of the site; there is no bunding and the majority of drums are sited on the concrete/tarmac hardstanding with some drums and IBCS located on unsurfaced ground.

A high spoil mound runs along the southern edge of the West Bank Dock site, which was established, circa 1999, as a visual bund and to attempt to mitigate the effects of odour emissions from the adjacent rendering works (Granox (PDM)).

Reclamation Site

The Reclamation site consists of an engineered mound comprised predominantly of galligu chemical waste, however other wastes from the local chemical industries were also known to have been deposited (the reclamation site was formerly known as Ditton Marsh prior to the deposition of waste). The mound rises above the surrounding land from 7.0 m AOD to a maximum of 28.5 m AOD and has been extensively landscaped with trees and vegetation. The reclamation scheme was a project undertaken by Cheshire County Council between 1995 and 1998 and comprised the re-grading, capping and landscaping of the waste material into stable slopes. A sheet piled wall was installed along the length of Steward's Brook, on the Mound's eastern side and part of the Ditton Brook, which bounds the mound to the south. AHC (Warehousing) Ltd subsequently took over the lease for the site, which covers a 999 year period, in October 2000. There are no activities undertaken on the mound, which is currently fenced off with gated access located to the north.

The area to the north of the Reclamation mound, which lies adjacent to the main Widnes railway line comprises undeveloped/unsurfaced land, which is currently utilised for container storage comprising a mixture of large, loaded/empty demountable gas/liquid containers.

Summary of Potential for Contamination from Current Activities

At the **Foundry Lane site** the potential for contamination to be present due to current activities is considered to be low, given that the activities on site have predominantly been warehousing and warehouse distribution since the late 1990s when AHC (Warehousing) Ltd took ownership of the site from Meyers Forests Products Ltd, a former saw mill. Potential areas of concern noted on the Foundry Lane site include the following:

- the site comprises a rail head, which consists of three railway lines, which encroach onto the site in the north-western corner from the main Widnes railway located to the north. Contaminants often associated with railways include various metal species, sulphate, PAHs and PCBs, however the railhead is a recent activity following its recent construction in 1998;

- four above ground fuel storage tanks; two of which are unbunded and used for site vehicle refuelling (*i.e.* fork lift trucks and container lifting trucks) with the remaining two tanks, which comprise secondary containment used for gas oil heating, one of which serves the boiler within the office block located on the western section of the site, with the other AST serving the boiler for the office area within the Rehau building located on the eastern section of the site. Potential contaminants may include hydrocarbons as a result of any uncontrolled loss of fuel, accidental spills or leaks, however, all of the ASTs are sited on hardstanding and with the exception of staining noted on the bund wall of the AST, which serves the office block, no visual evidence of contamination was noted. The gas storage facility, located adjacent to Unit 3, which is used for fork lift truck refuelling (propane), is not considered to pose a ground contamination risk;

- the potential for PCBs to be present due to the old electricity sub station located within the eastern section of the site. The sub station is likely to contemporary to the surrounding buildings. However, the electricity sub station is owned and maintained by the local electricity supply company, and therefore, since the sub station is the responsibility of a recognised operator the presence of PCBs at concentrations above the designated threshold is considered to be low;

- the storage of demountable tanks/containers, which can contain chemicals in a liquid, gaseous or powdered form on an unsurfaced/ unprotected area located to the north of the warehouses. However, these containers are only stored onsite and are not filled or emptied and are likely to be internally bunded, thus it is unlikely that these comprise a significant contaminant source; and

- the potential for asbestos containing materials (ACMs) to be present within the shallow ground as a result of the demolition and refurbishment works undertaken on the original site buildings, which were constructed circa 1970. The majority of the Foundry Lane site is surfaced in hardstanding comprising tarmac or concrete and thus unlikely to pose a risk to current site users.

The potential for contamination to be present due to current activities (open space) at the **Reclamation site** is considered to be low (although the mound itself comprises contaminated material which reportedly leached out into the water courses in the past). The Reclamation site consists of an engineered mound comprised predominantly of galligu chemical waste together with other industrial chemical wastes. However, between 1995 and 1999 the mound was re-graded, capped and landscaped into stable slopes. No activities are currently undertaken on the mound, which is currently fenced off with gated access.

The area to the north of the Reclamation mound, which lies adjacent to the main Widnes railway line comprises unsurfaced/unprotected land, which is currently utilised for container storage comprised a mixture of large, loaded/empty demountable gas/liquid/powder containers. Again, these containers are likely to be internally bunded and are not filled or emptied on site, only stored.

At the **West Bank Dock site** the potential for contamination to be present as a result of current on site activities is considered to be moderate. Although the majority of the site comprises warehousing activities, other activities such as solid/liquid packing together with liquid blending are also undertaken. Potential areas of concern noted on the West Bank Dock site include the following:

- the bulk storage of lube oil for the liquid packing operations, which involves the re-packing of lube oil from bulk storage into small containers for the consumer domestic market. The bulk oil storage facility (tank farm) associated with this activity comprises a number of vertical and horizontal ASTs, some of which are operational, but the majority of which are currently redundant as a result of the reduction in operations. The tanks were generally noted to be in a relatively poor condition, with inadequate or damaged secondary containment, all of which were located in an area were housekeeping was noted to be very poor. Potential contaminants may include hydrocarbons as a result of any uncontrolled loss of oil, accidental spills or leaks, which is considered possible given that visual evidence of contamination was noted in the form of significant staining along the bund walls. Also there was significant staining on the concrete hardstanding, which was noted to be cracked in places. The use of the filling machines could also lead to possible hydrocarbon contamination of the ground as a result of accidental spills and leaks. The powder packing activity is not considered to pose a significant ground contamination risk;

- the storage of uncontained drums of unknown composition, located within the area of the tank farm and the area in the south-western corner of the site (which also comprised the former emergency exit route for the Tessenderlo COMAH site);

- the liquid blending facility, which involves the mixing and blending of various chemical substances including n-propyl bromide, dioxolane, cyclohexene oxide, butylene oxide and dymethyl carbonate and the subsequent re-packing of the product into 205 litre drummed containers. However, there is no designated drum storage area comprising secondary containment. Therefore, there is a potential for accidental spillages to occur or leaks to go unnoticed, which may give rise to ground contamination, although the drums were located on tarmac/concrete hardstanding and no visual contamination in the form of staining, was noted;

- in addition to the tank farm, there are five operational above ground storage tanks located on the West Bank Dock site; three of which are unbunded and used for gas oil heating and waste oil. The remaining two ASTs, which comprise secondary containment, albeit inadequate, are used for vehicle refuelling, one of which serves fork lift trucks, whilst the other is a large derv tank for HGV refuelling; and

- there are a number of redundant ASTs located around the site, which have all previously been used for the storage either of diesel, gas oil, nitromethane, anti freeze or waste oil. Five of the redundant AST's, which were previously used for the bulk storage of anti freeze are currently sited on rough ground in the southern area of the West Bank Dock site.

All of the ASTs were sited on hardstanding comprising either tarmac or concrete, however, significant staining was observed of the bund wall of the AST, which comprises fuel for the fork lift trucks and some evidence of staining was observed on the bund wall of the DERV tank. Furthermore, an underground supply line from the AST lead to a dispensing pump and as with all underground lines, the possibility of accidental leaks going undetected cannot be ruled out. Therefore, there is a potential for localised hydrocarbon contamination to have occurred within the shallow soils in these locations;

- the potential for asbestos containing materials (ACMs) to be present within the shallow made ground as a result of the demolition of Unit 1, the original site building, prior to the construction of the new Unit 1 in 2002/2003 cannot be ruled out;

- there is a maintenance workshop located within the south-eastern section of the site, where low level, HGV maintenance and repair work is undertaken. The workshop area comprises a maintenance pit internally and an inspection pit internally and also involves the storage and use of ubiquitous contaminative materials such as fuels, oils, degreasers, and solvents, the use of which may have resulted in the possibility of localised ground contamination. However, garaging activities have only been operational in this section of the site , since AHC (Warehousing) Ltd acquired the land circa 2004; and

- the southern section of the site comprises unsurfaced land, which is utilised for lorry/trailer parking. Therefore, there is the potential for localised hydrocarbon contamination to have occurred as a result of the possible infiltration of oils/fuels from the surface into the shallow soils.

Considering the site overall, the potential for contamination to be present as a result of present site activities is considered to be low to moderate.

Surrounding Area

The current surrounding land use is typical of a heavy industrial location, with large chemical complexes interspersed with more recent industrial and commercial development and various waste sites. The likelihood of significant contamination being present from former activities in the surrounding area is known to be high with areas like the golf course to the north and HEDCO landfill to the south being notable in this regard (notwithstanding the widespread presence of galligu across this area generally).

The current on site activities and the potential areas of concern are presented in *Figure 14.2*

14.3.2 Historical Activities on Site

A number of historical maps were examined as part of the desk based review. A summary of the historical development of the site, which for ease of reading has been divided into the three separate areas, together with the local surrounding area are detailed in *Table 14.3(a)*, *14.3(b)* and *14.3(c)* below. Historical maps are presented in *Appendix 14.1* (Volume 3).

Table 14.3(a) - Site History of the West Bank Dock Site

Date/Scale	Features on Site	Features Off Site
1849 Ordnance Survey 1:10560	*The West Bank Dock site was part of the undeveloped Ditton Marsh.*	*Widnes Marsh, "covered by Spring tides" was located to the south and east, with Greenfield land to the north and west.*
1893 Ordnance Survey 1:2500	*No significant changes were apparent.*	*Railway lines to the north of the site, beyond which, was the Ditton Copper works.*
1907 Ordnance Survey 1:2500 and 1908 Ordnance Survey 1:10560	*By this date, the site was developed and comprised a Satinite works, a Saw mill and a pottery works annotated as Widnes pottery which occupied the northern part of the site.*	*Land to the south of the West Bank Dock site appeared to comprise marshland. The area to the north of the site comprised the Mathieson (Chemical) Works (presently occupied by O'Connor Transport Ltd). Beyond the railway lines, which formed the northern site boundary; various industrial works were located to the north-west comprising the Ditton Copper works, the Lever Alkali works and the Widnes Iron works. A rifle range was annotated to the south.*
1927 Ordnance Survey 1:2500 and 1928 Ordnance Survey 1:10560	*The site still comprised the Satinite works, Saw mill and Pottery works to the north.*	*The former Mathieson Works to the north of the site was now annotated as the Marsh works. This renaming possibly coincided with the transfer of the site's ownership to ICI.*
1937 Ordnance Survey 1:2500 and 1938 Ordnance Survey 1:10560	*No significant changes were noted.*	*Raised embankments were shown on land to the south of the West Bank Dock site, possibly indicating landfilling operations. No further changes were apparent.*
1955 Ordnance Survey 1 :2500 and 1956 Ordnance Survey 1 :10560	*The Saw mill was now annotated as Craigs Saw Mills.*	*West Bank Granite works had developed and occupied the southern section of the site.*
1958 Ordnance Survey 1:2500	*No changes were apparent.*	*No significant changes were noted.*
1969, 1970, 1977 and 1982 Ordnance Survey 1:10000	*The Satinite works, the Saw mill and Pottery works were no longer annotated. Changes were apparent to the configuration of the buildings which were now annotated as a depot. It is known that the site transferred ownership to the Hutchinsons around this time.*	*The immediate area was collectively annotated as Woodend, with the West Bank Dock site to the south of the study site. A large refuse heap had developed to the south-west of the site.*
1984, 1987, 1990 and 1994 Ordnance Survey 1:10000	*Further changes were noted to the configuration of the buildings / warehouses located on site, which were annotated as a Depot.*	*The immediate area had been collectively renamed as Ditton Marsh. No further changes were apparent.*
Ordnance Survey 1999, 1:10000	*Significant changes in the configuration of the site had occurred.*	*The refuse heap to the south-west of the site now appeared to have been redeveloped and forested.*

Table 14.3(b) – Site History of the Reclamation Site

Date/Scale	Features on Site	Features Off Site
1849 Ordnance Survey 1:10560	*The site formed part of the undeveloped Ditton Marsh.*	*Widnes Marsh, "covered by Spring tides" was located to the south and east, with Greenfield land to the north and west.*
1893 Ordnance Survey 1:2500	*No significant changes were apparent.*	*Railway lines were noted to the north of the site, beyond which was the Ditton Copper works.*
1907 Ordnance Survey 1:2500 and 1908 Ordnance Survey 1:10560	*A small chemical works together with a number of associated tanks were shown in the northern part of the site. The southern section of the site remained part of Ditton Marsh.*	*Land to the north beyond the railway lines, which formed the northern site boundary was occupied by various chemical works including Ditton Copper works, the Lever Alkali works and Widnes Iron works. To the east of Stewards Brook was a rifle range.*
1927 Ordnance Survey 1:2500 and 1928 Ordnance Survey 1:10560	*The site remained annotated as Ditton Marsh; however, ground levels on the marsh appeared to be elevated. This elevation is likely to have been caused by the deposition of the colloquially named galligu, a waste product of the Le Blanc process, which was known to have been used at the Mathieson Works.*	*The North British Fertiliser works, the Ditton Extract works and a Gelatine works now occupied the area to the south of the site.*
1937 Ordnance Survey 1:2500 and 1938 Ordnance Survey 1:10560	*Raised embankments were shown on the site.*	*The North British Fertiliser works was no longer annotated.*
1955 Ordnance Survey 1:10560	*No significant changes were noted.*	*No significant changes were apparent.*
1958 Ordnance Survey 1:2500	*Railway lines encroached on to the site from the main railway located to the north. Four buildings were shown on the site; however, the exact nature of activities could not be ascertained.*	*No significant changes were noted.*
1969, 1970, 1977 and 1982 Ordnance Survey 1:10000	*No significant changes were apparent.*	*A large refuse heap had been developed to the south-east of the site.*
1984, 1987, 1990 and 1994 Ordnance Survey	*A small mound was shown on the site, to the east of which a Timber yard was annotated. The railway*	*The surrounding area remained relatively unchanged.*

Date/Scale	Features on Site	Features Off Site
1:10000	lines were no longer shown. The appearance of the mound coincides with the reclamation of the site by Halton and Cheshire County Councils.	
1999 Ordnance Survey 1:10000	The small mound and the timber yard were no longer shown. Site developed as current configuration.	The refuse heap to the south-east of the site appeared to have been redeveloped and forested.

Table 14.3(c) – Site History of Foundry Lane Estate

Date/Scale	Features on Site	Features Off Site
1849 Ordnance Survey 1:10560	The site was undeveloped land. Ditton Brook was present in the south-western part of the site.	Ditton Marsh was located to the south-east. Widnes Marsh, "covered by Spring tides" was located to the south and east, with Greenfield land to the north and west.
1893 Ordnance Survey 1:2500	A Cement works was annotated in the north-western section of the site.	Railway lines were shown to the north of the site, beyond which was the Ditton Copper works
1907 Ordnance Survey 1:2500 and 1908 Ordnance Survey 1:10560	The course of Ditton Brook had been changed; a new straighter course formed the western boundary of the site. The Cement works was now annotated as disused.	An Oil Distillery was located to the west of Ditton Brook. The area to the north, beyond the railway lines which formed the site's northern boundary are Ditton Copper works, Lever Alkali works and Widnes Iron works.
1927 Ordnance Survey 1:2500 and 1928 Ordnance Survey 1:10560	Allotment gardens were shown in the north-western and south-eastern sections of the site. A Tar works and a Manure works were also annotated in the northern section.	To the west of Ditton Brook and to the south of the site were the North British Fertiliser works, Ditton Extract works and a Gelatine works.
1937 Ordnance Survey 1:2500 and 1938, Ordnance Survey 1:10560	No significant changes were apparent.	The surrounding area remained relatively unchanged.
1955 Ordnance Survey 1:10560	No significant changes were apparent.	No significant changes were apparent.
1958 Ordnance Survey 1:2500	A Mill was annotated near the eastern boundary of the site, which also comprised a Timber yard, including a timber treatment works. Railway lines ran into the northern section of the site and adjacent to the saw mill.	No significant changes were noted.
1969, 1970, 1977 and 1982 Ordnance Survey 1:10000	The building configuration on the site had been changed and the site was now annotated as the Meyers' Timber yard.	A Timber yard had been developed to the north of the site beyond the railway. A Joinery and a Scrap Metal yard were located beyond Ditton Brook to the west.
1984, 1987, 1990 and 1994 Ordnance Survey 1:10000	The site remained annotated as a Timber yard with a number of buildings appearing to have been extended.	The Joinery and Metal Scrap yard had become annotated as a Depot and a Warehouse.
1999 Ordnance Survey	There had been a significant alteration to the configuration of	The refuse heap to the south-west of the site appeared to have been redeveloped

Date/Scale	Features on Site	Features Off Site
1:10000	the buildings. This area remained annotated as a Timber yard, however anecdotal information reports that the buildings had been refurbished and were now used for the storage of tinned foodstuffs.	and forested.

Other Sources of Historical Information

In addition to the above, historical information was also researched by the Liverpool Museum as part of the archaeological assessment, the principal findings of which are summarised below:

- most of the identifiable archaeological sites that lie within the area of proposed development relate to its industrial development since the late 19th century. The development of this area since 1950 has however destroyed a majority of these sites and there is therefore little evidence of its industrial heritage;

- map evidence suggests that the area was not occupied during the Medieval and later periods. However, there is significant evidence for the presence of Roman and earlier deposits within the site; in particular deposits of peat associated with organic remains such as timber;

- Ditton Brook, which bounds the site to the south, is very likely to be the route by which tiles, produced at the tile works at Ochre Brook (a tributary of the Ditton Brook), were transported to Chester. There is therefore the possibility that the silts of the Ditton Brook contain remains relating to the transport network;

- borehole data suggests that the Roman deposits found during the excavation of a well at Ditton Station, situated in the north-west corner of the site, are present within the area of proposed development; and

- there is also a possibility that deposits relating to Prehistoric land use lie deeply buried within the site's area.

Furthermore, anecdotal evidence from site contacts, HBC and previous investigation reports suggests the following activities may have taken place.

- the West Bank Dock site is known to have originally been part of the Mathieson Chemical Works, which was located adjacent to the site's northern boundary. The predominant type of manufacture involved the production of soda ash via the *Leblanc* process;

- the *Le Blanc* process, was an extremely wasteful procedure, the waste from which, was colloquially known as "galligu". It is known that this waste from the Mathieson Chemical Works and wastes from other local industries (ash wastes from coal powered boilers and power stations) were deposited on the Ditton Marsh area;

- reportedly, in producing a single tonne of product, upwards of two tonnes of waste materials were generated. An indication of the scale of the waste material produced as a result of the *Le Blanc* process can be demonstrated from considering the operations of the Hutchinsons factory, as in its thirty five years of operation it is estimated that the factory produced a million tonnes of waste;

- the ownership of the West Bank Dock Site was transferred to ICI in the early 1930s. The site continued to be used for industrial chemical purposes related activities, including sulphuric acid and caustic soda production, for the next fifty years. Wastes from the ICI works continued to be tipped on Ditton Marsh and also on land that the West Bank Dock Site now occupies. Some of the railway lines associated with the original works are thought to be buried underneath the site. It is believed that no wastes were ever deposited on the Foundry Lane Site as the sites were historically separated by a drainage ditch;

- the site was purchased by Albert Constable who set up AHC Services circa 1980;

- Halton Borough Council and the freehold owners, Cheshire County Council, undertook a massive reclamation of the site between the West Bank Dock Site and the Foundry Lane site from 1995 to 1998. Following the insertion of sheet piling to protect the Ditton and Stewards Brooks, galligu waste from surrounding areas was heaped on the existing hardstanding and shaped to create a steep sided mound with an extensive plateau at its summit. This mound was then capped with clay, top-soiled and planted to provide the green hill visible today; and

- evidence also suggests that asbestos has also been buried on the West Bank Dock Estate and in construction of the present estate roads, battery cases were used as hard core.

<u>Summary of Potential for Contamination from Historical Activities</u>

The site has been under industrial usage from at least the 1890s to the present day. The earlier maps indicate that the Foundry Lane site comprised a Cement works, which occupied the site until circa 1920, when a Tar works and a Manure works were developed. These works were subsequently replaced in the late 1950s by a Timber yard, which occupied the site until recent times. The potential for historical contamination to be present on this part of the site is considered to be moderate to high. The presence of the Cement works may have led to contaminants such as arsenic, lead, chromium and sulphur being present on the site, together with hydrocarbons, polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). The Tar works provides the potential for contamination from various metals, cyanides, sulphates, phenol and PAHs. The Manure works was likely to produce contaminating materials such as metals, arsenic, cyanide, sulphate, various hydrocarbons and PCBs. The presence of a timber yard may have led to compounds such as white spirit, creosote, metal based (copper, chrome, arsenic) preservatives and pesticides being used on site. These compounds could lead to contamination from metals, boron, sulphate, various hydrocarbons and PAHs.

At the West Bank Dock site, a Satinite works together with a Saw mill and a Pottery works were developed during the early 1900s, which subsequently occupied the site until circa 1970. The Satinite works and the Saw mill appeared to have ceased their operations, which lead to the redevelopment of the site during the 1980s into a transport depot. The potential for historical contamination to be present on this part of the site is considered to be moderate to high. The Satinite works produced calcium sulphate for use in the paper, construction and fertiliser industry. Potential contaminants generally associated with this process would include, for example, various metals, sulphate, hydrocarbons, PAHs and PCBs, some of these contaminants together with sulphur are also indicative of pottery works. The Saw mill could potentially have generated contaminants such as metals, boron, arsenic, sulphate, phenols, and PAHs. The site's use as warehousing in recent years is not considered significantly contaminative, however, activities on site also include liquid/solid packing and liquid blending, these activities do involve the storage of oils and therefore, there is a potential for hydrocarbon and PAH contamination to have occurred through possible leaks and spills.

From the early 1900s until circa 1920, a small chemical works with associated tanks appeared to have occupied the northern section of the Reclamation site. From circa 1920, the ground level of the site appeared elevated. This elevation is likely to have been caused by the deposition of the galligu contamination, a by product of the *Le Blanc* process (manufacture of sodium carbonate), which is also know to contain other industrial contaminants, such as heavy metals, hydrocarbons and asbestos for example.

Railway lines have serviced the site and surrounding area since the mid 1800s. A variety of contaminants can be attributed to railway activities including metal species such as arsenic, cadmium and copper together with asbestos, polyaromatic hydrocarbons, oils and fuels.

<u>*Surrounding Area*</u>

The surrounding area still contains a number of medium to large scale chemical based industries that although operate to much higher standards today still, nonetheless have the potential to cause contamination of soils and groundwater.

14.3.3 Regulatory Authority Information

Halton Borough Council's Environmental and Development Services department provided the following information, as detailed in their Environmental Search Report entitled *Phase 1 Desktop Study Detailing Potentially Contaminative Land uses Affecting Foundry Lane & West Bank Dock Estate*, dated October 2004 (the summary cover letter for which is presented in *Appendix 14.3*). Recent discussions with HBC have confirmed that the results of this search are still valid, with the exception that the Tessenderlo facility has been demolished, although the licence is still in place and that St Michaels Golf Course, some 500m to the north (and through which Stewards Brook runs) has been formally designated as Contaminated Land:

- *the land within the search area has a diverse industrial base with multiple sources of potential contamination. The length of time that these processes have operated, and the fact that the industries were all but unregulated initially, means that contamination is likely to exist in significant quantities in the area. The most voluminous potentially contaminative material deposited is that associated with the Leblanc process. These wastes are typically heterogenic with a high variance in their structural competence. They are also prone to hydrogen sulphide gas production and can also contain significant concentrations of arsenic;*

- *The diversity of industry will likely mean that there will also be significant quantities of other contaminants present including metals and inorganic chemicals and their derivatives;*

- *a significant number of known or suspected sites of landfilling or tipping are located within the search area, however the most significant in the locality is the HEDCO Closed Landfill Site, which is located adjacent to boundary of the search area. The tip has been utilised predominantly for the disposal of chemical wastes, much of these from the Leblanc process. Much of the tipping occurred pre-licensing, commencing in 1865, so specific details of the waste input are enigmatic;*
- *The tip was in use until its closure in October 1987 and is thought to contain some 4.5 million cubic metres of waste, much of which derived from the surrounding chemical industries. The body of material has been built up to a height of approximately 30 m and covers an area of approximately 16 hectares;*

- *According to department records, there are two known landfilling areas located on the subject site. The Foundry Lane site was subjected to landfilling from 1859 onwards, known wastes deposited were all heavy chemicals, alkali, acids, sulphides, phosphates. From 1970-1984, the area occupied timber yards and mills. The Reclamation site was a tipped area dated 1970.*

- *It should be noted that apart from distinct landfill sites, the entire study area has been subject to waste disposal to 'reclaim' the former marshland;*

- *There are two groundwater abstractions licences within the search area, which are registered to Granox Ltd, located to the south of the West Bank site, for general industrial/commercial purposes and Croda Colloids Ltd, located to the south-west of the Foundry Lane site, where water is abstracted from a number of points for manufacturing and cooling purposes; and*

- *The department records also show three private water abstractions within the search area. The abstractions are registered to Croda Colloids Ltd, approximately 127 m and 136 m to the south-west of the Foundry Lane site and Granox Ltd, approximately 152 m to the south* *of the West Bank Dock site, however, information relating to abstraction sources and purposes have not been provided.*

Abstractions outside the search area are not included as they are beyond the scope of this investigation;

- Within the search area, there are eight Part A Processes, six of which relate to the processes undertaken at the former Tessenderlo site and fourteen Part B Processes, which are detailed in *Table 14.3(d)* below.

Table 14.3(d) – Part A and Part B Process

Process Type	Operator/Permission or Reference	Description	Distance From Site
Part A	Tessenderlo UK Ltd BT8104 BT8074 BT8066 BT8112	Manufacture and use of organic chemicals. (no longer operational)	102 m, south-east
Part A	Tessenderlo UK Ltd BU1903 BT8082	Processes involving halogens. (no longer operational)	102 m, south-east
Part A	GE Betz Ltd BU3213	Manufacture and use of organic chemicals.	Adjacent, south-west (beyond Ditton Brook)
Part A	P&O Trans European Ltd BJ6330	Recovery processes.	152 m, north
Part B	Millhouse Garage HB/1.4/01/01	Petrol Station.	51 m, north
Part B	ASDA Store HB/1.4/98/06 (*however, this is known to be no longer in operation)*	Petrol Station.	203 m, south-west
Part B	Cameron Industries HB/2.1/93/06	Metal cleaning furnace.	237 m, west
Part B	Widnes Galvanising HB/2.2/92/02	Galvanising of steel.	339 m, north
Part B	Oakfield Products HB/6.1/93/03	Oil refining for feedstuff.	305 m, east
Part B	Gulf Intermodal Repairs & Storage HB/6.5/92/25	Spray painting.	169 m, north
Part B	Initial Packaging HB/6.5/96/03	Flexographic printing.	254 m, north-west
Part B	Finn Forest HB/6.7/97/03	Wood working-retail.	51m, north
Part B	Croda Colloids Ltd HB/6.9/92/30	Gelatine extraction.	136m, south-west
Part B	Granox Ltd HB6.1/92/23	Animal rendering/ pet food/ greaves incinerator.	34m, south

- *there is an odour nuisance history associated with the plant operated by the PDM Group (historically known as Granox), a neighbouring property. This matter is an ongoing issue, with the authority working in conjunction with the site operator to mitigate this nuisance; however, it is still unresolved. A similar complaints history exists for the HEDCO closed Landfill Site. Although an odour abatement system is in operation on the site, this is an imperfect solution and the problem remains. Plans are currently in the design & theory stage for a method to resolve this problem, though no timeline has been agreed. Less frequently, complaints have been lodged against the Tessenderlo site; however these tend to be isolated incidents and are resolved quickly. The odour issues relating to these sites is a current priority for this authority, which is committed to resolving this problem;*

- *there are no planning issues outstanding for this site*;

- *there are no other environmental compliance issues relating to this site, other than those already discussed; and*

- *the site is not currently designated as contaminated land or a special site, as defined by the Part IIA Framework. The site or its surrounds has not been identified as contaminated land by the authority's inspection strategy, however this is a rolling programme and this may change in the future. Halton Borough Council is currently in negotiation with the owners of the HEDCO Landfill to undertake the inspection stage of a Part IIA investigation; it is likely that this work will result in a determination in the near future.* Updated information received from HBC has indicated that St Michaels Golf Course, some 500m north of the site has been formally designated as Contaminated Land.

The Planning Department of Halton Borough Council was contacted in 2004 with regards to any current or historic planning records pertaining to the site. The previous Environmental Statement was submitted in relation to the Planning Application for the entire site for redevelopment of the site as a Strategic Rail Freight Depot to form 7 new warehouses with associated roads and rail infrastructure. The information provided by Halton Borough Council's Planning department are summarised in the *Tables 14.3(e*), *14.3(f*) and *14.3(g)* below. The was granted permission in 2005 (05/00212/FULEIA)

Table 14.3(e) - Planning History for Foundry Lane Estate

Application No.	Description	Decision	Date
98/141/Ful	Proposed extension of existing railway lines on land off Foundry Lane, adjacent to AHC Warehousing Ltd.	Unconditional approval	14/05/98
94/272/Ful	Single storey extension to office building at Meyer, North Foundry Lane.	Unconditional approval	07/06/94
2/27757/F	Erection of timber storage shed at Montague L Meyer (Widnes) Ltd.	Conditional approval	19/07/91
2/22750/F	Extension to existing office building at Montague L Meyer (Widnes) Ltd	Unconditional approval	15/06/88
2/20958	Reclamation of derelict land and construction of roads and sewers on site to be used for industry on land off Foundry Lane.	Conditional approval	08/04/87
2/6089/F	Extension of Hardwood saw mills, Ditton sidings.	Conditional approval	15/06/78

Table 14.3(f) - Planning History for Reclamation Site

Application No.	Description	Decision	Date
02/498/Ful	Proposed erection of single storey 10,820 m^2 warehouse with offices at AHC Warehousing Ltd.	Conditional approval	19/05/03
97/61/CPO	Land reclamation project involving the controlled disposal contaminated materials at West Bank Dock Estate.	Unconditional approval	23/05/97
96/390/CPO	Sheet pile leachate cut off wall along Ditton Brook Widnes for a length of approx. 270 m and temporary storage of approx. 3000m^3 excavated material.	Conditional approval	07/10/96
94/172/CPO	1. Importation and temporary storage of clay subsoil for subsequent use in bunding, capping and sealing works. 2. Remodelling and sealing with clay subsoil the existing waste mound on land NW of Stewards Brook.	Unconditional approval	22/06/94

Table 14.3(g) - Planning History for West Bank Dock Site

Application No.	Description	Decision	Date
98/649/Ful	Proposed replacement warehouse (1445 m^2) at AHC Warehousing Ltd.	No information	29/01/99
93/753/Ful	Extension of blending plant, construction of offices, filing hall and canopy and relocation of security offices at AHC Warehousing Ltd.	No information	10/02/94
92/228/Ful	Proposed erection of 2 warehousing buildings at AHC Warehousing Ltd.	Conditional approval	06/05/92
91/563/Ful	Erection of a warehouse building at AHC Warehousing Ltd.	No information	07/11/91
2/25327/F	To store waste products as an intermediate transfer station AHC Warehousing Ltd.	Conditional approval	04/04/90
2/25212/D	Details of precast concrete works and welded lattice girder works including offices and toilets at Plots 4 and 5, Ronan Road.	Conditional approval	17/01/90
2/23906/O	Outline application for use of land for precast concrete works and welded lattice girder works at Plots 4 & 5 Ronan Road.	Conditional approval	02/06/89
2/22424/FB	Erection of double car garage and switch room at Plot 3 Ronan Road.	Conditional approval	10/03/89
2/22946/F	Proposed workshop and office with stores and garage at Plot 3.	Conditional approval	02/08/88
2/21453/F	Proposed workshop and office with stores ad garage, Plot 3.	Conditional approval	15/06/87
2/20941/F	Erection of workshop building for storage of gas valves and refurbishment of gas cylinders and tanks at, Mathieson Road.	Conditional approval	23/03/86
2/17695/F	Erection of new office and warehouse for storage of camping and other equipment for distribution to retail outlets at Amazon depot, Mathieson Road.	Conditional approval	12/10/84
2/12114/F	Use of land for open storage of caravans and boats together with fencing and site surface details at Mathieson Road.	No information	02/05/81
2/10887/F	Proposed canopy to existing Warehouse (No.4) for covered unloading of vehicles at Mathieson Road.	Unconditional approval	03/09/80
2/10789/F	Alterations to existing garage/workshop at Hutchinson Estate and Dock Company Ltd.	Unconditional approval	05/08/80
2/9879/F	Use of land for storage of 100 tonnes (total capacity) of liquefied petroleum gas in bulk tank and cylinders on site south of Mathieson Road.	Conditional approval	03/04/80
2/9671/F	*The permission is illegible, therefore details cannot be provided*	*Conditional approval*	*12/02/80*
2/9656/F	Repositioning of existing vehicle pressure wash and fuel storage tanks at West Bank Dock Estate.	No information	11/01/80
2/7578/F	Single storey warehouse, West Bank Dock Estate.	Conditional approval	20/02/79
2/6806/F	Use of land for the open storage of calor gas bottles (total weight up to 25 tons) site south of Mathieson Road.	Conditional approval	23/10/78
2/4308/F	Single storey warehouse building at Hutchinson Estate & Dock Co Ltd.	Conditional approval	28/04/77

Pertinent information relating to the study site was requested from the Environment Agency (EA), although this has not been received at the time of the preparation of this ES. The EA previously provided information in 2004 and holds the following records on ground condition:

- the Agency is unaware of any details of any reports or works undertaken on Reclamation/Remediation/Site Investigations;
- there is no specific information about contamination at this site and the site is not recorded on the Agency Register of Special Sites;
- the Agency records indicate two former landfills located on the subject site itself, these are detailed in *Table 14.3(h)* below:

Table 14.3(h) - Closed Landfills located on study site

Operator/Licence	*Site*	*Wastes Deposited*
HCC (Pre Licensing)	Ditton Marsh Tip, West Bank, Widnes (Foundry Lane site)	From 1859 – all heavy chemicals, alkalis, acids, sulphides and phosphates.
Hutchinson Estate & Dock Co HEDCO (Widnes) Ltd (60381)	Dock Site, Widnes	Construction wastes.

- There are also two current waste management licence holders within 500 m of the site. A household, commercial and industrial waste transfer station is located approximately 480 m to the north-west of the West Bank Dock site, and is licensed to accept a maximum of 75,000 tonnes of inert, general and biodegradable household, commercial or industrial waste per year. The second waste management licence (Licence reference 60945) is for a metal recycling site located approximately 70 m to the north of the reclamation site, which is licensed to accept commercial, industrial and special wastes.

Third Party Environmental Database (Envirocheck®)

A commercial database was obtained in 2004 to provide further information regarding the site and the surroundings. Relevant information/records are summarised below.

Landfills

According to the environmental database, there are no former landfills located on the study site. Although it is known that the reclamation mound was a former landfill, subsequent details of the landfill have not been given within this environmental database, as this landfill existed pre licensing and was therefore, not a registered landfill.

A number of historic landfill sites were/are located in the immediate surrounding area, along the site's southern, western and northern boundaries; the most significant off-site landfill being the HEDCO landfill located adjacent to the West Bank Dock site to the south-west. There are two licenses relating to this landfill site:

- the first recorded licence (licence reference 60381) for the landfill was registered to Hutchinson Estate & Dock Co (Widnes) Ltd. Under this licence, the landfill was categorised as being very small (less than 10,000 tonnes per year) and was licensed to accept construction and demolition waste (chemical waste was also known to have been accepted), however, since June 1977, the licence for the site either lapsed/ceased or was surrendered.
- The second recorded licence (Licence reference 60303) for the landfill is registered to Waste Management Ltd. Under this licence, the landfill has been categorised as very large (equal to or greater than 250,000 tonnes per year) and was licensed to accept an array of industrial and chemical wastes, including for example, distillation residues, tank cleaning sludge, tannery and fellmongers waste, waste treated timber and lead, chromium, iron, nickel and copper compounds. This site ceased landfilling operations in the 1980s, however, the waste management licence has not been surrendered.

Waste Transfer/Treatment/Disposal Sites

There are numerous waste transfer/treatment/disposal sites within a 1 km radius of the site. The closest to the Reclamation site is a waste treatment and disposal site licensed to M & J Burns, (Licence reference 60945), which is located approximately 70 m to the north. The site is operational as far as is known and is licensed to accept scrap metal and batteries. Widnes Skip and Reclaim is the closest waste transfer station to the Foundry Lane site. The site (Licence reference 80039), which is operational as far as is known, is located approximately 49 m to the north-west and is licensed to receive commercial and industrial non-hazardous waste, uncontaminated hardcore and soils. The closest waste transfer site to the West Bank Dock site is located approximately 244 m to the east and is operated by P Mc Cawley. Authorised wastes include non hazardous construction, household and industrial wastes together with uncontaminated hardcore and soils.

According to the environmental database, a former waste treatment and disposal site was located within the site boundary. The licence was held by AHC (Warehousing) Ltd (Licence reference 61515) for waste storage, which was undertaken on the West Bank Dock site, authorised wastes included distillation residues, pesticides, organic/inorganic and nitro compounds, phenols and tar. However, it is stated that this licence has a completion certificate (which implies the area carries no on-going significant pollution potential associated with the licensed activities).

Site personnel from AHC (Warehousing) Ltd confirmed that the site was formerly licensed to operate as an industrial waste storage and transfer station. The site was contracted to receive and store waste from Cleanaway, a major industrial waste disposal company, until such a time when Cleanaway were ready to process this waste at their own facility. Reportedly, all waste was packaged correctly prior to being accepted on site and was stored in designated areas, both internally (old Unit 1, prior to demolition) and externally. Site personnel confirmed that this licence was surrendered in approximately 1994/1995, when the operation became economically unviable to continue with.

Discharge Consents

There are no current licensed surface water discharge consents associated with the site.

There are numerous licensed discharge consents within a 500 m radius of the site, and are believed to be related to the former occupiers of the site. The closest discharge consent to the Reclamation site (approximately 21 m to the west) and the Foundry Lane site (approximately 13 m to the south-west) is operated by Meyer Forest Products Ltd (former site tenant) and is for trade discharges (process water) into the Ditton Brook. The closest discharge consent to the West Bank Dock site is located approximately 25 m to the east and is registered to Marsh Maintenance Ltd, for sewage discharges (treated effluent) into Marsh Brook. Under normal circumstances the discharge of such materials would not be expected to impact upon the study site.

IPC/IPPC Authorisations

There are no current IPC or IPPC Authorisations associated with the activities of the study site. However, there are two authorisations to operate a process under Integrated Pollution Prevention Control (IPPC) within a 1 km radius of the site. The authorisations are registered to Tessenderlo UK Ltd, approximately 90 m to the east of the West Bank Dock site and GE Betz Ltd, located approximately 148m to the south of the Foundry Lane site and both relate to organic chemical processes including hydrocarbons and nitrogen and sulphur containing compounds. The Tessenderlo operations and infrastructure are no longer present, as the site has been demolished, however it is understood that the COMAH designation is extant, although believed to be in a transition period, and due to be revoked shortly.

Pollution Incidents

There have been four pollution incidents to controlled waters associated with the study site, the details of which are summarised in the *Table 14.3(i)* below:

Table 14.3(i) - Pollution Incidents to Controlled Waters

Date	***Location***	***Receiving water***	***Pollutant***	***Category of incident***
12/03/94	Foundry Lane site	Given the grid reference it can be inferred that Ditton Brook was the likely receiving water course.	Chemicals – Paints/Dyes	Minor Incident (Category 3)
19/01/93	Reclamation Mound	Ditton Brook.	Rubble/Litter	Minor Incident (Category 3)
24/05/95	Reclamation Mound	Steward's Brook.	Tip leachate	Minor Incident (Category 3)
31/07/96	Reclamation Mound	Steward's Brook.	Tip leachate	Significant Incident (Category 2)

Prosecution & Enforcement

No prosecutions or enforcement actions are reported to have been taken against the study site or any other sites within a 1 km radius (according to the published database).

Radioactive Consents

No consents are listed for the holding or disposal of radioactive material at the study site. There are however, two installations, which hold Radioactive Substance Consents within a 1km radius of the site. The closest consent is registered to Tessenderlo UK Ltd, approximately 125 m to the east of the Foundry Lane site and is for the keeping and use of radioactive materials, in relation to a closed source of radiation. Again, this is historical as the site operations and infrastructure have since been demolished. The second radioactive consent is operated by Croda Chemicals Europe Ltd, approximately 277 m to the to the south of the site and is for the keeping and use of radioactive substances in relation to an open source of radiation together with the disposal of radioactive waste. Under normal circumstances the disposal, keeping or use of such materials would not be expected to impact upon the study site.

Contaminated Land Register

According to the database there are no Contaminated Land Register Entries or notices associated with the study site or any other sites within a 1km radius. Recent information from HBC Environmental Health Department has indicated that St Michaels Golf Course, some 500m to the north of the site has recently been designated as Contaminated Land.

14.3.4 Review of Previous Investigation Reports

Various parcels of land within the study site have been previously investigated and a review of previous site investigations has been undertaken to assist with the determination of the contamination status of the site. During the review of reports, it was identified that, although some did facilitate the assessment of chemical conditions across the site, the majority were completed for geotechnical purposes and were thus of limited value to this study. A summary of the previous reports is contained within *Table 14.3(j)* below.

The various sampling positions as identified within the previous reports are presented within *Figure 14.3*.

Table 14.3(j) – Summary of Previous Reports

Author	*Title*	*Date*	*Description*	*Chemical Tests*	*Report Conclusions*
Norwest Holst Soil Engineering Ltd	Site Investigation Report Ground Investigation Foundry Lane Reclamation, Widnes	June 1984	Ground investigation, involving the drilling of 43 boreholes, excavation of 4 trial pits and 5 concrete probes to obtain information on the sub-surface conditions on an area of land at the eastern end of Foundry Lane (the Reclamation site). The site is covered in a layer of chemical waste to between 3m and 5m A.O.D.	Heavy metal and chemical content of chemical waste. Sulphate content and pH of soil.	The origin of the chemical waste was unknown, although it appeared to be Leblanc waste. The materials tested contained relatively high concentrations of ammonia (<0.30 - 546.00 µg/l), chloride (18.50 – 3125.00µg/l) and sulphate (396 – 55420 µg/l) ions and had high pH values (7.22 – 12.49). Compaction tests indicated the chemical waste had natural moisture in excess of the optimum moisture content and would be considered unsuitable for re-use as structural filling. These materials are considered unsuitable in their present condition for the support of structural foundations.
Strata Surveys Ltd	Report No. 4116 Foundry Lane Stewards Brook Diversion	August 1988	Geotechnical Report. Ground investigation to obtain information on the ground conditions and soil properties for use in the selection of the most economic method of construction and the preferred route for a proposed diversion of Stewards Brook.	Chloride, Sulphide, Sulphate and pH tests.	The made ground consists predominantly of chemical waste which varies in colour from dark grey, light grey to white and from granular to cohesive in 'soil' type. The alluvium can be divided into two zones; the upper consisting of soft and occasionally firm grey silty clay; and the lower consisting of fine silty sand. All alluvium has been discoloured and contaminated by the overlying chemical waste. Underlying the alluvium is stiff to very stiff, brown sandy, slightly gravely clay which is further underlain by red fine to medium grained sandstone.
Strata Surveys Ltd	4 & 5 Ronans Road, Widnes	September 1988	Geotechnical Report. Ground investigation, involving the drilling of two boreholes and excavating 13 trial pits, to obtain information on the ground conditions and soil properties for use in the design and construction of foundations at 4 and 5 Ronan Road, Widnes.	Sulphate content and pH of groundwater and soil.	Fill was encountered in each trial pit and borehole. This consisted generally of thick layers of clay and fine to coarse granular material. Within the fill boulder sized conglomerates of bricks and concrete were encountered and also organic material (timber, rubber). Underlying the granular fill was a chemical waste, which varied in character between that of a granular and cohesive material. Soluble sulphates are present in the subsoil and groundwater in Class 1 concentrations as defined by B.R.E. Digest 250. pH values are within the range of normal concrete.

Author	Title	Date	Description	Chemical Tests	Report Conclusions
Strata Surveys Ltd	Factual Report No: 6246 AHC Warehousing , West Bank, Widnes	December 1991	Ground investigation, involving the drilling of five boreholes to obtain information on the ground conditions and soil properties for use in the design and construction of foundations on the site in connection with the proposed development.	Sulphate content and pH of groundwater and soil.	No conclusions were included in the report. Borehole logs indicate the made ground comprised ash, brick and concrete in the upper zone and in the lower zone the fill consisted of chemical waste. Sulphate concentrations in the soil samples range from 0.07-0.24 g/l. In the groundwater samples, a sulphate concentration was recorded at 0.2 g/l. pH ranged between 6.7 and 11.7.
WS Atkins Environment	Amazon Gas Site, West Bank Dock, Widnes, Ground Contamination Desk Study	June 1992	Desk based study to determine the potential ground contamination on the site occupied by Amazon Gas in the north-west corner of the West Bank Dock Estate.	Comments on Strata Survey's investigations undertaken in 1988 and 1991.	The ground contamination on the former Amazon Gas site does not present a hazard to present site use. Although the site may be contributing to contamination of the underlying water table, the relative size of the site suggests that the contribution is small compared to overall groundwater contamination in the area. Contaminants are unlikely to be migrating onto the site via groundwater, in any significant quantities. It is possible that landfill gas may be migrating onto the site from the HEDCO landfill site.
Strata Surveys Ltd	Ground Investigation Report No. 6612 AHC (Warehousing) Ltd, Widnes	July 1992	Geotechnical Report. Ground investigation, involving the drilling of six boreholes in connection with a proposed warehouse at the West Bank Dock Estate.	Sulphate content, chloride content and pH of groundwater.	The site has been levelled by adding a clay layer on top of a chemical waste tip. The clay is generally firm, brown, slightly gravely with varying amounts of ash and brick fragments. The chemical waste consists of grey, white, black speckled sand to fine gravel size angular fragments in clay matrix. The made ground is underlain by alluvial clay and further underlain by (chemically discoloured) sand. Sulphates are present in Class 2 concentrations as defined by B.R.E. Digest 363.
Sub Surface Ltd	Ground investigation at Foundry Lane, Widnes for North West Corrugated Ltd Report No:2118	September 1992	Geotechnical Report. Ground investigation, involving the drilling of six boreholes to obtain an indication of the nature of the subsurface for the proposed construction of a single storey factory. The site is bordered by Foundry Lane in the north-east and south-east and bordered by industrial units and an ASDA store with associated car parking to the north and west.	Sulphate content and pH value of the soil and groundwater samples. Gas monitoring results.	During the site investigation the upper zone of the chemically contaminated fill was being removed and replaced by grey fly ash type material. The report therefore assumes that all chemically contaminated fill is to be removed and replaced and therefore no comments or recommendations on chemical contamination were made. The made ground is underlain by highly compressible, organic clayey silts, silty clays and clayey peats. Sandy clay and boulder clay extended down to weathered sandstone. No significant levels of CO2 were recorded. The gas hazard assessment indicated levels of methane up to 2.5%. O2 levels were low suggesting other gases may have been present.
Strata Surveys Ltd	Ground Investigation Report No. 7177 AHC Warehousing West Bank Dock Estate, Widnes	August 1993	Geotechnical Report. Ground investigation, involving the drilling of four boreholes in connection with a proposed warehouse at the West Bank Dock Estate. The site is bounded to the north by Rovan Road and to the south by an industrial development. No site plan was included therefore no reference is made on the previous sampling plan, identified as *Figure 14.3.*	Sulphate content and pH of groundwater.	The made ground consisted of two types. The upper layer comprised firm brown clay with some gravel and occasional bricks. The lower layer consisted of soap works waste, cohesive and granular material interbedded and intermixed with ashes. The alluvium consisted of dark grey/black clay over fine to medium grained sand. A chemical odour was detected. This was underlain by glacial strata consisting of stiff dark brown clay over dense brown fine to medium grained sand. Soluble sulphates were present in the groundwater in Class 3 concentrations as defined by B.R.E. Digest 363 and pH values ranged from 7.0 to 12.6.
Strata Surveys Ltd	Ground Investigation Report No.8300 South Widnes Reclamation Scheme	August 1995	Geotechnical Report. Ground investigation, involving the drilling of six boreholes, in order to design a sheet pit cut off for leachate alongside Ditton Brook as part of South Widnes Reclamation Scheme. No site plan was included therefore no reference is made on the previous sampling plan, identified as *Figure 14.3.*	No chemical results.	No conclusions were included in the report. Borehole logs indicate that the made ground comprises soap waste varying in character from dense/medium dense grey/yellow to very dense white waste. The made ground is underlain by contaminated black clay, further underlain by silt with some gravel and clay, followed by stiff black clay.
DTS Technology Ltd	DTS 6497 Report on a Contaminated Survey Carried Out at Foundry Lane, Widnes, Cheshire	May 1996	A contamination survey, concentrating around the Hickson Tanolith and Hickson Vascol timber treatment plants and radiating across the site located at SJ 490 840. The ground investigation consisted of 10 trial pits, ten probe holes for a 'Spiker Bar' gas survey and two boreholes.	Gas and soil test results.	The results of the soil sample analysis revealed high levels of arsenic (0.01-524 mg/kg). In one sample concentrations of gamma-Hexachlorocyclohexane (HCH) or lindane, and Tributylin Oxide (TBTO) were found. These are likely to have accumulated from spillages during the timber treatment process. High levels of sulphate (140-100570 mg/kg) represent a risk only to building materials, concrete in particular. In the water samples levels of copper and arsenic reconfirmed the presence of the timber treatment process on the site. High concentrations of Phenols (<0.05-0.7 mg/kg) and TPH (<10-64300 mg/kg) were recorded.

Author	Title	Date	Description	Chemical Tests	Report Conclusions
					Results from the gas hazard assessment indicated levels of CO_2 up to 1.6%, O_2 down to 6.3% and hydrocarbon gas to a maximum of 6.9%. However it was not known whether this was generated within the organic alluvial deposits. There are no current processes of re-contamination occurring.
Strata Surveys Ltd	Draft Report No. 9148 South Widnes Reclamation Data Review	September 1997	Ground investigation, involving the drilling of two boreholes to obtain information on the ground conditions and soil properties for use in the design and construction of foundations on the site. One borehole was located within the ICI Stockyard, the second was located within AHC Warehouse land, close to the old BOC site.	Groundwater and soil test results	No conclusions were included in the report. Borehole logs indicate that the made ground comprised black ash with concrete and brick rubble fragments over grey chemical waste. The laboratory results indicated high levels of sulphate in the soil (20100-238000 mg/kg) and in the groundwater (1880-4360 mg/l). The groundwater samples indicated high concentrations of the major ions and two soil samples also recorded high levels of copper (281 and 854 mg/kg) and zinc (897 and 8350 mg/kg).
WS Atkins North West	Foundry Lane Site, Widnes, Environment Liability Assessment Draft Report	December 1997	Desk based review to determine the environmental liability of the site occupied by AHC (Warehousing) Ltd, formerly owned by Meyer Forest Products Ltd for storage and treatment of timer.	cc. Gas and soil results from DTS 6497 report	The DTS investigation (6497) was primarily concerned with contamination arising from the timber treatment works and may not have identified other localised areas of contamination resulting from other former uses of the site. Due to the present surface covering of the site, the presence of contamination is not considered

14.3.5 Geology and Hydrogeology

Published Geology

According to the British Geological Survey Solid and Drift Map for Runcorn (Sheet 97, scale 1:50,000), the site is directly underlain by recent Marine and Estuarine Alluvium (the River Mersey is tidal within this area). This is further underlain by the Upper Mottled Sandstone of the Triassic Sherwood Sandstone Group at depths ranging from 12m bgl to over 35m bgl. The Sherwood Sandstone Group is underlain by Permian sandstones and further underlain by the Carboniferous Coal Measures to depth.

Estuarine alluvial deposits commonly comprise soft dark grey clays, silts and occasionally sands, which may be organic and contain shelly material. The Sherwood Sandstone Group comprises sandstones which are typically red in colour, occasionally mottled with yellow and white patches. The fine grained sandstone bedrock is variably weathered and is encountered in varying forms of compaction from loose sand to hard rock. The BGS map (Sheet 97; Runcorn) for the area is presented in *Figure 14.4*.

According to data issued by the National Radiological Protection Board (2002), the land is located in an area where less than 1% of residential properties are above the action level for Radon set by the National Radiological Protection Board. No radon protection measures are considered necessary by the British Geological Survey.

Palaeo- Channel

The current course of the River Mersey flows to the south of the site and upstream [east] through an obvious geological gap between Runcorn and Widnes, the Runcorn gap can be seen annotated see *Figure 14.5*. based upon approximate rock head contours. Discussions with the Contaminated Land Officer at HBC indicated that it is conjectured that a previous channel (palaeo-channel) lies to the north of the Runcorn promontory and was subsequently naturally infilled with fluviatile [possibly fluvio-glacial] deposits. This stratum may either be the result of deposition from glacial melt waters during the Devensian [last Ice age], a recent infilled meander of the R Mersey or a combination of both. A review of the Drift edition BGS Sheet 97 - Runcorn indicates that the depth to rock head in this area is in the region of -20 to -40m relative to OD.

The site investigation data found drift deposits present across the site, generally comprising alluvium over sands with interbedded glacial clay with sand horizons below. The thickness of the drift deposits vary across the site from east to west with depth to rock head recorded as varying between 14m bgl [BH8] to 37.50m bgl [BH31[] in the eastern section. This significant variation appears to co-incide with the conjectured palaeo-channel but may be explained also by the undulating unconformable sandstone bedrock, infilled rock head hollows or an unrecorded faultline. A fuller description of the geological conditions observed on site is presented below.

Geological Field Observations

During the 2004 site investigation, the field observations of the geological conditions beneath the site was found to be largely consistent with published information and generally comprises the following strata:

- **Made Ground** was encountered in all sampling locations. This generally comprises hardstanding (concrete) of varying thickness or a soil/clay matrix overlying brown/grey/black sand, silt or clay with various quantities of brick, gravel concrete, ash and occasional pieces of reinforced wire, plastic, ceramic tiles together with fragments of wood, clinker and metal slag overlying galligu chemical waste material. All window sample locations and trial pit locations were terminated within the made ground deposits.

- **Natural deposits** comprising a variable depth of Alluvium consisting of soft to firm grey/brown/black silty clay, clayey silt or sands with occasional bands of peat and traces of gravel was encountered in the majority of the sampling locations. The alluvial deposits are further underlain by Glacial Till consisting of firm to stiff, brown/reddish brown, silty or sandy clay with inclusions of sand and gravel deposits. The solid geology underlying the site is Sandstone, which was encountered at variable depths across the site as described above.

However, variances within each of the geological stratifications were noted between the three distinct areas of the site comprising the Foundry Lane site, the West Bank Dock site and the Reclamation site. Therefore, the more detailed discussion of geology is discussed separately for each specific area below:

Foundry Lane Site

Made ground comprising a surfacing layer either of concrete, limestone chippings or a soil/clay matrix of varying thickness overlying brown/grey clay/ sand or a discrete dense black ash layer with various quantities of brick and gravel was encountered at each of the sampling locations. Inclusions of metal slag were noted in BH9 and BH11 with fragments of cinder noted within BH12. The depth of made ground was proven in all exploratory sampling locations and ranged between 1.8 m (BH11) to a maximum depth of 5.0 m (BH9). No industrial chemical waste i.e. galligu was encountered in any of the sampling locations within the Foundry Lane site.

The made ground was underlain in four (BH8, BH9, BH11 and BH15) of the five boreholes, by alluvial deposits. These deposits, comprising soft to firm grey/brown silty clay, clayey silt with occasional bands of peat, were encountered to depths of between 3.8 m (BH11) and 10.5 m (BH9).

Low permeability drift deposits of Glacial Till are encountered beneath the alluvium/made ground, which comprise firm to stiff, brown/reddish brown, silty or sandy clay with occasional sand and gravel deposits, which ranged in thickness from 1.0 m (BH9) to 10.0 m (BH15). The clay deposits within the Glacial Till were encountered up to the interface of the sandstone bedrock in three of the borehole locations (BH11, BH12 and BH15) to depths of between 10.5 m (BH11) and 12.8 m (BH12). However, sand and gravel deposits were encountered at the base of the Glacial Till at the sandstone interface in BH8 and BH9, which were encountered to a maximum thickness of 1.0 m (BH9).

The solid geology underlying the site is sandstone and the sandstone stratum encountered in BH12, comprised very weak to moderately weak, poorly cemented red/brown, medium/coarse grained sandstone and was generally encountered at a depth ranging between 10.5 m (BH11) and 13.8 m (BH8).

Reclamation Site

All of the nine trial pits (TP15-TP23) excavated in the southern area of the reclamation mound, were terminated within the made ground at depths of between 3.2m (TP23) and 5.3 m (TP15). The made ground horizon within the southern area of the reclamation mound generally comprises grass/soil over a soft to firm brown/grey silty/sandy clay of varying thickness with various quantities of brick, gravel and wood together with occasional pieces of reinforced wire, plastic and inclusions of organic matter. This clay cap ranged in thickness between approximately 2.7 m (TP19 and TP21) and 3.5 m (TP21). The underlying layer in the majority of the trial pits comprised chemical waste (galligu). The galligu chemical waste appears in various guises from a clayey/silty, silty/clayey material to a loose unconsolidated material, which can range in colour from dark grey to grey/black, grey/white, grey/green, grey/blue and blue/white. Examples of the galligu chemical waste encountered with the trial pit locations within the southern area of the reclamation mound are detailed below:

Plate 14.1(a) - Dark grey/black, silty clayey, galligu chemical waste encountered in TP 15

Plate 14.1(b) - Grey/white, silty, galligu chemical waste encountered in TP 22

Three of the trial pits (TP16, TP17 and TP18) were abandoned at 3.6 m bgl and one trial pit (TP23) at 3.2 m bgl due to a concrete obstruction underlying the galligu chemical waste. According to the Health and Safety file for the Reclamation site, waste material (predominantly galligu) was deposited on a concrete plinth. Of the four remaining trial pits, two (TP21 and TP22) were terminated in the galligu chemical waste at 5.0 m and 4.4 m respectively and two were terminated in a soft, grey sandy clay (TP15) and a red gravely silt (TP20) underlying the distinct galligu layer, whilst not recognised as galligu, these may have been another variation in the chemical waste.

The subsequent investigation by Earthworks Testing Limited in 2007 also confirmed that topsoil and clay were present over galligu.

Within the area to the north of the reclamation mound, adjacent to the main Widnes railway, made ground was encountered at each of the sampling locations, the depth of which, proven in only the two borehole locations (BH14 and BH23). The made ground horizon within this area generally comprises a surfacing layer of limestone chippings or a soil/clay matrix of varying thickness overlying soft to stiff brown/grey sandy, silty clay/clayey silt or a discrete dense black ash layer. Various quantities of red brick, gravel, concrete, wood, reinforced wire and pieces of plastic are also present within this clay/silt stratum, which ranged to depths of between 1.5 m (BH14) and 2.5 m (BH23). The made ground horizon also comprises a layer of galligu chemical waste, which all of the trial pits, with the exception of TP13 (which was abandoned at 1.0 m due to the rapid ingress of perched water) were terminated in with the maximum depth being 5.0 m (TP14). The galligu chemical waste was encountered to a maximum depth of 7.0 m (BH23). The galligu chemical waste was noted to be either a clayey or silty material or a loose, powdery or solidified material, which ranged in colour from grey to grey/white, grey/blue, blue/white and to yellow. Underling this distinct galligu layer within the two borehole locations was a soft to firm grey/black silty waste, the odour of which, reminiscent of gas works waste, a tarry, hydrocarbon rich contaminant, which ranged in thickness from 1.8 m (BH14) to 3.5 m (BH23).

The made ground was underlain by alluvial deposits, consisting of medium dense, fine silty sand within BH23 and low permeability drift deposits of Glacial Till within BH14. The alluvial deposits in BH23 were further underlain by Glacial Till, generally comprising firm to stiff, brown, silty/sandy clay with occasional sand and gravel deposits. Sand and gravel deposits were encountered at the base of the Glacial Till, at the sandstone interface in BH14 from 11.4 m and BH23 from 30.1 m.

The solid geology underlying the site is Sandstone, which was encountered at variable depths of 11.8 m (BH14) and 30.5 m (BH23). The sandstone stratum encountered with BH23, comprised very weak to weak, poorly cemented red/brown, medium/fine grained sandstone.

West Bank Dock Site

Made ground was encountered at each of the sampling locations, the depth of which was proven only in the borehole locations. Made ground within this area generally comprises a surfacing layer of either hardstanding (concrete) of varying thickness, a soil/clay matrix or limestone chippings overlying either brown/grey/black sand, silt or clay or a discrete dense black ash layer with various quantities of brick, gravel concrete, ash, metal slag together with occasional pieces of wood, reinforced wire, plastic, ceramic tiles, fragments of coal and organic matter.

Galligu chemical waste was encountered in all of the sampling locations, with the exception of BH34 and generally comprised either a clayey or silty material or a loose, powdery or friable material, which ranged in colour from yellow to grey, yellow/grey, grey/white, grey/black, blue/grey and to white. All of the trial pit locations (excavated in the southern area of the site, which comprises the parking area for articulated lorries/trailers and the maintenance area) were terminated in the galligu chemical waste, with the exception of TP1, with the maximum depth being 4.4 m (TP4). The galligu chemical waste was encountered in the borehole locations of BH51 and BH55, which were drilled in the southern area, to depths of 9.0 m (BH51) and 10.0 m (BH55) comprising a maximum thickness of 2.5m (BH51) and 9.1 m (BH55). The majority of the window sample locations (excavated in the northern and central areas, with the exception of WS1 and WS2) were terminated in the galligu chemical waste, with the maximum depth being 5.0m (WS1, WS2, WS4, WS6, WS16), however, the galligu chemical waste was encountered in this area to a maximum depth of 9.0 m with a total thickness of 6.6 m (BH43).

The made ground was underlain in all five boreholes by alluvial deposits, generally comprising soft to firm grey/brown/black silty clay, clayey silt or sand, which were encountered to depths of between 15.6 m (BH23) and 22.0 m (BH51, although the depth (base) of Alluvium was not proven in this borehole). Low permeability drift deposits of Glacial Till were encountered beneath the Alluvium, with the exception of BH51, which was terminated in the alluvial deposits. The Glacial Till consists of firm to stiff, brown, silty or sandy clay with occasional sand and gravel deposits. The clay deposits within the Glacial Till were encountered up to the interface of the sandstone bedrock in BH43 at a depth of 33.3 m, however, sand and gravel deposits at the base of the Glacial Till were encountered at the interface of the sandstone bedrock in BH31 and BH34. BH55 was terminated in the Glacial Till at 35.0 m.

The solid geology underlying the site is Sandstone, which was encountered at depths ranging between 33.3 m (BH43) and 38.8 (BH34), which is at significant depth in comparison to the Foundry Lane site. The sandstone stratum encountered within BH31, comprised very weak to weak, poorly cemented red/brown, fine grained sandstone.

Summary of Geological Observations

The geological strata for the whole development site are summarised in *Table 14.3(k)*.

Table 14.3(k) - General Summary of Site Geology

Site	*Strata*	*Description*	*Depth Encountered (m bgl)*	*Thickness*
Foundry Lane Site	**Made Ground**	Limestone chippings, concrete or soil/clay matrix.	From ground level.	Generally between 0.3 m and 1.5 m thickness
		Variable brown/grey, clay/sand or dense black ash with fragments of gravel brick and occasional inclusions of metal slag and cinder.	Between 0.3 m and 5.0 m bgl.	Between 0.6 m and 3.7 m thickness.
	Alluvium	Soft to firm, grey/brown, silty CLAY or clayey SILT with occasional inclusions of peat	Between 2.0 m and 10.5 m bgl.	Between 1.2 m and 7.5 m thickness.
	Glacial Till	Firm to stiff, brown/reddish brown, silty or sandy CLAY with occasional sand and gravel deposits.	Between 4.0 m and 12.8 m bgl.	Between 1.0 m and 8.8 m thickness.
	Sandstone	Weak/moderately weak, poorly cemented, red/brown, medium/coarse grained SANDSTONE.	From 10.5 m bgl.	Not proven, in excess of 5.0 m thickness.
Reclamation Site – southern section of mound	**Made Ground**	Grass over topsoil.	From ground level.	Generally between 0.3 m and 0.7 m thickness.
		Variable, soft to firm, brown/grey, silty/sandy clay with fragments of gravel, brick, wood and inclusions of reinforced wire, plastic and organic matter.	Between 0.3 m and 3.6 m bgl.	Generally between 2.0 m and 3.2 m thickness.
		Galligu chemical waste.	Between 2.7 m and 5.3 m bgl.	Not proven, in excess of 5.3 m thickness.
Reclamation Site – the area to the north	**Made Ground**	Limestone chippings or a soil/clay matrix.	From ground level.	Generally between 0.3 m and 0.9 m thickness.
		Soft to firm brown/grey, sandy silty clay/clayey silt or dense black ash with fragments of gravel brick, concrete, reinforced wire and plastic.	Between 0.3 m and 2.5 m bgl.	Generally between 1.1 m and 1.9 m thickness.
		Galligu chemical waste.	Between 1.5 m and 7.0 m bgl.	Generally between 4.1 m and 4.5 m thickness.
		Soft to firm, black silt with an odour reminiscent of gas works waste.	Between 5.6 m and 10.5 m bgl.	Generally between 1.8 m and 3.5 m thickness.
	Alluvium	Medium, dense, fine grey/brown silty SAND.	Between 10.5 m and 15.0 m bgl.	Approximately 4.5 m thickness.
	Glacial Till	Firm to stiff/ brown silty/sandy CLAY with sand and gravel deposits.	Between 7.4 m and 30.5 m bgl.	Generally between 4.4 m (BH14) and 15.5 m (BH23) thickness.
	Sandstone	Weak/moderately weak, poorly cemented, red/brown, medium/coarse grained SANDSTONE.	From 11.8 m (BH14) and from 30.5 m (BH23) bgl.	Not proven, in excess of 5.0 m thickness.
West Bank Dock Site	**Made Ground**	Limestone chippings, concrete or soil/clay matrix.	From ground level.	Generally between 0.2 m and 1.0 m thickness.
		Variable, brown/grey/black sand, silt or clay or a dense black ash with fragments of gravel brick, concrete, metal slag and occasional pieces of wood, reinforced wire, ceramic tiles, plastic, organic matter and coal.	Between 0.2 m and 6.5 m bgl.	Generally between 0.6 m and 5.5 m thickness.
	Made Ground	Galligu chemical waste.	Between 0.7 m and 10.0 m bgl.	Generally between 4.2 m and 9.3 m thickness.
	Alluvium	Soft to firm, grey/brown/black, silty CLAY, clayey SILT or SAND.	Between 8.0 m and 19.4 m bgl.	Generally between 7.6 m and 9.6 m thickness.
	Glacial Till	Firm to stiff, brown, silty or sandy CLAY with sand and gravel deposits.	Between 15.6 m and 38.8 m bgl.	Generally between 15.7 m and 22.9 m thickness.
	Sandstone	Very weak to weak, poorly cemented, red/brown, fine grained SANDSTONE.	From 33.3 m bgl	Not proven, in excess of 8.0 m thickness.

The above table is reflective of the conditions encountered during ENVIRONs investigation in 2004. Subsequently in 2007, additional trial pit investigation of the Reclamation Mound was undertaken by others, which identified that the Mound comprised topsoil and clay over galligu. Samples were obtained for subsequent chemical and physical constraints. The base of the Mound was not penetrated.

14.3.6 Hydrogeology

Published Hydrogeology

The groundwater vulnerability map for West Cheshire (Sheet 16, scale 1:100,000) shows the site to be located on a minor aquifer, relating to the superficial drift deposits. These are variably permeable formations and can be fractured or potentially fractured rocks or other formations of variable permeability. They seldom produce large quantities of water for abstraction, but may support local abstractions and are important in supplying base flow to rivers. The underlying Sherwood Sandstone Group are considered to be a major aquifer.

It is anticipated that groundwater levels beneath the site would be tidally influenced by the River Mersey and may be saline.

As the site is within an urban area, any underlying soils are automatically classified as having high leaching potential (HU), i.e. they have little ability to diffuse source pollutants and liquid pollutants have the potential to move rapidly into underlying strata (it should be noted that all soils within urban areas are classified according to the worst case scenario).

According to an independent, third party environmental database (Envirocheck), there are four groundwater abstractions within a 500 m of the site, one of which (Croda Colloids Ltd) abstracts water from three different abstraction points. The details of these are summarised in the *Table 14.3(l)* below:

Table 14.3(l) - Groundwater Abstractions

Operator	*Abstraction use*	*Distance from site*
Granox Ltd	General use	195 m south of West Bank Dock site
Croda Colloids Ltd	General cooling and process water	199 m south of Foundry Lane site 271 m south-west of Reclamation site 340 m south-west of Foundry Lane site
McKechie (Widnes) Ltd	Cooling and conveying materials	338m north of West Bank Dock site
Fisons Ltd (Fertilizer Division)	Manufacturing	448m south east of West Bank Dock site

Hydrogeological Field Observations

Shallow groundwater strikes/seepage were encountered in the made ground horizon in seven (BH9, BH12, BH14, BH23, BH31, BH34 and BH43) of the twelve boreholes and were encountered at approximate depths of between 0.6 m (BH9) and 5.9 m (BH43).

Groundwater strikes were encountered in the alluvial deposits within two of the boreholes (BH43 and BH55), however, the majority of the groundwater strikes were encountered within the underlying glacial till horizon. Groundwater strikes within the clay deposits of the Glacial Till were encountered in seven (BH9, BH14, BH23, BH31, BH34, BH43 and BH55) of the twelve boreholes excavated and groundwater strikes were encountered in the sand and gravel deposits at the base of the Glacial Till within three of the boreholes (BH14, BH23 and BH34).

No discernible groundwater strikes were encountered during the excavation of the remaining four boreholes (BH8, BH11, BH15 and BH51), however, all of the boreholes, with the exception of BH51, subsequently 'made water' following well installation.

Details of the groundwater strikes are presented in *Table 14.3(m)*.

Table 14.3 (m) - Groundwater Strike Details

Position	*Depth to Strike m bgl*	*Strata*	*Rise m bgl (after 20 minutes)*	*Drillers comments*	*Date*
BH9	0.6	Made Ground	0.6	Slow seepage	09.11.04
BH12	1.3	Made Ground	-	Seepage	15.11.04
BH14	1.5	Made Ground	1.5	Slow seepage	11.11.04
	4.2	Made Ground	2.8	Medium seepage	11.11.04
	11.4	Glacial Till (sand and gravels)	8.0	Medium seepage	11.11.04
BH23	3.9	Made ground	3.0	Medium seepage	12.11.04
	16.2	Glacial Till (sand)	10.0	Medium seepage	15.11.04
	17.0	Glacial Till (silty clay)	16.3	Slow seepage	15.11.04
	21.0	Glacial Till (silty clay)	16.5	Medium seepage	15.11.04
	22.6	Glacial Till (silty clay)	22.0	Slow seepage	16.11.04
	25.6	Glacial Till (silty clay)	20.0	Medium seepage	16.11.04
	27.6	Glacial Till (silty/sandy clay)	22.6	Medium seepage	16.11.04
	30.1	Glacial Till (sand and gravels)	22.0	Medium seepage	16.11.04
BH31	3.8	Made Ground	3.0	Slow seepage	23.11.04
	20.2	Glacial Till (sand)	18.0	Medium seepage	24.11.04
	23.7	Glacial Till (sand)	18.0	Medium seepage	24.11.04
	27.5	Glacial Till (silty clay)	26.5	Medium seepage	25.11.04
	36.1	Glacial Till (silty sand)	30.0	Medium seepage	25.11.04
BH34	3.3	Made Ground	3.0	Slow seepage	29.11.04
	20.6	Glacial Till (sand)	18.0	Medium seepage	30.11.04
	21.2	Glacial Till (sand)	18.0	Medium seepage	30.11.04
	33.0	Glacial Till (sand)	29.6	Medium seepage	01.12.04

Position	Depth to Strike m bgl	Strata	Rise m bgl (after 20 minutes)	Drillers comments	Date
	38.4	Glacial Till (sand and gravels)	34.0	Medium seepage	01.12.04
BH43	5.9	Made Ground	5.0	Medium seepage	02.12.04
	11.5	Alluvium (silty sand)	6.4	Medium seepage	02.12.04
	21.9	Glacial Till (sand)	18.0	Fast seepage	03.12.04
	34.0	Glacial Till (sand) / SANDSTONE	30.0	Medium seepage	06.12.04
BH55	10.5	Alluvium (silt)	9.8	Slow seepage	18.11.04
	13.5	Alluvium (sand)	10.0	Medium seepage	18.11.04
	21.6	Glacial Till (silty clay)	21.0	Slow seepage	19.11.04
	23.4	Glacial Till (sand)	20.0	Medium seepage	19.11.04
	26.6	Glacial Till (sand)	25.0	Medium seepage	19.11.04

Four window sample locations (WS4, WS6, WS11 and WS16) were pre-emptively installed as monitoring wells, although no discernible shallow groundwater strikes were encountered during drilling. However, two of the window sample locations (WS4 and WS6) subsequently 'made water' following well installation.

Resting groundwater levels were monitored following the installation of the wells and prior to purging and sampling. The resting groundwater levels provide a more accurate representation of groundwater levels across the site compared to inflow depths. From a topographic survey conducted at the site, the groundwater levels were calculated in relation to ordnance datum, as shown in *Table 14.3 (n)* below:

Table 14.3(n) - Groundwater Levels

Position	Date	Groundwater level (m bgl)	Ground Elevation (m AOD)	Groundwater level (m AOD)
BH8	24.11.04	1.43	6.672	5.242
	10.01.05	1.32	6.672	5.352
BH9	24.11.04	4.57	6.346	1.776
	10.01.05	4.35	6.346	1.996
BH11	29.11.04	0.80	6.362	5.562
	10.01.05	0.78	6.362	5.582
BH12	03.12.05	2.88	6.828	3.948
	10.01.05	4.17	6.828	2.658
BH14	30.11.04	2.57	9.669	7.099
	10.01.05	2.58	9.669	7.089
BH15	03.12.04	5.32	6.373	1.053
	10.01.05	4.36	6.373	2.013
BH23	02.12.04	9.26	11.127	1.867
	10.01.05	8.21	11.127	2.917
BH31	06.12.04	9.59	11.217	1.627
	10.01.05	8.25	11.217	2.967

Position	Date	Groundwater level (m bgl)	Ground Elevation (m AOD)	Groundwater level (m AOD)
BH34	06.12.04	6.15	11.177	5.027
	10.01.05	6.00	11.177	5.177
BH43	07.12.04	4.72	13.089	8.369
	10.01.05	4.66	13.089	8.429
BH51	30.11.04	Dry	16.173	----
	10.01.05	Dry	16.173	----
BH55	30.11.04	7.62	14.244	6.624
	10.01.05	11.07	14.244	3.174
WS4	26.11.04	3.43	11.616	8.186
	10.01.05	3.41	11.616	8.206
WS6	26.11.04	3.09	11.20	8.11
	10.01.05	3.07	11.20	8.13
WS11	26.11.04	Dry	15.47	---
	10.01.05	Dry	15.47	---
WS16	26.11.04	Dry	13.40	---
	10.01.05	Dry	13.40	---

m AOD = m Above Ordnance Datum
m bgl = m below ground level
BH14, BH34, BH43 and BH51 installed with a 50mm diameter standpipe within the Made Ground deposits.
WS4, WS6, WS11 and WS16 installed with a 19mm diameter piezometer within the Made Ground deposits.
BH8, BH9, BH11 and BH15 installed with a 50mm diameter standpipe within the alluvial drift deposits.
BH31and BH23 installed with a 50mm diameter standpipe within the sand and gravel deposits within the Glacial Till horizon.
BH12 and BH55 installed with a 50mm diameter standpipe within the clay deposits within the Glacial Till horizon.

Four different groundwater bodies have been identified at the site within the depth range of the site investigation. These comprise:

- perched water located within the made ground horizon above the alluvial deposits.

  Perched groundwater was encountered in three (BH14, BH34 and BH43) of the four boreholes, which were installed to capture this water bearing strata, and was encountered at shallow depths of between 1.5 m and 5.9 m bgl. Perched water within the made ground is generally due to infiltration from unsurfaced ground and site drainage, which is known to be in a poor state of repair;

- water bearing silt/sand lenses within the Alluvium.

Four boreholes (BH8, BH9 BH11 and BH15) located on the Foundry Lane site were installed to capture this water bearing strata, which is believed to be tidally influenced and possibly in continuity with the lower groundwater body;

- water bearing silt/sand lenses within the clay deposits encountered in the Glacial Till.

  Two boreholes (BH12 and BH55) were installed to capture this water bearing strata, however, there is likely to be variability in the groundwater levels across the site area, within this stratum, which is dependent on the presence of sand/silt lenses within the clay deposits. It is believed that the thickness of the clay reduces in the eastern section of the site;

- sand and gravel deposits encountered within the Glacial Till;

  Two boreholes (BH23 and BH31) were installed to capture this groundwater located within the drift/solid geology transition zone. These sands and gravels are likely to be a good indicator of potential contamination risk to the deeper major aquifer. In other words, if this horizon is relatively uncontaminated it is likely that the major aquifer will not have been affected by site based contaminants; and

- The Sherwood sandstone aquifer which underlies the area.

The groundwater within the alluvial/glacial till horizons appears to be flowing in a south-westerly direction, towards the river basin, which is not unexpected. There appears to be no discernible trend or dynamic to the perched water within the Made Ground.

However, the groundwater regime is complicated due to the influence of other factors including for example, the installation of the sheet piled wall along the length of Steward's Brook adjacent to the Reclamation side of the site and the Ditton Brook (in part), which was installed approximately 17 m below ground level. Furthermore, the hydrostatic pressure exerted by the reclamation mound and the adjacent HEDCO site is also likely to be an influencing factor together with the granular glacial deposits within the palaeo channel, which may affect the overall groundwater regime.

It is also likely that groundwater levels are influenced by the tide. In an attempt to try and determine if such a linkage exists, automatic hydraulic level loggers were inserted in Steward's and Ditton Brooks and in four boreholes (BH8, BH23, BH43 and BH55) each representing a different groundwater body. The units were synchronised to record over the same time period and the data retrieved and plotted. The plots are presented in *Appendix 14.4*. The study indicates that there is a tidal influence on the water bodies within the Alluvium and Glacial Till, as there is clearly a cyclical fluctuation in water levels in these boreholes that has a similar signature to tidal fluctuations. It should be noted, however, that no such regular fluctuations occurred within perched water. This cyclical fluctuation in the natural groundwater implies that in the natural strata at least there is some connectivity between the surface waters and groundwater.

There is a possibility that the water bearing strata in the alluvial deposits (and maybe the made ground) is in continuity with the lower water body encountered beneath the site drift deposits. Therefore, the groundwater encountered on site, was also analysed for major ions, since the balance of ions in groundwater can be used to distinguish between different water bodies. Diagrams (stiff diagrams) were produced in order to fingerprint the ionic balance for the water bodies.

The results show that on the whole the ionic balance of the various groundwater bodies underlying the site varies significantly and no clear links between the water bodies was evident, however, some similarities were noted between the samples presented in *Appendix 14.4*, but the results are inconclusive.

These diagrams show that in some cases the ionic balance in each of the water bodies exhibit a very similar pattern and thus may imply that the groundwaters are inter-connected. These results should be treated with caution, however, as the regime on site maybe complex and the ionic balance influenced by contamination within the groundwater bodies and probably historic tidal inundation. As a worst case scenario from an environmental risk perspective, however, it seems reasonable to assume that at least on parts of the site there is some interconnectivity between the groundwater bodies.

14.4 BASELINE CONDITIONS – CHEMICAL CONTAMINATION

14.4.1 Field Evidence of Contamination

Visual and olfactory field evidence of potential contamination was noted during the investigation at a number of locations. In general, occasional to frequent gravel size fragments of brick, concrete, cinder, coal and inclusions of metal slag were found throughout the made ground across the site, along with discrete granular ashy layers or chemical waste material.

In addition to this, occasional locations were noted to have hydrocarbon odours and/or visual evidence of hydrocarbon contamination (oily stains) within the made ground. Hydrogen sulphide odours were noted, generally within the chemical waste (galligu) material together with unidentifiable odours noted within the alluvial deposits.

Field evidence of contamination was noted and is summarised in *Table 14.4(a).*

Table 14.4(a) – Field Evidence of Contamination

Position	Strata	Depth m bgl	Observations
BH9	Made ground	1.50-3.70	Dense, black, ash and metal slag fill.
BH9	Made ground	3.70-5.00	Medium dense, grey, sand, ash and broken brick fill.
BH11	Made ground	GL-1.20	Firm, grey/brown, clay with metal slag fill.
BH11	Made ground	1.20-1.80	Firm, grey/brown, gravely clay with metal slag fill.
BH12	Made ground	0.30-3.50	Dense/very dense, black ash, cinder and broken brick fill.
BH14	Made ground	GL-0.30	Stone and ash fill.
BH14	Made ground	0.30-1.20	Broken brick, wood and metal fill.
BH14	Made ground	1.50-4.20	Very loose, grey, chemical waste fill.
BH14	Made ground	4.20-4.80	Metal slag.
BH14	Made ground	4.80-5.60	Loose, grey/blue and grey, chemical waste fill.
BH14	Made ground	5.60-7.40	Soft to soft/firm, odorous, silty waste (possible gas works waste).
BH15	Made ground	0.40-2.50	Loose/medium dense, black ash, cinder, brown clay and broken brick fill.
BH23	Made ground	2.50-3.60	Loose, grey, chemical waste fill.
BH23	Made ground	3.60-3.90	Medium dense, black ash fill.
BH23	Made ground	3.90-7.00	Very loose/loose, grey/blue, clayey chemical waste fill.
BH23	Made ground	7.00-10.50	Soft to soft/firm, grey/black, odorous, silty waste (possible gas works waste).
BH31	Made ground	0.20-3.80	Very loose, black, clayey ash fill.
BH31	Made ground	3.80-5.70	Very loose, grey, chemical waste fill.
BH31	Made ground	5.70-6.40	Medium dense, broken concrete and grey chemical waste fill.
BH31	Made ground	6.40-8.00	Loose, grey/black, clay chemical waste fill.
BH31	Alluvium	8.00-10.00	Firm, black, odorous SILT.
BH34	Made ground	0.30-2.50	Very loose, black ash and cinder fill.
BH34	Made ground	2.50-7.00	Medium dense, grey/white, ash and cinder fill.
BH34	Alluvium	7.00-9.00	Firm, black, odorous SILT.
BH43	Made ground	0.60-0.80	Black ash fill.
BH43	Made ground	1.70-2.40	Medium dense, black ash and broken concrete fill.
BH43	Made ground	2.40-3.40	Grey, waste fill.
BH43	Made ground	4.80-6.90	Very loose, grey/black, chemical waste fill.
BH43	Made ground	6.90-7.50	Very loose, grey/blue, chemical waste fill.
BH43	Made ground	7.50-9.00	Loose, black, silty waste fill.
BH43	Alluvium	9.00-11.50	Firm, black, odorous silt.
BH51	Made ground	3.00-6.50	Loose/medium dense, black/brown, ash and broken brick fill.
BH51	Made ground	6.50-9.00	Loose, grey, chemical waste fill.
BH51	Alluvium	9.00-22.00	Very loose, grey /black, odorous SAND/SILT.
BH55	Made ground	0.70-8.50	Very loose/loose, grey/white/green, chemical waste fill.
BH55	Made ground	8.50-9.00	Very loose, grey/black, chemical waste fill.
BH55	Made ground	9.00-9.60	Hard, grey/black, chemical waste fill.
WS1	Made ground	0.35-1.00	Soft, yellow/grey, silty clayey chemical waste fill.
WS1	Made ground	1.00-1.10	Coarse black ash fill.
WS1	Made ground	1.10-4.00	Soft, yellow/grey, silty clayey chemical waste fill.
WS1	Made ground	4.00-5.00	Blue/grey, silty chemical waste fill.
WS2	Made ground	0.50-4.50	Soft, yellow/grey, clayey silty chemical waste fill.
WS2	Made ground	4.50-5.00	Dark grey, clayey silty chemical waste fill.
WS3	Made ground	0.35-0.70	Soft, dark grey, silty clay with gravel, ash and cobbles of brick.

Position	***Strata***	***Depth m bgl***	***Observations***
WS3	Made ground	0.70-1.50	Coarse, orange/brown, sand, with pockets of clay, coarse gravel and fragments of ash.
WS3	Made ground	1.50-4.00	Blue/grey, chemical waste fill.
WS4	Made ground	0.50-1.40	Metal slag and ash fill.
WS4	Made ground	1.80-5.00	Loose, blue/grey, chemical waste fill.
WS5	Made ground	0.50-1.30	Ash fill with brick, metal slag and gravel fragments.
WS5	Made ground	2.30-4.00	Loose, blue/grey, chemical waste fill.
WS3	Made ground	1.50-4.00	Blue/grey, chemical waste fill.
WS6	Made ground	0.40-0.80	Saturated, black, gravely silty clay with strong hydrocarbon odour.
WS6	Made ground	1.00-1.60	Coarse, brown, gravely sand with hydrocarbon odour.
WS6	Made ground	1.60-2.40	Black ash fill with hydrocarbon odour.
WS6	Made ground	2.60-2.70	Soft, yellow, silty clayey chemical waste fill.
WS6	Made ground	2.70-3.00	Saturated, black, odorous silty waste (possible gas works waste).
WS6	Made ground	3.00-4.70	Soft, black, odorous, gravely silty clay.
WS6	Made ground	4.70-5.00	Loose, blue/grey, chemical waste fill.
WS7	Made ground	1.50-2.00	Coarse gravel with metal slag.
WS7	Made ground	2.50-3.50	Yellow, silty clayey chemical waste fill.
WS7	Made ground	3.50-4.00	Black, odorous, silty waste (possible gas works waste).
WS8	Made ground	0.30-1.50	Coarse, black, gravely sand with fragments of metal slag.
WS8	Made ground	1.60-2.00	White, friable chemical waste fill.
WS8	Made ground	2.00-2.50	Coarse ash and sand with fragments of wood.
WS9	Made ground	GL-1.10	Rough ground over mottled brown, silty clay with occasional sand lenses, fragments of brick, wood and ash.
WS9	Made ground	1.10-1.30	Soft, yellow, silty clayey chemical waste fill.
WS9	Made ground	1.60-2.60	Soft, yellow, silty clayey chemical waste fill.
WS9	Made ground	2.60-4.00	Ash and metal slag fill.
WS10	Made ground	1.50-2.50	Soft, yellow, silty clayey chemical waste fill.
WS10	Made ground	2.70-3.00	Black ash and metal slag fill.
WS10	Made ground	3.50-4.00	Loose, brown, clayey silt with gravel brick and coal fragments.
WS11	Made ground	0.60-1.20	Soft, orange/brown, sandy clay with fragments of ash.
WS11	Made ground	1.50-2.50	Soft, yellow, silty clayey chemical waste fill.
WS11	Made ground	2.50-3.50	Loose, brown, silt with fragments of metal slag.
WS12	Made ground	0.50-0.70	Loose, brown, clayey silty with gravel, brick and metal slag fragments.
WS12	Made ground	0.70-1.60	Soft, yellow, silty clayey chemical waste fill.
WS12	Made ground	1.60-2.50	Soft, mottled brown, sandy clay with fragments of gravel and ash.
WS12	Made ground	3.30-3.50	Loose, blue/grey, chemical waste fill.
WS13	Made ground	0.50-1.00	Black ash with metal slag and fragments of gravel.
WS13	Made ground	1.00-1.50	Loose, black, gravely silt with fragments of brick and coal.
WS13	Made ground	2.50-3.00	Loose, blue/grey, chemical waste fill.
WS14	Made ground	0.70-1.30	Loose, black, gravely silt with fragments of brick and coal.
WS14	Made ground	2.60-4.00	Loose, blue/grey, chemical waste fill.
WS15	Made ground	1.00-1.50	Brown sand, silt and gravel with occasional metal slag fragments.
WS15	Made ground	1.50-2.50	Black ash.
WS15	Made ground	2.70-3.00	Loose, blue/grey, chemical waste fill.
WS16	Made ground	1.10-1.50	Soft, dark brown, clayey silt with fragments of gravel, brick, coal and wood.
WS16	Made ground	1.50-2.80	Soft, yellow/grey, silty clayey chemical waste fill.
WS16	Made ground	2.80-3.00	Black ash.
WS16	Made ground	3.60-5.00	Loose, blue/grey, chemical waste fill.
TP1	Made ground	1.40-2.00	Soft, yellow, silty clayey chemical waste fill.
TP1	Made ground	2.00-4.00	Loose, brown, silt with fragments of coal, gravel and clay pockets.
TP2	Made ground	3.80-4.00	Loose, yellow, clayey silty chemical waste fill.
TP3	Made ground	0.30-3.50	Soft, dark brown, silty clay with reinforced wire, pieces of plastic, cobbles of concrete and fragments of wood and coal.
TP3	Made ground	4.20-4.30	Soft, yellow, clayey silty chemical waste fill.
TP4	Made ground	0.80-4.40	Soft, yellow, clayey silty chemical waste fill.
TP5	Made ground	1.20-3.00	Soft, yellow/grey, clayey silty chemical waste fill.
TP5	Made ground	3.00-3.90	Coarse, black ash with fragments of red brick and metal slag.
TP5	Made ground	3.90-4.00	Grey/white, friable chemical waste fill.

Position	Strata	Depth m bgl	Observations
TP6	Made ground	0.50-4.10	Soft/very soft, yellow/grey, clayey silty chemical waste fill.
TP7	Made ground	0.50-4.20	Soft/very soft, yellow/grey, clayey silty chemical waste fill.
TP8	Made ground	GL-0.30	Loose limestone chippings with fragments of brick and ash.
TP8	Made ground	1.50-2.00	Loose/powdery, blue/white, chemical waste fill.
TP8	Made ground	2.00-2.30	Solidified, yellow, chemical waste fill.
TP8	Made ground	2.30-2.60	White/black, silty chemical waste fill.
TP8	Made ground	2.60-4.50	Soft, grey/white, silty chemical waste fill.
TP9	Made ground	2.00-4.00	Soft, grey/white, chemical waste fill.
TP10	Made ground	2.00-3.00	Loose, blue/white, chemical waste fill.
TP10	Made ground	3.00-4.40	Soft, dark grey, silty chemical waste fill.
TP11	Made ground	2.00-3.00	Soft, blue/white, chemical waste fill.
TP11	Made ground	3.00-3.50	Soft, dark grey, silty chemical waste.
TP12	Made ground	2.00-3.00	Soft, blue/white, chemical waste fill.
TP12	Made ground	3.00-3.50	Soft, dark grey, silty chemical waste.
TP14	Made ground	1.90-5.00	Soft, grey/white, chemical waste fill.
TP15	Made ground	3.30-5.00	Dark grey/black, silty clayey chemical waste with strong hydrogen sulphide odour.
TP16	Made ground	0.40-1.30	Soft, mottled brown, silty clay with black streaking and fragments of gravel, red brick and wood.
TP16	Made ground	2.40-2.80	Saturated, black, gravely clay with strong hydrogen odour.
TP16	Made ground	2.80-3.60	Loose, grey/white, chemical waste with gravel and ash.
TP17	Made ground	0.50-2.50	Moist, soft, dark brown, sandy clay with black streaking, fragments of brick, wood and pieces of wire.
TP17	Made ground	2.50-3.30	Dark brown, silty clay with pieces of wire and fragments of brick and gravel. Traces of blue/white chemical waste.
TP18	Made ground	2.00-3.50	Firm, brown, sandy clay with black streaking and fragments of gravel and brick.
TP18	Made ground	3.50-3.60	Grey/green, chemical waste fill.
TP19	Made ground	2.70-5.00	Loose, grey/blue, silty chemical waste fill.
TP20	Made ground	2.80-3.60	Loose, grey/white, chemical waste fill.
TP20	Made ground	3.60-5.00	Red, gravely silt with white, chemical waste fill.
TP21	Made ground	0.70-2.70	Soft, dark brown, silty clay with black streaking, fragments of gravel and concrete, pieces of plastic

Position	Strata	Depth m bgl	Observations
			and occasional sand lenses.
TP22	Made ground	3.00-4.40	White/grey, chemical waste fill.
TP23	Made ground	0.60-2.90	Soft, brown, silty clay with black streaking and fragments of brick and gravel.
TP23	Made ground	2.90-3.20	Saturated, dark grey, chemical waste fill with hydrogen sulphide odour.

Suspected asbestos-containing materials were not observed within any of the made ground samples in the field, but one sample recorded amosite (brown asbestos) during laboratory analysis.

All samples from the boreholes, window sample and trial pit locations were headspace tested for the presence of volatile organic compounds (refer to *Section 14.2.3*). The results of the headspace testing did not reveal the presence of significant concentrations of volatile hydrocarbons in any of the samples tested. All readings were recorded below the analytical detection limit of the instrument.

During the purging and sampling of groundwater from each of the installed borehole and window sample locations, or during the excavation of the location where groundwater seepage was observed, any evidence of contamination *i.e.* free phase product, hydrocarbon sheens or odours, were recorded.

Evidence of contamination was observed during the purging and sampling of groundwater within four of the installed monitoring wells. This was noted on the perched water as a significant oily sheen within WS6, and a slight oily sheen noted on the perched water within BH43 and BH14. This was observed to have a strong distinctive odour, reminiscent of gas works.

Evidence of contamination was also noted within the lower water body as a slight sheen was noted during the purging and sampling of BH15, which was installed in order to capture the deeper groundwater within the alluvial drift deposits.

There was no field evidence of contamination in the groundwater at the drift/solid geology horizon (*i.e.* the sand and gravel band at the sandstone interface).

14.4.2 Land Gas Assessment

Land gas is generally produced as a result of the decomposition of organic materials such as paper, vegetation, wood *etc* but can also be present from the breakdown of solvents and petroleum hydrocarbons or be present from coal measures (mines gas). The principal components of landfill gas are methane (CH_4) and carbon dioxide (CO_2), but other gases such as hydrogen sulphide (H_2S) can also be present (especially with high sulphate content wastes like galligu). Land gas can present a hazard to site workers during construction activities (*e.g.* carbon dioxide is heavier than air and may accumulate in service trenches, *etc.*), and can enter buildings, thus presenting a toxic, asphyxiation or explosion hazard.

Methane is a flammable asphyxiating gas, the flammable range being 5 to 15% by volume. In air, carbon dioxide is a non-flammable, toxic gas, with a long-term exposure limit of 0.5% by volume, and a short-term exposure limit of 1.5% by volume. Waste Management Paper No. 27 (Department of the Environment 1991) states that the level of concern for carbon dioxide is 1.5% by volume and for flammable gas (*i.e.* methane) it is 1% by volume.

The Building Regulations 1991, Approved Document C, states that there is a need to consider possible measures to prevent gas ingress into new buildings if concentrations of carbon dioxide above 1.5% are detected in the ground and that measures are definitely required at concentrations above 5%. Approved Document C also states that where methane concentrations do not exceed 1% and that the floor of the building to be constructed is suspended and ventilated, no further protection needs to be provided.

Following the previous submission, a number of new guidance documents have been produced in relation to landfill gas and new developments, including:

- *Assessing Risks Posed by hazardous Ground Gases to Buildings, CIRIA Report C659, 2006;*
- *Guidance on Evaluation of Development Proposals on Sites where Methane and Carbon Dioxide are Present, NHBC and RSK Group 10627-R01 (04), January 2007*

These were recently published and produced to provide clarity and advice with regards to existing hazardous ground gas guidance. In addition, the report provides information on government policy with regard to the redevelopment of Brownfield sites where there is the potential for elevated concentration of potentially hazardous soil gases to be present. These documents complement the previous guidance documents, however it should be noted that additional monitoring would be required to provide details of the gas regime at the site. It is, unlikely to be significant for the proposed development however as the site surface will be substantially re-engineered and re-surfaced (including treated galigu) and the size of the proposed buildings and nature of their use (large volume freight handling) makes them less prone to gas accumulation if there was a substantial gas source present.

Hydrogen Sulphide can be both flammable and toxic.

Monitoring was undertaken for methane, carbon dioxide, oxygen, carbon monoxide (indicative of underground fires) and hydrogen sulphide using a fully calibrated portable infra-red gas analyser (Geotechnical Instruments Gas analyser GA2000) in all locations. The instrument provides quantitative analysis of methane and carbon dioxide by infra-red detection and oxygen by galvanic cell. Additionally it measures by an internal transducer. The analytical range for the gases analysed are 0% to 100% in 0.1% increments. The minimum detection limit is 0.1%.

To date, two gas monitoring visits have been completed at the site. The deeper wells of BH8, BH9, BH11, BH12, BH15, BH23, BH31 and BH55 were principally installed for the recovery of groundwater samples with the Alluvium, Glacial Till and Fluvio-glacial Sand and Gravel deposits, but were also included in the assessment of the gas regime for completeness.

The gas monitoring results are presented in *Table 14.4(b)*. The results presented are the maximum concentrations recorded for methane, carbon dioxide, carbon monoxide and hydrogen sulphide and the minimum concentrations recorded for oxygen.

Table 14.4(b) – Gas Monitoring Results

BH/WS	*Date*	*Methane (% volume)*	*Carbon Dioxide (% volume)*	*Oxygen (% volume)*	*Hydrogen Sulphide (ppm)*	*Carbon Monoxide (ppm)*	*Flow Rate (l/h)*	*Atmospheric Pressure (mb)*
BH8	24.11.04	<0.1	0.1	20.1	<0.1	<0.1	+0.0	1027
	10.01.05	<0.1	0.1	20.8	<0.1	<0.1	+0.3	1005
BH9	24.11.04	0.2	0.1	15.8	<0.1	<0.1	-0.3	1027
	10.01.05	<0.1	0.2	15.1	<0.1	<0.1	+0.2	1005
BH11	29.11.04	<0.1	0.1	20.4	<0.1	<0.1	-0.9	1021
	10.01.05	<0.1	0.3	20.4	<0.1	<0.1	+0.9	1005

BH/WS	Date	Methane (% volume)	Carbon Dioxide (% volume)	Oxygen (% volume)	Hydrogen Sulphide (ppm)	Carbon Monoxide (ppm)	Flow Rate (l/h)	Atmospheric Pressure (mb)
BH12	03.12.04	<0.1	0.1	20.8	<0.1	<0.1	-0.4	1018
	10.01.05	<0.1	0.4	16.4	<0.1	<0.1	+0.2	1005
BH14	30.11.04	0.1	<0.1	11.7	<0.1	3	+0.2	1010
	10.01.05	0.2	<0.1	1.0	<0.1	2	+0.0	1007
BH15	03.12.04	3.6	<0.1	14.1	<0.1	2	-0.6	1018
	10.01.05	6.5	0.4	8.2	<0.1	1	+0.1	1005
BH23	02.11.04	<0.1	<0.1	20.7	<0.1	8	-1.41	1013
	10.01.05	<0.1	<0.1	11.5	<0.1	1	-0.1	1007
BH31	06.12.04	<0.1	0.1	18.7	<0.1	4	+0.5	1023
	10.01.05	0.1	<0.1	18.8	<0.1	1	+0.2	1006
BH34	06.12.04	<0.1	<0.1	20.5	<0.1	<0.1	-0.6	1022
	10.01.05	<0.1	<0.1	19.8	<0.1	<0.1	+0.9	1006
BH43	07.12.04	<0.1	1.0	18.3	<0.1	2	-0.2	1027
	10.01.05	0.1	2.2	17.9	<0.1	3	-0.1	1007
BH51	30.11.04	<0.1	5.1	17.7	<0.1	2	+1.5	1008
	10.01.05	0.1	<0.1	20.6	<0.1	<0.1	-0.1	1007
BH55	30.11.04	0.2	<0.1	15.9	<0.1	3	-0.6	1008
	10.01.05	0.2	0.2	15.7	<0.1	5	+0.0	1006
WS4	26.11.04	<0.1	0.4	17.8	<0.1	<0.1	-0.2	1016
	10.01.05	0.1	0.3	19.5	<0.1	<0.1	-0.1	1006
WS6	26.11.04	<0.1	7.0	7.0	<0.1	<0.1	-1.5	1016
	10.01.05	0.1	6.3	7.7	<0.1	4	+0.9	1006
WS11	26.11.04	<0.1	<0.1	20.6	<0.1	<0.1	-0.7	1015
	10.01.05	0.1	4.7	15.2	<0.1	<0.1	+0.0	1007
WS16	26.11.04	0.4	0.9	7.7	<0.1	3	-1.2	1018
	10.01.05	0.1	1.0	9.0	<0.1	1	+0.5	1006

<0.1 = below instrument analytical detection limit.

- Concentrations of **methane** ranged from non detectable (<0.1%) to 6.5% (BH15). With the exception of BH15, all results were below the guidance level of 1% by volume set in the Building Regulations and Waste Management Paper No. 27 (Department of Environment 1991) on both monitoring occasions. The maximum concentration of methane was detected in BH15 (located on the Foundry Lane site), with elevated concentrations of 3.6% recorded during the first monitoring round and 6.5% on the second monitoring round. This well comprises a monitoring standpipe installed in the alluvial deposits, therefore, it is possible that the degradation of natural organic matter within the Alluvium is giving rise to this elevated level of methane. Although, no organic horizons (such as peat), which may lead to the generation of land gas, was noted within the soil profile of this borehole.

- Concentrations of **carbon dioxide** were detected above the Building Regulations guideline of 1.5% (above which gas control measures should be considered in new buildings) in four (BH43, BH51, WS6 and WS11) of the sixteen monitoring wells, of which, two wells (BH51 and WS6) recorded concentrations in excess of the 5% guideline set out by BRE (where ground floor slab constructions are required for buildings). The maximum concentration recorded within BH51 was 5.1%, which was recorded during the first monitoring round, however, this concentration was not sustained and the concentration reduced to below 1% within thirty seconds of the monitoring time. The second monitoring occasion did not record carbon dioxide concentrations from this borehole above the instruments analytical limit of detection (0.1%). The maximum concentrations recorded within WS6 were 7.0% during the first monitoring round and 6.3% during the second monitoring round. The presence of carbon dioxide in wells corresponds to the presence of the fill material, which in WS6 comprised a strong hydrocarbon odour. The levels observed are not, however, atypical of those that can be found naturally

- Concentrations of **oxygen** ranged between 7.0% (WS6) and 21.1% (BH12) during the first monitoring round. This depleted concentration of 7.0% coincided with the elevated carbon dioxide level detected within the well. The concentrations of oxygen during the second monitoring ranged between 1.0% (BH14) and 21.1% (BH9), although, the concentrations of carbon dioxide within BH14 were all recorded below the instruments analytical detection limit an odour was noted within this borehole.

- **Hydrogen sulphide** concentrations were not detected above the analytical limit of detection (<0.1 parts per million (ppm)) in all of the sixteen monitoring wells on both monitoring occasions.

- Concentrations of **carbon monoxide** ranged between <0.1 ppm and 8 ppm, which was recorded within BH23 on the first monitoring round. These concentrations are considered to be low.

- **Flow rates** in the sixteen wells ranged between +1.5 litres/hour and -1.41 litres/hour during the first monitoring round, however, by the second monitoring round low measurable flow rates of +0.9 litres/hour to -0.1 litres/hour were detected within the monitoring wells. These flow rates are not considered to be representative of land gases being positively released on site, at any significant rate.

Following the first gas monitoring round, gas samples were collected for laboratory analysis from the two monitoring wells, which detected the highest methane (BH15) and carbon dioxide (WS6) concentrations. The laboratory analysis of the gas samples is a more robust test, which is undertaken to confirm the results from the field test and to establish whether the results represent methane or a mixture of methane and other hydrocarbon vapours. Therefore, the gas samples were analysed for carbon dioxide, oxygen, carbon monoxide, methane and volatile organic compounds (VOCs).

- Concentrations of **methane** were recorded at 7.3% (BH15) and 0.2% (WS6), which accord with the field data.
- Concentrations of **carbon dioxide** were recorded at 0.4% (BH15) and 6.4% (WS6), which accord with the field data.
- Concentrations of **oxygen** were recorded at 11.4% (BH15) and 9.3% (WS6), which coincides with the recorded carbon dioxide levels and accords with the field data.
- **Carbon monoxide** concentrations were detected below the analytical limit of detection (0.1%) in both of the monitoring wells. However, carbon monoxide concentrations were detected in the field, albeit low, on both of the monitoring occasions.
- The two gas samples were also submitted for **VOC** analysis. All of the individual vapours were detected at concentrations below the analytical detection limit, with the exception of the compound dichloromethane, which was detected at a concentration of 15ppm within WS6. Dichloromethane is an industrial solvent typically used in chemical processing, which evaporates quickly to gas if released as a liquid. Although this chlorinated solvent was not detected within the soil sample recovered from the window sample location (refer to section on *soil analytical results*), a small pocket would have existed within the soils, in order to have caused the compound to volatilise in the space of the monitoring well, albeit at a low concentration.

14.4.3 Analytical Strategy

The analytical strategy was designed to provide a broad assessment of the ground conditions underlying the site. The analytical strategy was developed with reference to known and potential contaminants associated with the current and historical activities at the site, whilst taking into account common industrial contaminants, on-site visual and olfactory information and the results of the field screening of samples gained during the site works. The following schedule of analysis was employed:

- ***a general suite of analytes:*** testing included pH, monohydric phenol, total cyanide, water soluble sulphate and a range of metals (arsenic, cadmium, chromium, lead, mercury, selenium, copper, nickel, zinc);
- ***sulphide:*** undertaken on selected soil and groundwater samples;
- ***total petroleum hydrocarbons (TPH) (screening):*** in particular, samples which indicated field evidence of hydrocarbon contamination (e.g. oily odours, staining, etc.) were submitted for TPH analysis;
- ***polyaromatic hydrocarbons (PAHs) (screening and speciated):*** to determine the presence of fuel derivatives and associated compounds;
- ***volatile organic compounds (VOCs):*** to determine the presence of fuel derivatives, solvents and associated compounds;
- ***semi-volatile organic compounds (SVOCs):*** to determine the presence of a wider range of semi-volatile organic contaminants including PAH compounds and phenols,
- ***water soluble boron:*** undertaken on selected soil samples;
- ***pesticide suite (organochlorine (OCP) and organophosphorus (OPP) compounds):*** was undertaken on selected soil and groundwater samples;
- ***polychlorinated biphenyls (PCB's):*** to determine whether they have been formerly present on the site;
- ***major ions suite:*** testing included sodium, potassium, calcium, iron, alkalinity as $CaCO_3$, ammonia, chloride and nitrate;
- ***timber treatment suite:*** undertaken on selected soil samples;

- ***asbestos screening:*** was carried out on samples of made ground rather than natural strata, as these samples have a higher potential to contain asbestos;

- ***total organic content (soils)/total organic carbon (water) (TOC):*** was undertaken on selected soil and groundwater samples; and

- ***leachability testing:*** undertaken on selected soil samples to assess the potential leachability of soil contaminants to groundwater.

14.4.4 Soil Analysis – Review of Results

The soil chemical analysis results are summarised in *Table 14.4(c)* and are discussed below. Analytical certificates are presented in *Appendix 14.5.*

Table 14.4(c) – Summarised Soil Analytical Results (mg/kg)

Determinand	***No. Analysed***	***No. Results Exceeding or Equal to CLEA Guideline***	***No. Results Exceeding or Equal to Dutch I Guideline***	***Max. Conc. Detected***	***Max. Conc. Detected (Sample Ref.)***	***Guideline Values***	
						CLEA[1]	***Dutch I[2]***
pH	74	-	-	Min – 5.8 Max – 12.8	BH34 (7.0-7.5 m) WS3 (1.5-2.0 m) TP11 (2.4-2.8 m)	NG	NG
Metals							
Arsenic	74	4	28	21,000	TP20 (4.7-5.0 m)	500	55
Cadmium	74	0	0	3.6	BH31 (2.0-2.5 m)	1,400	12
Chromium (total)	74	0	1	3,580	WS15 (0.5-0.7 m)	5,000	380
Lead	74	5	6	5,000	WS12 (2.7-3.0 m)	750	530
Mercury	74	0	1	16.0	WS9 (2.5-3.0 m)	480	10
Selenium	74	0	-	23	BH34 (5.9-6.4 m)	8,000	NG
Copper	74	-	11	1,200	TP20 (4.7-5.0 m)	NG	190
Nickel	74	0	0	120	TP20 (4.7-5.0 m)	5,000	210
Zinc	74	-	6	2,000	TP9 (3.8-4.0 m)	NG	720
Water Soluble Boron	7	-	-	5.1	BH14 (5.0-5.5 m)	NG	NG
Organic Analysis							
Monohydric Phenol	74	-	0	18	WS6 (0.5-0.7 m)	NG	40
Total TPH (C_{10} – C_{40})	74	-	0	2,500	WS6 (0.5-0.7 m)	NG	5,000
Speciated TPH (Aromatic/ Aliphatic)	2	-	0	3,647.65	WS6 (0.5-0.7 m)	NG	5,000
PAH Total (sum of 10)	74	-	4	200	BH43 (10.5-11.0 m)	NG	40
PAH Speciated (sum of 10)	7	-	0	9.7	BH14 (5.0-5.5 m)	NG	40
PCBs (sum of 7)	15	-	-	ND	n/a	NG	1
VOC's							
Dichloro-methane	34	-	0	0.051	BH12 (0.3-1.2 m)	NG	10
1,1 Dichloro-ethane	34	-	0	0.033	BH51 (5.0-5.45 m)	NG	15
Trichloro-ethane	34	-	0	0.003	WS5 (0.7-1.0 m)	NG	15
Benzene	34	-	1	2.2	BH34 (2.5-3.0m)	NG	1
Trichloro-ethene	34	-	0	0.039	WS5 (0.7-1.0 m)	NG	60
Toluene	34	0	0	6.8	BH34 (2.5-3.0 m)	150	130
Tetrachloro-ethene	34	-	0	0.33	BH51 (5.0-5.45 m)	NG	4
Chloro-benzene	34	-	-	0.003	BH34 (2.5-3.0 m) TP12 (3.0-3.4 m)	NG	NG
Ethylbenzene	34	0	0	0.7	BH34 (2.5-3.0 m)	48,000	50
Total Xylenes (m,p&o)	34	-	0	10.6	BH34 (2.5-3.0 m)	NG	25
1,3,5 Trimethyl-benzene	34	-	-	1.5	BH34 (2.5-3.0 m)	NG	NG
1,2,4 Trimethyl-benzene	34	-	-	2.2	BH34 (2.5-3.0 m)	NG	NG
1,4 Dichloro-benzene	34	-	-	0.002	TP10 (0.3-0.5 m)	NG	NG
SVOC's							
PAH (sum of 10)	12	-	0	35.07	WS16 (1.0-1.3 m)	NG	40
Other Analysis							
Total Cyanide	74	-	0	390	BH23 (11.5-12.0 m)	NG	650
Asbestos Screen	35	-	-	Present	TP5 (0.6-1.0 m)	NG	NG
Water Soluble	74	-	-	2.2	BH23 (17.9 m)	NG	NG

Determinand	***No. Analysed***	***No. Results Exceeding or Equal to CLEA Guideline***	***No. Results Exceeding or Equal to Dutch I Guideline***	***Max. Conc. Detected***	***Max. Conc. Detected (Sample Ref.)***	***Guideline Values***	
						CLEA¹	***Dutch I²***
Sulphate (g/l)							
Sulphide	14	-	-	6,800	BH23 (6.5-7.0 m)	NG	NG
Pesticides (OCL/OPP)	11	-	0	ND	n/a	NG	Various
TOC (%)	11	-	-	6.7	BH9 (9.0-9.5 m)	NG	NG
Timber Treatment	2	-	0	ND	n/a	NG	Various
Major Ions	*Discussed Separately*						
Leachability	*Discussed Separately*						

All results expressed in mg/kg except for WS Sulphate (g/l), pH (unitless) and Asbestos.

TPH = Total Petroleum Hydrocarbons
PAH = Polycyclic Aromatic Hydrocarbons
PCB = Polychlorinated Biphenyls
VOC = Volatile Organic Compound
SVOC = Semi Volatile Organic Compound
OCP = Organochlorine Pesticides
OPP = Organophosphorus Pesticides
TOC = Total Organic Content

NG = No Guideline
ND = Not Detected Above Analytical Detection Limit
n/a = Not Applicable
\- = Not Relevant

1 = CLEA Soil Guideline Value (SGV) for commercial/industrial sites
2 = Dutch Intervention Values

Soil **pH** values were recorded as ranging from slightly acidic to alkaline in the range of pH 5.8 - 12.8. The alkaline conditions predominate largely as a result of the galligu. These values are not normally considered significant in themselves, with the main relevance of soil pH in environmental terms is its effect on the mobility of metals. Metal species are generally less mobile under alkaline conditions, which generally appear to be present across the site. The potential for leaching of metal species at the site, is therefore, considered to be reduced under alkaline conditions. The galligu is considered to be having an influence on the soils being mildly to strongly alkaline in nature, with the higher strength alkalinity being reflective of the caustic properties of galligu and galligu contaminated soils.

Water soluble sulphate concentrations ranged from 0.02 g/l (BH43, 33.5-34.0 m) to 2.2 g/l (BH23, 17.9 m). No environmental guidelines are currently available for sulphate and elevated sulphate levels are of limited significance in environmental terms. However, sulphate rich conditions are aggressive to building materials and this issue will be a consideration during the redevelopment. Therefore, the ground conditions for buried concrete should be specified in accordance with the requirements of AC-2/3 of BRE Special Digest 1: 2000. A separate geotechnical report will be prepared for the implementation phase of the development and should be referred to for an understanding of this.

Total cyanide concentrations were generally recorded below the analytical limit of detection (<5 mg/kg), with the exception of three samples, two of which were recovered from BH23 and one which was recovered from TP5. The maximum concentration detected was 390 mg/kg and was recorded within the natural alluvial deposits within BH23 at a depth of 11.5-12.0m. This was encountered beneath the odorous, silty material, indicative of gas works derived material, which would typically contain high cyanide concentrations and thus may be indicative of downward leaching of contaminants, it should be noted, however, that all concentrations were below the Dutch Intervention value of 500 mg/kg (there is no CLEA guideline value).

Monohydric phenol concentrations were recorded below the analytical detection limit (<3 mg/kg) in seventy two of the seventy four samples analysed. The two concentrations detected above the laboratory detection limit were recorded in WS6 (0.5-0.7 m) at 18 mg/kg and BH43 (10.5-11.0 m) at 5.4 mg/kg. There is no CLEA guideline for this parameter, but both concentrations were recorded below the Dutch I guideline value of 40 mg/kg. It is generally accepted, however, that phenol contamination in contact with plastic water pipes can leach through the pipe and taint water supplies and so some protection of these will be a consideration for any new water services that are laid.

Seventy four soil samples recovered from the made ground and the underlying natural strata were submitted for a range of metals. Trace concentrations of **cadmium**, **selenium** and **nickel** were all detected, although at levels significantly below the respective CLEA guideline values, where available.

Concentrations of **arsenic** ranged between 5 mg/kg (WS8, 1.5-2.0 m and BH43, 33.5-34.0 m) and 21,000 mg/kg (TP20, 4.7-5.0 m). Twenty eight of the seventy four samples analysed exceeded the Dutch I value (55 mg/kg), of which, only four samples exceeded the CLEA industrial guideline value of 500 mg/kg. All of the four samples were recovered from the made ground horizon, two of which comprised an ash fill (BH31, 2.0-2.5 m and BH51, 5.0-5.45 m), with the other two samples comprising galligu chemical waste (WS7, 3.5-4.0 m and TP20, 4.7-5.0 m). High arsenic levels are a typical characteristic of galligu contamination.

Five of the seventy four samples submitted for **lead** analysis recorded concentrations above the CLEA guideline value (750 mg/kg). The highest measured concentration of 5,000 mg/kg was obtained from WS12, located in the former transport yard, in close proximity to the redundant nitromethane AST. The sample was obtained from a depth of 2.7-3.0 m and comprised a black gravely sand within the made ground horizon. The remaining elevated lead concentrations were also detected in samples of made ground recovered from BH31 (2.0-2.5 m) and BH51 (5.0-5.45 m), both of which, comprised black ash fill, together with BH43 (2.2-2.7 m), which comprised an ashy, grey, waste fill material and TP18 (3.5-3.6 m) which, comprised galligu chemical waste.

All results for **chromium** and **mercury** were low and below their respective available UK CLEA guideline for industrial/commercial use (chromium, 5,000 mg/kg and mercury, 480 mg/kg). However, one sample (WS15, 0.5-0.7 m) recorded a chromium concentration (3,580 mg/kg) in excess of the Dutch I value of 380 mg/kg and a sample obtained from WS9 (2.5-3.0 m) recorded a mercury concentration (16.0 mg/kg) above the Dutch I value of 10 mg/kg.

There are no CLEA guideline values for copper or zinc and therefore, their Dutch I guideline values have been used for comparison. **Copper** concentrations were detected above the Dutch I value (190 mg/kg) in eleven of the samples analysed. The maximum concentration measured was 1,200 mg/kg and was detected in TP20 at a depth of 4.7-5.0 m. This sample has also recorded elevated concentrations of other compounds (most notably very high arsenic). The Dutch I value for **zinc** (720 mg/kg) was exceeded in six of the seventy four samples analysed. The maximum concentration of 2,000 mg/kg was recorded in TP9 at a depth of 3.8-4.0 m, which comprised galligu chemical waste.

Analysis of **water soluble boron** was undertaken on seven soil samples obtained from both the made ground and the underlying natural strata. The concentrations ranged between <0.5 mg/kg (below laboratory detection) and 5.1 mg/kg (BH14, 5.0-5.5 m). The maximum concentration was detected in a sample recovered from the galligu chemical waste within BH14, however, not all samples comprising galligu chemical waste recorded boron concentrations. No CLEA guideline values exist for Boron, however, these values are not considered to be significant in the context of this development.

The boron concentration with BH14, maybe associated with the galligu chemical waste, which is known to contain numerous industrial contaminants. However, it may also be attributable to the former timber yards located to the north and west and the copper works located to the north, as boron is commonly used within these industries.

Sulphide analysis was undertaken on fourteen samples, twelve of which were recovered from the made ground, with the remaining two samples recovered from the natural strata. Of the twelve made ground samples, seven samples comprised galligu chemical waste with the remaining four samples comprising silt, ash or metal slag fill. Sulphide levels ranged between 50 mg/kg, which was detected in a sample obtained from the natural strata (BH8, 2.0-2.45 m) and 6,800 mg/kg, which was detected in a sample obtained from the galligu chemical waste (BH23, 6.5-7.0 m).

In the absence of relevant guideline criteria, the Environment Agency disposal guideline value of 250mg/kg has been used for comparison. The sulphide levels recorded in the samples from the galligu chemical waste are considered to be significantly elevated and are in excess of the EA's disposal value in comparison to the other samples, which were all subsequently below the 250mg/kg disposal value. This would accord with documented material, which states that waste (galligu) arising from the *Le Blanc* process (manufacture of sodium carbonate) was rich in sulphur compounds.

Total Petroleum Hydrocarbon **(TPH)** analysis is a general assay of middle distillate compounds. No CLEA guidelines are available for TPH at present, therefore, the Dutch Intervention value for mineral oils of 5,000 mg/kg (although this varies depending on the natural organic content of the soil) has been used for comparison. A target value commonly applied by the Environment Agency for remediation sensitive areas is 1,000 mg/kg (0.1%).

Seventy four soil samples were screened for Total Petroleum Hydrocarbon (TPH) analysis in the carbon chain range C_{10} – C_{40}. Two samples exceeded the 1,000 mg/kg `target' value with a maximum concentration of 2,500 mg/kg recorded in WS6 at a depth of 0.5-0.7 m, which accords with the field evidence of contamination. Overall, taking into account the field observation and the TPH analytical results in soils, the investigation has not identified significant TPH contamination in soils. There is no evidence of significant contamination from the current fuel/oil storage which takes place on site. In addition, two samples were also submitted for **TPH characterisation**, which provides an indication on the concentrations of aromatic and aliphatic compounds. Neither of the samples recorded aliphatic or aromatic compounds above the Dutch I value of 5,000 mg/kg. The maximum concentration was recorded in WS6 at a depth of 0.5-0.7 m, which detected an aliphatic concentration of 3,647.65 mg/kg. Generally the aliphatic hydrocarbon component of petroleum hydrocarbons is less hazardous that the aromatic fraction.

No CLEA guideline value currently exits for poly-aromatic hydrocarbons (PAH) concentrations in soil. The Dutch total PAH (sum of 10) Intervention value is 40 mg/kg, however, the samples were analysed for the sixteen most common PAH's. Concentrations of **total PAH** ranged from <2 mg/kg (below laboratory detection) to 200 mg/kg, (BH43, 10.5-11.0 m) and of the seventy four samples analysed, only four samples recorded concentrations in excess of the stringent Dutch I value. Three of the four elevated PAH concentrations were recorded in samples obtained from the made ground, however, the maximum concentration (200 mg/kg) was recorded in BH43 at a depth of 10.5-11.0 m, which was obtained from the natural strata and comprised a black silt, which was noted to be odorous.

Seven samples obtained from the made ground and the underlying natural strata were submitted for **speciated PAH** analysis. Speciated PAHs were detected in five of the samples analysed, but none were detected above the PAH (sum of ten) Dutch I value of 40 mg/kg. The maximum concentration detected was 9.7 mg/kg in BH14 at a depth of 5.0-5.5 m and was recovered from the made ground, which comprised galligu chemical waste.

The PAH results are not considered on the whole to represent significant contamination of the site.

Fifteen samples recovered from the made ground were analysed for the presence of Poly-chlorinated bi-phenyls (**PCBs**). A range of seven PCB congeners were tested for, however, none were found to be present above their respective analytical detection limits.

Asbestos screening was undertaken on thirty five samples recovered from the made ground horizon. Asbestos was detected in only one of the shallow soil samples of made ground (<1.0 m bgl) submitted for this analysis. Amosite was reported to be significant within TP5 (0.6-1.0 m), which is located on the unsurfaced area in the southern section of the West Bank Dock site. During the investigation no suspect asbestos containing materials were observed during sampling.

Volatile Organic Compound (**VOC**) analysis targets certain volatile aromatic compounds (specifically petroleum based hydrocarbons) and solvents (notably chlorinated solvents). Thirty four samples were submitted for VOC analysis and were chosen on the basis of field observations (where hydrocarbon odours were recorded) and/or their location adjacent to potential sources of contamination, whilst ensuring a spatial coverage of the made ground profile and natural deposits.

The majority of individual compounds were not detected at concentrations above their respective analytical detection limit. Several samples recorded trace concentrations of benzene, toluene, ethyl-benzene and xylene (BTEX compounds) and trimethylbenzenes, which are light to middle distillates typically associated with fuel. This was in addition to individual chlorinated solvent compounds. The analytical results for the individual determinants are presented in *Table 14.4(d)*.

Table 14.4(d) – Summary of VOC Analytical Results (mg/kg)

Determinand	***No. Analysed***	***No. Samples Recorded***	***Max. Conc. Detected***	***Max. Conc. Detected (Sample Ref)***	***Guideline Values***	
					CLEA (mg/kg)	***Dutch I (mg/kg)***
Dichloromethane	34	3	0.051	BH12 (0.3-1.2 m)	NG	10
1,1 Dichloroethane	34	1	0.033	BH51 (5.0-5.45 m)	NG	15
Trichloroethane	34	1	0.003	WS5 (0.7-1.0 m)	NG	15
Benzene	34	5	2.2	BH34 (2.5-3.0m)	NG	1
Trichloroethene	34	4	0.039	WS5 (0.7-1.0 m)	NG	60
Toluene	34	25	6.8	BH34 (2.5-3.0 m)	150	130
Tetrachloroethene	34	6	0.33	BH51 (5.0-5.45 m)	NG	4
Chlorobenzene	34	3	0.003	BH34 (2.5-3.0 m) TP12 (3.0-3.4 m)	NG	NG
Ethylbenzene	34	13	0.7	BH34 (2.5-3.0 m)	48,000	50
Total Xylenes (m,p&o)	34	22	10.6	BH34 (2.5-3.0 m)	NG	25
1,3,5 Trimethylbenzene	34	8	1.5	BH34 (2.5-3.0 m)	NG	NG
1,2,4 Trimethylbenzene	34	9	2.2	BH34 (2.5-3.0 m)	NG	NG
1,4 Dichlorobenzene	34	1	0.002	TP10 (0.3-0.5 m)	NG	NG

All of the concentrations recorded were well below the respective CLEA and Dutch Intervention guidelines, where available, with the exception of the compound benzene, which was detected at concentrations slightly in excess of the relevant guideline criteria in one soil sample (recovered from the made ground horizon). This is consistent with field observations, with no elevated soil gas readings obtained during the field screening of the soil samples. Contamination by VOCs is not considered to be significant at the site.

Twelve samples recovered from the made ground and the underlying natural strata were submitted for Semi-Volatile Organic Compound (**SVOC**) analysis. The SVOC analysis includes PAHs, phenols, phthalates, ethers and branched benzenes. Of these, PAH's are of most interest in terms of site contamination. As discussed earlier the Dutch Total PAH (sum of 10) Intervention value is 40 mg/kg. No Dutch I values are specified for individual PAH compounds and there are no CLEA guideline values. The results of the individual determinants are presented in *Table 14.4(e)*.

Table 14.4(e) – Summary of SVOC (Speciated PAH) Analytical Results (mg/kg)

Determinand	***BH14, 5.0-5.5 m (mg/kg)***	***WS16, 1.0-1.3 m (mg/kg)***	***TP5, 3.2-3.5 m (mg/kg)***	***Guide Value***
Naphthalene	<0.1	0.13	0.16	ND
2-chloronapthalene	<0.1	<0.1	<0.1	ND
Acenaphthylene	<0.1	0.22	<0.1	ND
Acenaphthene	<0.1	0.26	<0.1	ND
Fluorene	<0.1	0.22	<0.1	ND
Phenanthrene	0.38	3.1	0.47	ND
Anthracene	<0.1	0.69	0.11	ND
Fluoranthene	0.61	6.3	0.56	ND
Pyrene	0.52	5.7	0.52	ND
Benzo (a) anthracene	0.28	2.9	0.33	ND
Chrysene	0.29	3.1	0.37	ND
Benzo (b) fluoranthene	0.24	3.7	0.35	ND
Benzo (k) fluoranthene	<0.1	1.6	<0.1	ND
Benzo (a) pyrene	0.18	3.0	0.23	ND
Indeno (1,2,3-cd) pyrene	<0.1	0.45	<0.1	ND
Dibenzo (a,h) anthracene	<0.1	1.7	<0.1	ND
Benzo (g,h,i) perylene	<0.1	2.0	<0.1	ND
Total PAH (Sum of 10)	2.5	35.07	3.04	40

Three soil samples recovered from the made ground horizon had detectable PAHs present. The samples were obtained from the borehole BH14 (located on the land to the north of the Reclamation site at a depth of 5.0-5.5 m); from the window sample location WS16 (located within the central area of the West Bank Dock site, at a depth of 1.0-1.3 m) and from the trial pit TP5 (located within the southern area of the West Bank Dock site, at a depth of 3.2-3.5 m). The samples comprised galligu, fill with fragments of coal and wood, and ash fill with brick and slag respectively.

Of the three samples, where PAH concentrations were recorded, none returned a respective total PAH concentration above the Dutch I value for PAHs (sum of 10). It should also be noted that the Dutch guideline is based on ten PAH compounds whereas the analytical data is more comprehensive and records seventeen compounds. It was noted, however, that benzo(a) pyrene was present, albeit at relatively low levels.

Trace concentrations of phenols were recorded in three samples notably in BH31 (6.5-7.0 m), BH43 (10.5-11.0 m) and TP5 (3.2-3.5 m) with concentrations ranging between 0.15 mg/kg (TP5) to 2.9 mg/kg (located within BH43). The sample from this borehole also recorded a trace concentration of the compound 4-methylphenol (1.7 mg/kg). A trace concentration of anthraquinone (0.46 mg/kg) was detected in WS16 (1.0-1.3 m). In the UK context of this site, these data are not considered to be of significance for the proposed development.

A range of commonly occurring organochlorine and organophosphorus **pesticide** compounds were analysed in eleven samples. None of the compounds were present above their respective analytical detection limits.

Total Organic Carbon (**TOC**) analysis was undertaken on eleven soil samples recovered from the natural strata that were free of obvious contamination, in order to establish a baseline indication of the total organic matter in the soil. TOC concentrations ranged between <0.1 % (below laboratory detection) and 6.7 % (BH9, 9.0-9.5 m). There is no guideline criteria for TOC, but the results will be of relevance for more detailed quantitative risk assessments that may be required post planning consent.

A timber storage and treatment yard was known to have formerly occupied part of the Foundry Lane site, and thus may have given rise to contamination of the soils by the cumulative effect of drips, leaks, spills and poor waste disposal practices. Two samples obtained from borehole locations excavated within the Foundry Lane site were thus submitted for **timber treatment** chemicals analysis, which includes chemicals (e.g. organochlorines, phenolics, organotin compounds and additives) commonly associated in timber treatment. The two samples analysed were recovered from the made ground horizon within BH12 at a depth of 0.3-1.2 m and from the natural strata within BH9 at a depth of 5.1-5.9 m. None of the individual determinands were identified above their respective analytical detection limits.

Twenty three samples recovered from the made ground and underlying natural strata were submitted for **major ions** analysis. The results of the individual determinands are present in *Table 14.4(f).*

Table 14.4(f) – Summary of Major Ions (in soils) Analytical Results (mg/kg)

Determinand	*No. Analysed*	*Max. Conc. Detected*	*Max. Conc. Detected (Sample Ref.)*	*Guideline Values*
Chloride	23	1,500	BH9 (5.1-5.6 m)	ND
Nitrate	23	76.8	BH51 (17.0 m)	ND
Ammonia	23	91	BH14 (5.0-5.5 m)	ND
Alkalinity as $CaCO_3$ (mg/l)	23	89	TP6 (1.0-1.5 m)	ND
Iron	17	69,000	WS14 (0.7-1.0 m)	ND
Sodium	23	3,100	TP6 (1.0-1.5 m) TP11 (2.4-2.8 m)	ND
Potassium	23	6,800	BH8 (10.2 m)	ND
Calcium	23	239,000	TP2 (3.8-4.0 m)	ND
Magnesium	23	25,000	BH8 (10.2 m)	ND

Major ion analysis was undertaken in order to provide a baseline assessment of chemical conditions as these substances can influence certain analytical results and may be relevant for remediation design. There are no guideline criteria for the individual determinands as such, as with the exception of ammonia and nitrate, these are not typically regarded as pollutants. Generally, the maximum concentrations were detected in samples recovered from the made ground horizon, with the exception of **magnesium** and **potassium**, both of which recorded maximum concentrations within the natural strata comprising Glacial Till (BH8, 10.2 m). The highest measured concentration of **nitrate** was also recorded within the natural strata, but comprising the alluvial drift deposits (BH51, 17.0 m) together with the maximum concentration of **chloride**, which was detected in BH9 at a depth of 5.1-5.6 m. The maximum concentrations of **ammonia**, **alkalinity as $CaCO_3$**, **sodium** and **calcium** were all detected in samples within the galligu chemical waste, which were obtained from excavated locations situated in the area to the north of the Reclamation site and the area to the south of the West Bank Dock site. The highest concentration of **iron** was detected in a sample obtained from WS16, located within the central area of the West Bank Dock site, which comprised fill material containing silt, brick and coal.

The elevated soil determinands are presented in *Figure 14.6*. This figure also provides an indication of the spatial extent of galligu within the investigated areas (noting that the whole of the reclamation mound itself is based on galligu deposits).

Leachability Analysis

Leaching tests were undertaken on twelve samples recovered from the made ground from various locations across the site. The samples were analysed for leachable metals, total sulphate, monohydric phenol, total cyanide, speciated PAH and leachable TPH. This analysis is used to assess the potential for leaching of contaminants from soil into groundwater and watercourses.

The leaching tests were undertaken in accordance with the test method detailed in the National Rivers Authority (NRA) Interim Guidance Note issued in 1994, entitled Leaching Tests for the Assessment of Contaminated Land. These tests involve passing a sample of laboratory prepared water through the soil samples under control conditions and analysing the leachate. The results of the leachate testing are summarised in *Table 14.4(g)* and discussed below.

Table 14.4(g) – Soil Leachability Analytical Results (µg/l)

Determinand	*No. Analysed*	*No. Results Exceeding or Equal to Dutch I Guideline*	*No. Results Exceeding or Equal to UK DWQ Guideline*	*Max. Conc. Detected*	*Max. Conc. Detected (Sample Ref.)*	*Guideline Values*	
						Dutch I (µg/l)	*UK DWQ (µg/l)*
pH	12	-	4	Min – 7.4 Max – 12.4	WS14 (3.5-4.0 m) TP2 (3.8-4.0 m) BH14 (2.5-3.0 m) WS5 (2.5-3.0 m)	NG	5.5-9.5
Sulphate (SO_4) mg/l	12	-	12	6,300	BH23 (6.5-7.0 m)	NG	250
Monohydric Phenol	12	0	-	60	BH14 (2.5-3.0 m)	2,000	NG
Total Cyanide	12	0	0	ND	n/a	1,500	50
PAH Total	12	-	3	0.11	TP21 (1.5-2.2 m)	NG	0.1

Determinand	No. Analysed	No. Results Exceeding or Equal to Dutch I Guideline	No. Results Exceeding or Equal to UK DWQ Guideline	Max. Conc. Detected	Max. Conc. Detected (Sample Ref.)	Guideline Values	
						Dutch I (µg/l)	UK DWQ (µg/l)
TPH	12	1	4	1,250	BH12 0.3-1.2 m)	600	10
Arsenic	12	1	12	70	TP15 (0.8-1.0 m)	60	10
Cadmium	12	0	0	ND	n/a	6	5
Chromium	12	0	0	20	WS14 (3.5-4.0 m)	30	50
Lead	12	0	0	12	BH14 (2.5-3.0 m) WS5 (2.5-3.0 m)	75	25
Mercury	12	0	0	ND	n/a	0.3	1
Selenium	12	0	0	ND	n/a	160	10
Copper	12	0	0	11	TP15 (0.8-1.0 m)	75	2,000
Nickel	12	0	0	13	BH23 (6.5-7.0 m)	75	50
Zinc	12	0	0	43	TP2 (3.8-4.0 m)	800	5,000

The samples analysed for **leachable metals** displayed results that were generally below the analytical limits of detection or below the relevant guideline values, with the exception of arsenic. This exceeded the UK DWQ standard (10 µg/l) in four samples and exceeded the Dutch I value (60 µg/l) in one of the samples analysed. The maximum recorded concentration was 70 µg/l (TP15, 0.5-0.8 m), which although not likely to be considered a significant risk to groundwater and surface water resources is indicative of leaching of metals from galligu into water.

None of the samples recorded **total cyanide** concentrations above the analytical limit of detection and concentrations of **monohydric phenol** were all detected below the relevant guideline criteria (where available). **Sulphate** levels exceeded the UK DWQ guideline (250 µg/l) in all of the twelve samples analysed. The concentrations ranged between 6 mg/l ((BH9, 1.5-2.0 m) to 6,300 mg/l (BH23, 6.5-7.0 m). It should be noted however, that the UK DWQ standards provide a conservative assessment guideline and is generally applied in situations where the groundwater is abstracted for potable water supply, which is not appropriate to the site. What these samples do indicate is the likely high levels of sulphate (and possibly sulphide) contamination that can be imparted from the galligu to waters.

The twelve samples selected for leaching analysis were also submitted for TPH leachability. The results for TPH leachability indicate that three samples exceeded the UK DWQ standards of 10 µg/l, however, only one sample (BH12, 0.3-1.2 m) recorded a concentration (1,250 µg/l) in excess of the Dutch I value of 600 µg/l and was identified by the laboratory as ranging between the C10 – C40 range.

In respect of **PAH** leachability, of the twelve samples analysed, nine samples recorded PAH concentrations below detection limits and three samples recorded concentrations equal to or in excess of the UK DWQ (0.1 µg/l). However, none of the individual compounds were detected above relevant Dutch I guidelines (where available).

The leachate results show that under laboratory conditions the majority of the determinands within the made ground are not in a readily soluble form and are below relevant guideline values. However, where elevated concentrations above guideline values have been detected, these imply that the soils on site (and particularly the galligu) do represent a risk to groundwater and surface water quality.

<u>Analysis of Mounds</u>

The soil chemical analysis undertaken on the spoil mound material comprised a general suite of analytes including pH, monohydric phenol, total cyanide, water soluble sulphate and a range of metals (arsenic, cadmium, chromium, lead, mercury, selenium, copper, nickel, zinc) together with PCB, pesticide, major ions and asbestos analysis.

<u>Excavated Spoil Mound – West Bank Dock Site</u>

Analysis was undertaken on four bulk composite samples obtained from the spoil mound situated on the southern area of the West Bank Dock site separating it from the Granox (PDM) facility. The spoil mound generally comprised soil, clay, rubble and significant amounts of galligu chemical waste.

The majority of the analytical tests returned results that were below detectable concentrations and relevant guideline criteria, where available. Neutral **pH** values in the range of 7.6-8.2 were recorded and **water soluble sulphate** concentrations ranged from 0.3 g/l to 1.5 g/l in the three samples analysed for a general suite of analytes.

Trace concentrations of **metals** were detected in all three of the samples analysed, although at levels significantly below the respective CLEA guideline value, where available. However, one sample recorded an arsenic concentration of 89 mg/kg and another sample recorded a zinc concentration of 900 mg/kg, which both exceed their respective Dutch I guideline values. These were associated with galligu contaminated soils.

Concentrations of **total cyanide** were detected in two of the samples and **TPH** concentrations were recorded in three samples analysed, however, the measured concentrations are considered trace and are well below the relevant guideline values.

No detectable concentrations of **phenol** or **PAHs** were measured in any of the samples submitted for this analysis and none of the samples recorded the presence of asbestos.

PCB analysis was undertaken on one bulk sample, which recorded PCB concentrations above the analytical detection limits in two individual PCB congeners. The total PCB concentration for the sample analysed was recorded as 0.015 mg/kg, however, this concentration is considered trace. There is no CLEA soil guideline value for this parameter, however, the concentration is below the Dutch Intervention value of 1 mg/kg.

Two samples were analysed for a range of organochlorine and organophosphorus **pesticide** compounds, although, none were detected above the laboratory detection limits.

Excavated Spoil Mound – Foundry Lane Site

Analysis was undertaken on five bulk composite samples of soil obtained from the mound on the Foundry Lane site. The spoil mound generally comprised soil, clay with some brick rubble, no galligu chemical waste or other potentially contaminated materials were identified within the mound.

The majority of the analytical test results were below detectable concentrations and relevant guideline criteria, where available. Neutral **pH** values of 8.1 and **water soluble sulphate** concentrations of 1.7 g/l were detected in the two samples analysed for a general suite of analytes.

Trace concentrations of **metals** were detected in the samples analysed with the exception of cadmium, which was not present above the analytical detection limit (<0.5 mg/kg). All concentrations detected were significantly below the respective CLEA guideline values or the Dutch Intervention guideline value.

No detectable concentrations of **phenol, cyanide, pesticides** or **PAHs** were measured in any of the samples submitted for this analysis and none of the samples recorded the presence of asbestos.

PCB analysis was undertaken on one bulk sample, which recorded PCB concentrations above the analytical detection limits in six of the individual PCB congeners. The total PCB concentration for the sample analysed was detected at 0.07 mg/kg, which is considered trace and is well below the Dutch I value of 1 mg/kg.

14.4.5 Groundwater Analytical Results

Analysis was undertaken on fifteen samples of groundwater, eleven of which were obtained from the installed boreholes (BH8, BH9, BH11, BH12, BH14, BH15, BH23, BH31, BH34, BH43 and BH55), two of which were obtained from the installed window samples (WS4 and WS6), with the remaining two obtained from the excavated trial pits (TP16 and TP23). The groundwater chemical analysis results are summarised in *Table 14.4(h)* and discussed below.

Table 14.4(h) – Summarised Groundwater Analytical Results

Determinand	*No. Analysed*	*No. Results Exceeding or Equal to Dutch I Guideline*	*No. Results Exceeding or Equal to UK DWQ Guideline*	*Max. Conc. Detected*	*Max. Conc. Detected (Sample Ref.)*	*Guideline Values*	
						Dutch I (µg/l)	*UK DWQ* (µg/l)
pH	15	-	6	Min - 7.4 Max – 13.0	BH8 BH15 WS6 BH43 WS4	NG	5.5-9.5
Metals							
Arsenic	15	7	15	2,700	WS6	60	10
Cadmium	15	2	2	34	WS6	6	5
Chromium (total)	15	0	0	ND	n/a	30	50
Lead	15	1	1	200	WS4	75	50
Mercury	15	1	0	0.91	BH43	0.3	1
Selenium	15	0	2	100	BH43	160	10
Copper	15	0	0	5	BH15	75	2,000 mg/l
Nickel	15	0	0	12	BH14	75	20

Determinand	No. Analysed	No. Results Exceeding or Equal to Dutch I Guideline	No. Results Exceeding or Equal to UK DWQ Guideline	Max. Conc. Detected	Max. Conc. Detected (Sample Ref.)	Guideline Values	
						Dutch I (µg/l)	UK DWQ (µg/l)
Zinc	15	0	0	89	WS4	800	5,000
Organic Analysis							
Monohydric Phenol	15	0	-	140	BH31	2,000	NG
TPH (C_{10} – C_{40})	15	4	5	6,900	WS6	600	10
PCBs	6	-	0	ND	n/a	NG	0.01
PAH (Speciated)	*Discussed Separately*						
VOC's							
1,1 Dichloro-ethane	13	0	-	1	BH34	900	ND
Benzene	13	0	1	2	BH34	30	1
Toluene	13	0	-	2	BH34 BH43	1,000	ND
o-Xylene	13	0	-	1	WS6	70	ND
1,3,5 Trimethyl-benzene	13	-	-	3	WS6	ND	ND
1,2,4 Trimethyl-benzene	13	-	-	3	WS6	ND	ND
SVOC's							
PAH (sum of 10)	6	0	0	ND	n/a	Various	Various
Other Analysis							
Total Cyanide	15	0	1	150	TP23	1,500	50
Sulphate (SO_4) mg/l	15	-	15	6,380	TP23	NG	250
Sulphide	15	-	-	200,000	TP23	NG	NG
Pesticides (OCP/OPP)	5	0	0	ND	n/a	Various	0.50
TOC	15	-	-	34,000	BH8	NG	NG
Major Ions Suite	*Discussed Separately*						

All results expressed in µg/l except for pH, sulphate (mg/l) and copper DWQ (mg/l).

DWQ = Drinking Water Quality Guideline – Water Supply (Water Quality) Regulations 2000

TPH = Total Petroleum Hydrocarbons
PAH = Polycyclic Aromatic Hydrocarbons
PCB = Polychlorinated Biphenyls
VOC = Volatile Organic Compound
SVOC = Semi Volatile Organic Compound
OCP = Organochlorine Pesticides
OPP = Organophosphorus Pesticides
TOC = Total Organic Carbon

NG = No Guideline
ND = Not Detected Above Analytical Detection Limit
n/a = Not Applicable
\- = Not Relevant

The **pH** values were found to be neutral to alkaline (in the range pH 7.4-13.0). Six samples recorded alkaline pH's greater than 9.5, with the maximum pH value detected in the samples from BH43 and WS4, both of which, comprise water contained within the made ground horizon. These high pH values are reflective of the strongly alkaline nature of galligu and typical for groundwaters in contact with Le Blanc waste.

Sulphate concentrations ranged from 68 mg/l (BH11) to 6,380 mg/l (TP23), with eleven of the fifteen samples recording sulphate concentrations in excess of the of the UK Drinking Water Quality (DWQ) Guideline of 250 mg/l. The maximum concentration of 6,380 mg/l was detected within the perched water of TP23 (i.e. in galligu), with the other significantly elevated concentrations of sulphate detected in samples, generally also being from water s contained within the galligu contaminated Made Ground.

It is important to note that both the Dutch and Drinking Water standards are conservative and generally applied in situations where the groundwater is abstracted for potable water supply, which is not appropriate to the site.

Total cyanide concentrations were recorded below the analytical detection limit (<30µg/l) in thirteen of the fifteen samples analysed. The two concentrations detected above the analytical detection limit were recorded in BH14 at 32 µg/l and TP23 at 150 µg/l. Both concentrations were recorded below the Dutch Intervention guideline value of 1,500 µg/l, however, TP23 detected a concentration in excess of the UK DWQ standard of 50 µg/l.

Concentrations of **monohydric phenol** ranged between <20 µg/l (below the analytical detection limit) and 140 µg/l (BH31), however, the maximum concentration recorded in BH31 was significantly below the Dutch I guideline value of 2,000 µg/l. There is no Drinking Water standard for this parameter.

The majority of samples returned **metal** concentrations below the analytical limits of detection and subsequently below relevant guideline criteria. In particular, concentrations of **chromium (total)** were detected below the analytical detection limit in all of the fifteen samples analysed and therefore below all relevant guideline values. Low concentrations of **copper** (BH15), **nickel** (BH13 and BH23) and **zinc** (BH14, WS4 and WS6) were recorded in several locations, however, all concentrations were subsequently below the relevant guideline values.

Elevated concentrations of **arsenic** were detected in all of the fifteen groundwater samples analysed, all of which exceeded the UK DWQ standard (10 µg/l) and six of which, recorded concentrations in excess of the Dutch I guideline value (60 µg/l). The most significantly elevated level of arsenic was recorded in WS6 at a maximum concentration of 2,700 µg/l, however, other significantly elevated concentrations were recorded in the locations of BH23 (830 µg/l) and BH34 (140 µg/l). The water samples from WS6 and BH34 were recovered within the made ground, however, the sample from BH23 comprised water from the sands and gravels strata at the drift/solid geology transition zone. Arsenic is a notable contaminant associated with galligu.

Lead concentrations were detected in two of the locations (WS4 and WS6), one of which (WS4 at 200 µg/l), exceeded the Dutch I value of 75 µg/l and the Drinking Water standard of 50 µg/l. **Cadmium** concentrations were also detected above the analytical detection limit and above the relevant guideline values in two of the fifteen samples analysed, with the maximum concentration of 34 µg/l recorded in WS6. **Mercury** was detected in BH43 at a concentration of 0.91 µg/l. This concentration exceeds the Dutch I value of 0.3 µg/l, but is below the UK DWQ guideline (1 µg/l). The sample obtained from BH43 also contained **selenium** at a concentration of 100 µg/l. This concentration, together with the selenium concentration within TP23 (21 µg/l) exceed the UK DWQ standard (10 µg/l) but are both below the Dutch I guideline value (160 µg/l).

Eleven of the fifteen samples submitted for **sulphide** analysis returned concentrations below the analytical limit of detection. Of the four samples, where sulphide concentrations were recorded, levels ranged between 400 µg/l (TP16) and 200,000 µg/l (TP23). All of the detected concentrations were recorded in locations installed with the made ground horizon (comprising the galligu chemical waste) and from an excavated trial pit terminated in the galligu chemical waste. Although there are no relevant guideline criteria, the sulphate levels recorded in BH14 (140,000 µg/l) and TP23 (200,000 µg/l) are considered to be significantly elevated.

A hydrocarbon broad scan (C_{10} – C_{40}) was conducted on all fifteen groundwater samples. The maximum concentration of **TPH** was recorded in WS6 at 6,900 µg/l, which is significantly above the guideline value (the Dutch I value for mineral oil (600 µg/l)). The sample was interpreted by the laboratory as being consistent with diesel and lubricating oil, which accords with the on-site field evidence of contamination at that location. TPH was also detected at concentrations above the relevant guideline criteria in BH12 (1,100 µg/l), which was interpreted as being consistent with gas oil and lubrication oil, BH43 (1,100 µg/l), which was interpreted as being consistent with lubrication oil and TP16 (900 µg/l), which was described as ranging between the C_{10} – C_{40} range. Three (WS6, BH43 and TP16) of the four detected concentrations were recorded in locations installed with the made ground horizon, however, the sample recovered from BH12 comprised groundwater from the silty/sandy clay deposits within the Glacial Till horizon.

However TPH contamination is not considered to be widespread as elevated concentrations of TPH have not been found in the soil or groundwater at nearby locations. This is therefore, likely to be more indicative of localised hotspots associated with oil based activities in this area rather than widespread contamination of the site by hydrocarbons.

Seven groundwater samples recovered from five boreholes (BH8, BH14, BH23, BH34 and BH55) and two excavated trial pits (TP16 and TP23) were submitted for the analysis of **speciated PAHs**. Two of the samples (BH8 and BH55) recorded concentrations below the analytical limits of detection, however, trace concentrations of individual PAH compounds were detected in the remaining locations with a number of the individual compounds detected above relevant Dutch I guidelines (where available). *Table 14.4(i)* below summarises the detected PAH concentrations.

Table 14.4(i) - Summary of PAH (in Groundwater) Analytical Results (µg/l)

Determinand	*No. Analysed*	*No. Equal to or exceeding Guideline*	*Max. Conc. Detected (Sample Ref.)*	*Guideline Values*
				Dutch I (µg/l)
Naphthalene	7	0	24 (BH34)	70
Acenaphthylene	7	-	1.0 (BH34)	NG
Acenaphthene	7	-	1.1 (BH34)	NG
Fluorene	7	-	1.2 (BH34)	NG
Phenanthrene	7	0	3.2 (BH34)	5
Anthracene	7	0	0.68 (BH34)	5
Fluoranthene	7	1	1.3 (TP16)	1
Pyrene	7	-	1.3 (TP16)	NG
Benzo (a) anthracene	7	1	0.65 (TP16)	0.5
Chrysene	7	1	0.81 (TP16)	0.2
Benzo (b) fluoranthene	7	-	0.75 (TP16)	ND
Benzo (k) fluoranthene	7	1	0.78 (TP16)	0.05
Benzo (a) pyrene	7	2	0.88 (TP16)	0.05
Indeno (1,2,3-cd) pyrene	7	2	0.56 (TP16)	0.05
Dibenzo (a,h) anthracene	7	-	0.11 (BH23)	NG
Benzo (g,h,i) perylene	7	2	0.70 (TP16)	0.05
Total PAH (total 16)	-	-	33.05 (BH34)	ND

It should be noted that the Dutch Intervention Value for several of the individual compounds (benzo (k) fluoranthene, benzo (a) pyrene, indeno (1,2,3-cd) pyrene and benzo (g,h,i) perylene) is 0.05 µg/l, which is below the analytical detection limits for each of the PAH compounds, therefore, concentrations above the screening value cannot be ruled out.

PCBs were not detected in any of the six samples submitted for analysis. However, it should be noted that the Dutch Intervention Value (0.01 µg/l) is below the analytical detection limits for each of the PCP congeners. While concentrations above the screening value cannot be ruled out, there is no evidence of significant PCB contamination, and none would be considered likely given the current and past uses. Furthermore, PCB contamination has not been identified within the soils.

VOCs were detected in three (BH34, BH43 and WS6) of the thirteen samples analysed. The majority of measured concentrations are considered trace and are well below relevant guideline values (where available). However, in BH34 benzene was recorded at a concentration (2 µg/l) slightly in excess of the UK DWQ standard but significantly below the Dutch I value.

No **SVOCs** were detected above laboratory detection limits in any of the six samples analysed.

Five samples were analysed for a range of organochlorine and organophosphorus **pesticides**. None were detected above the analytical detection limit.

Total organic carbon was analysed in order to provide a generic baseline assessment of the organic content in the groundwater across the site. The concentrations ranged between 3,500 µg/l (BH23) and 34,000 µg/l (BH8). No guideline criteria are available for this parameter.

Eleven groundwater samples recovered from each of the boreholes were submitted for the analysis of **major ions**. The results of the individual determinands are presented in *Table 14.4(j).*

Table 14.4(j) – Summary of Major Ions (in Groundwater) Analytical Results (µg/l)

Determinand	*No. Analysed*	*No. Equal to or exceeding Guideline*	*Max. Conc. Detected (Sample Ref.)*	*Guideline Values*
				UK DWQ (µg/l)
Chloride	11	11	2500,000 (BH55)	250
Nitrate	11	-	1,300 (BH43)	ND
Ammonia	11	11	9,900 (BH8)	500
Alkalinity as $CaCO_3$ (mg/l)	11	-	1,600 (BH43)	ND
Iron	11	0	87 (BH8)	200,000
Sodium	11	11	1100,000 (BH55)	200
Potassium	11	-	40,000 (BH34)	ND
Calcium	11	-	960,000 (BH43)	ND
Magnesium	11	5	100,000 (BH55)	50,000

Individual ions were generally detected at significantly elevated concentrations. All of the eleven samples analysed for **chloride** recorded concentrations that significantly exceeded the UK DWQ standard for this parameter, with concentrations ranging from 130,000 µg/l (BH31) to 2,500,000 µg/l (BH55). **Ammonia** concentrations were all recorded at concentrations in excess of the guideline value of 500 µg/l, with concentrations ranging from 860 µg/l (BH11) to 9,900 µg/l (BH8). All of the samples recorded **sodium** concentrations in excess of the guideline value (200 µg/l) and five samples recorded concentrations of **magnesium** above the 50,000 µg/l guideline value as set by the UK DWQ standard.

There are no set guideline criteria for **nitrate**, **alkalinity**, **potassium** or **calcium**, however concentrations of each of the compounds were detected within each of the groundwater samples, with the exception of nitrate, which was only detected above the laboratory analytical detection limit in one sample recovered from the perched water within BH43.

The elevated determinands within the groundwater are presented graphically in *Figure 14.7*

14.4.6 Summary of Chemical Analysis

Chemical testing of the soil and groundwater has revealed that the site is contaminated to varying degrees and that this is impacting upon groundwater. The investigation findings are summarised below for the key species of concern. It should be noted that the above provides an indication of the presence and general magnitude of contamination at the site and has shown that there are areas where further work may be required. Following the last application (and assessment), The Chartered Institute of Environmental Health (CIEH) (whose members include the Local Authority Environmental Officers involved with contaminated land matters) in partnership with Land Quality Management Limited have produced a set of Generic Assessment Criteria (GAC) for 31 contaminants (derived using the CLEA UK model). It is anticipated that these 'look up tables' will be utilised in conjunction with other assessment tools by the Local Authorities as an initial screening criteria in order to assess contaminated land and will be applied together with more robust assessment criteria for the site for deriving remedial targets.

Metals

Metal contamination of the shallow made ground soil was recorded in several locations across the site. Lead was recorded at levels significantly above the CLEA soil guideline value (SGV) of 750 mg/kg in five locations, four of which were located on the West Bank Dock site (WS12, BH31, BH43 and BH51) and one located on the southern section of the reclamation mound (TP18). The locations of BH31 and BH51 also detected elevated arsenic levels together with the locations of WS7 (West Bank Dock site) and TP20 (south of reclamation site) above the CLEA SGV of 500 mg/kg. However, three of the four samples only recorded moderately elevated arsenic concentrations, but the sample obtained from TP20 recorded a significantly elevated level of 21,000 mg/kg. These elevated levels of lead and arsenic were generally recorded in samples recovered from the galligu chemical waste or ash fill material.

Lead and arsenic are general contaminants associated with a number of industrial activities, one of which being chemical manufacturing. Elevated levels of these metals are generally associated with the presence of ash, which is widespread in industrial areas. Furthermore, the galligu chemical waste is also known to contain numerous industrial contaminants, including heavy metals. Lead has also been used as part of the glazing process within the pottery industry, which has also been a former industrial site usage.

In the absence of CLEA soil guideline values, copper and zinc were compared to the Dutch Intervention values, which resulted in copper being detected above its respective guideline value in eleven samples and zinc in six samples. However, the Dutch guidelines do impose stringent values and given the industrial context of the site, the majority of the copper and zinc levels are not considered to be significant. However, the copper concentrations of 1,200 mg/kg and 1,000 mg/kg detected in TP20 and BH43, respectively, are considered to be elevated, together with the zinc concentration recorded in TP9 (2,000mg/kg). Ash can typically contain elevated levels of copper and zinc together with the galligu chemical waste, however, wastes containing copper could also be associated with pyrites residues from the *Le Blanc* process. Copper and zinc are generally not harmful to human health in an environmental context, unless they are at very high concentrations, although, they are phytotoxic and may have an adverse effect on plant growth.

Generally, these metals are considered to be relatively immobile, especially as soil conditions are neutral to alkaline. Furthermore, leachability testing concludes that the metals within the made ground are not in a readily soluble and thus leachable form.

Metals were detected within the groundwater, the majority of which being low, however, slightly elevated concentrations of arsenic (BH14, BH34, BH9, BH31), cadmium (WS6, BH23), lead (WS4) and mercury (BH43) were recorded. Generally, the elevated metal levels were recorded within the perched groundwater, with the exception of a cadmium concentration detected in BH23 and two arsenic concentrations detected in BH9 and BH31, which were detected within the natural, deeper groundwater.

Total Petroleum Hydrocarbons

Shallow soil samples obtained from WS6 and TP10 recorded elevated hydrocarbons (TPH) above the 1,000 mg/kg target value commonly applied by the Environment Agency. WS6 was located on the West Bank Dock site, adjacent to the vertical storage tanks, within the tank farm area. The tanks were poorly bunded and surface staining was noted around the base of the bund (which comprised breeze block) and on the concrete hardstanding, which was noted to be cracked in places and to generally be in a poor state of repair. The drainage system did not appear to be functioning properly i.e. oily water present on the surface. Field evidence of hydrocarbon contamination was noted in both the soil profile, in the form of a hydrocarbon odour and the perched water, which was discoloured and comprised a significant oily sheen. This location also recorded significantly elevated hydrocarbons in the perched water, which were identified by the laboratory as being consistent with diesel and lubricating oil.

TP10 was situated on the area of land located to the north of the Reclamation site. This area is currently unsurfaced and has numerous vehicle movements. Storage of the demountable tanks/containers, which can contain chemicals in liquid, gaseous or powered form are currently stored on this unsurfaced area. No visual or olfactory evidence of contamination was noted during the excavation of this trial pit location.

TPH was also detected at elevated levels within the groundwater of BH12, BH43 and TP16. TP16 was located on the southern area of the reclamation mound and during the excavation, the soil arising was noted to contain a clay layer comprising black streaking (noted between the depths of 0.4-1.3 m) over galligu chemical waste. No hydrocarbon odours were noted within the soil arising and no hydrocarbon sheens were noted on the perched water sample.

BH43 was located within the former transport yard, which was once also occupied by Amazon Gas. No field evidence, generally associated with TPH contamination, was noted within the soil arising and only trace chemical concentrations were recorded within the soils, however, a slight oily sheen was noted during the purging and sampling of the perched water.

BH12 was located on the Foundry Lane site and during the excavation of this borehole no visual or olfactory evidence of contamination was noted within the soil profile, nor was any evidence of contamination noted during the purging and sampling of the groundwater. The groundwater within BH12 is representative of the lower water body, as the borehole was installed in order to capture the groundwater encountered in the drift/solid geology transition zone. Therefore, as TPH contamination has been detected in this water body, there is a possibility that the underlying Triassic Sandstone Aquifer may have been impacted. This could not be ascertained as drilling into the sandstone bedrock in order to determine the presence/absence and the relative magnitude of soil/groundwater contamination was not deemed necessary at this initial stage of the investigation. Drilling into the sandstone bedrock can generate a conduit, by which contamination from the shallower soils/groundwater impacts the underlying major aquifer, hence this was avoided in preference to obtaining shallower data.

TPH contamination is not considered to be widespread. Elevated TPH concentrations in the soil/groundwater have not been identified at nearby locations the investigation results are indicative of localised hotspots rather than widespread contamination of the site by hydrocarbons.

Polyaromatic Hydrocarbons (PAHs)

Generally, PAHs were not detected at elevated levels within the soils, although four samples analysed, did record elevated levels of total PAH in excess of the Dutch I value (sum of 10) (40 mg/kg), which has been used for comparison in the absence of CLEA SGV. Total PAH includes the analysis of the sixteen most common PAH's rather than the ten compounds as referenced in the Dutch I guideline. Therefore, PAH levels are not considered to represent significant contamination in the context of this site.

Generally, PAH contamination within the groundwater is not considered significant, as the majority of the recovered groundwater samples detected individual PAHs below their respective analytical detection limits. However, the perched water recovered from TP16 (located in the southern section of the mound) and BH34 (situated adjacent to an above ground, diesel, storage tank, located on the West Bank Dock site) together with the natural groundwater within the Fluvio-glacial Sands and Gravels horizon recovered from BH23 (area to the north of the reclamation site) did record elevated concentrations of some of the individual PAH compounds.

Seven of the individual compounds, namely fluoranthene, benzo (a) anthracene, chrysene, benzo (k) fluoranthene, benzo (a) pyrene, indeno (1,2,3-cd) pyrene and benzo (g,h,i) perylene were detected at elevated levels within the perched water in TP16. However, only one compound, benzo (a) pyrene, was detected at an elevated concentration within BH34 and two compounds, indeno (1,2,3-cd) pyrene and benzo (g,h,i) perylene within BH23.

Ash can be a source of PAH's, and was encountered within the made ground horizon. This an be attributed to the coal/coke residues from historical chemical activities at the site and in the immediate surrounding area or PAH contamination may also have resulted from the former timber treatment yards located on site and in the immediate surrounding area.

The elevated PAHs in the groundwater appear to be indicative of localised hotspots rather than site wide contamination, however, in the context of the site's environmental setting these levels are not considered to be significant.

Asbestos

Asbestos presence within the ground was only identified to one exploratory location, TP5 located on the unsurfaced area in the southern section of the West Bank Dock site. Here amosite (brown asbestos) was detected as 'significant' in a sample recovered from the made ground horizon at a depth of 0.6-1.0 m. This is indicative of an isolated hotspot as no other exploratory locations recorded the presence of asbestos. However, given the historic landfilling, which is known to have been undertaken on the site, the presence of other asbestos containing materials present on the site cannot be ruled out.

The presence of isolated fragments of asbestos within the made ground does not represent a significant risk to site occupiers under the current or future site usage, however, it does represent a potential risk through inhalation during any excavation works, if such material is disturbed in significant quantities. It is not expected that this will be the case, but appropriate PPE and site health and safety procedures, as well as vigilance by experienced field scientists during the excavation works will ensure this potential issue is well managed.

Sulphide

Soil samples obtained from the galligu chemical waste recorded significantly elevated sulphide concentrations above the 250 mg/kg Environment Agency disposal guideline value, which has been used for comparison in the absence of set guideline criteria. Sulphide levels within the galligu chemical waste ranged between 790 mg/kg and 6,800 mg/kg, compared with the concentrations recovered from other compositions of made ground (silt, ash and slag) and the underlying natural strata, which ranged between 50 mg/kg and 150 mg/kg, all of which below the Environment Agency's waste disposal guidance. One sample, which recorded a significantly elevated concentration, was however, recovered from the natural alluvial deposits, but was noted to be odorous.

Of the eight samples, which recorded elevated sulphide, three were detected in the trial pit locations of TP15, TP16 and TP23 (located on the southern section of the reclamation mound), two of which (TP15 and TP23), were noted as having hydrogen sulphide odours. The remaining samples were obtained from the locations of BH14 and BH23, situated on the unsurfaced area to the north of the reclamation mound and BH31, BH55 and BH43, which were all located within the central and southern areas of the West Bank Dock site. The sample recovered from BH43 comprised odorous, alluvial deposits, which was overlain by galligu chemical waste.

Galligu waste arising from the *Le Blanc* process is known to be rich in sulphur compounds. These levels are significant and considered to represent widespread contamination of the site, where galligu chemical waste has been deposited.

Sulphide analysis was undertaken on all of the groundwater samples, eleven of which did not detect levels of sulphide. However, concentrations of sulphide were recorded in the remaining four samples, two of which, comprised perched water within BH14 and BH43, with the other two samples comprising perched water from the excavated trail pit locations of TP16 and TP23.

Although sulphide contamination was noted within the shallow soils, comprising galligu, the groundwater des not appear to have been significantly impacted. Sulphide was detected in the groundwater at significant concentrations only in locations of BH43 (7,300 µg/l), BH14 (140,000 µg/l) and TP23 (200,000). These locations were in Made Ground.

Sulphate

Significantly elevated sulphate levels were recorded on-site within both the soils, with concentrations ranging from 0.02g/l to 2.2 g/l and groundwater, with concentrations ranging from 68 mg/l to 6,380 mg/l. There are currently no set criteria for this contaminant within soils, however, all fifteen groundwater samples analysed, recorded sulphate in excess of the UK DWQ guideline value (250 µg/l), with the highest levels generally recorded within the perched water. The galligu is the most obvious source of these elevated sulphate levels.

Whilst elevated sulphate levels are of limited significance in environmental terms, in the UK, sulphates in soil and groundwater are the most common chemical agents likely to cause concrete deterioration. In accordance with BRE Special Digest 1:2000, the classification system for sulphate concentrations in soil are based on the Design Sulphate Class. Generally, water soluble sulphate concentrations within the made ground ranged between 1.2 and 2.3 g/l (with the exception of BH8, BH9 and BH11 which were less than 1.2 g/l) and therefore would tentatively be given a DS-2 classification, however the water soluble sulphate concentrations within the deeper natural soils were generally below 1.2 g/l, which would subsequently result in a DS-1 classification. However, this would need to be assessed by a structural engineer during the construction phase.

VOCs

VOC's were not detected at elevated levels within the soils or groundwater. Individual compounds were detected within both the soils and groundwater but are considered trace. One soil sample recovered from the made ground (2.5-3.0 m) of BH34 recorded a benzene concentration of 2.2 mg/kg, which slightly exceeds the Dutch I value and although benzene was detected within the groundwater sample recovered from the made ground horizon, the concentration is considered trace and an isolated hotspot.

Major Ions

The analysis of major ions was undertaken on a variety of soils together with the groundwater within the boreholes, which represented the various water bodies. There are no set guideline criteria for major ions in soils, however, the maximum concentrations were generally detected within samples recovered from the made ground horizon. Significant levels of the individual ions were detected within the groundwater beneath the site and were generally found within the shallow perched water, where the maximum concentrations of nitrate, potassium, calcium and alkalinity were recorded. The maximum concentrations of chloride, ammonia, sodium and magnesium were detected in the natural groundwater within the alluvial and glacial clay deposits. Given the significant levels of the individual ions, it could indicate that these chemicals are leaching out of the soils and into the groundwater, but these may also be a result of saline intrusions.

14.5 ASSESSMENT OF IMPACTS AND PROPOSED MITIGATION

Clearly there is a substantial contamination source on the site that, even without the proposed development, appears to be impacting upon groundwater quality to varying degrees and in turn may also be contributing to poor surface water quality.

A new regime for contaminated land was set out in Part IIA of the Environmental Protection Act 1990, as inserted by S.57 of The Environment Act 1995 which came into effect in England on 1st April 2000 as The Contaminated Land (England) Regulations 2000 (SI 2000/227). These regulations were subsequently revoked with the provision of The Contaminated Land (England) Regulations 2006 (SI 2006/1380), which consolidated the previous regulations and amendments and added in provisions regarding radioactive contaminated land. These regulations came into force on 4th August 2006. This modified the wording for "Contaminated Land" under Part IIA of the EPA. Section 78A(2) defines contaminated land as "land which appears... to be in such a condition, by reason of substances in, on or under the land, that -

- *significant harm is being caused or there is a significant possibility of such harm being caused*; or
- *pollution of controlled waters is being, or is likely to be caused*.

The above definition is amended with respect to radioactive contaminated land. "*Significant harm*" is defined in the Guidance on risk based criteria and must be the result of a significant "*pollutant linkage*". The presence of a pollutant linkage relies on the Source-Pathway-Receptor concept, where all three factors must be present and potentially or actually linked for a potential risk to exist. An initial assessment of pollutant linkage can be made qualitatively (*i.e.* through identifying these factors) and may be assessed using qualitative risk assessment models.

In order for land to be determined as "*contaminated land*" under the Statutory Guidance a "pollutant linkage" must be present. This follows the generally accepted risk assessment philosophy that requires that all three elements are present in order for a potential risk to be present:

- *a contaminant source;*
- *a plausible pathway; and*
- *a target receptor (s), which could be affected by the contaminant.*

All discussions in this section have been made in relation to the site's proposed industrial/commercial setting and have taken account of the temporary and permanent diversion of Stewards Brook. The new course of Steward's Brook will pass at substantial depth through contaminated soils and groundwater that will not be treated (stabilised) as part of the development works so remains as a pollution source. The sealed sections that will form the new channel will break any pollutant linkage between the residual contaminants in the surrounding ground and Steward's Brook and thus will protect the water quality of Steward's Brook from further deterioration from impact from contaminants entrained within the ground. The following is based upon the generally accepted risk assessment principles set out above. These are discussed in more detail below in the context of this site.

Sources of Contamination

The analytical results have highlighted a number of contaminants at concentrations greater than the initial screening levels. These are summarised in *Table 14.5(a)* below:

Table 14.5(a) – Contaminants Exceeding Initial Screening Levels

Sample Reference	***Contaminants***	***On-Site Location***
BH8 (groundwater)	Cl, Ammonia, SO_4	Unsurfaced area adjacent to Ditton Brook on Foundry Lane site
BH9 (groundwater)	As, Cl, Ammonia, SO_4	Unsurfaced area adjacent to Ditton Brook on Foundry Lane site
BH11 (groundwater)	Cl, Ammonia, SO_4	Unsurfaced area adjacent to Ditton Brook on Foundry Lane site
BH12 (groundwater)	TPH, Cl, Ammonia, SO_4	Northern area of the Foundry Lane site
BH14 (soil) BH14 (groundwater)	S_2 S_2, As, Cl, Ammonia, SO_4	Unsurfaced area north of the Reclamation site
BH15 (groundwater)	Cl, Ammonia, SO_4	Adjacent to Rehau building on Foundry Lane site
BH23 (soil)	S_2	Unsurfaced area north of the Reclamation site
BH23 (groundwater)	PAH, As, Cd, Cl, Ammonia, SO_4	
BH31 (soil) BH31 (groundwater)	Pb, As, S_2 As, Cl, Ammonia, SO_4	Adjacent to ASTs in tank farm area within West Bank Dock site
BH34 (soil) BH34 (groundwater)	VOC PAH, As, Cl, Ammonia, SO_4	Adjacent to AST located in northern section of West Bank Dock site
BH43 (soil) BH43 (groundwater)	Pb, Cu, S_2 TPH, S_2, Hg, Cl, Ammonia, Nitrate, SO_4	Close proximity to the derv AST within former transport yard on the West Bank Dock site
BH51 (soil)	Pb, As	Adjacent to Tessenderlo's emergency exit route and in uncontained drum store in southern section of West Bank Dock site
BH55 (soil) BH55 (groundwater)	S_2 Cl, Ammonia, SO_4	Unsurfaced area in southern section of West Bank Dock site
WS4 (groundwater)	Pb, SO_4	Adjacent to uncontained drums behind Unit 2 on the West Bank Dock site
WS6 (soil) WS6 (groundwater)	TPH TPH, As, Cd, SO_4	Adjacent to ASTs in the tank farm located on West Bank Dock site
WS7 (soil)	As	Inside Unit 2 located on West Bank Dock site comprising the liquid filling machines
WS12 (soil)	Pb	Close proximity to redundant nitromethane AST within former transport yard on the West Bank Dock site
TP5 (soil)	Asbestos	Unsurfaced area in southern section of West Bank Dock site
TP9 (soil)	Zn	Unsurfaced area north of the Reclamation site
TP10 (soil)	TPH	Unsurfaced area north of the Reclamation site
TP15 (soil)	S_2	Southern section of Reclamation mound
TP16 (soil) TP16 (groundwater)	S_2 TPH, PAH, SO_3	Southern section of Reclamation mound
TP18 (soil)	Pb	Southern section of Reclamation mound
TP20 (soil)	As	Southern section of Reclamation mound
TP23 (soil) TP23 (groundwater)	S_2 S_2	Southern section of Reclamation mound

Receptors

The following receptors have been identified:

- Site buildings and structures;
- Site workers (*i.e.* current and future employees located at the site);
- Groundworkers *(i.e.* construction workers, maintenance workers or other personnel who may be directly exposed to contaminated soil or groundwater in the course of their activities);
- Planted vegetation associated with the landscaping proposals;
- Local flora and fauna (particularly aquatic) whose habitat could be damaged or altered by chemical contamination;
- Groundwater, encountered within the Made Ground, alluvial drift deposits, Glacial Till horizon and Fluvio-glacial Sand and Gravel drift deposits;
- surface water *(i.e.* Steward's Brook (in its current course), which flows between the Reclamation site and the West Bank Dock site (in part) and the Ditton Brook, which flows adjacent to the south-west boundary of the Foundry Lane site and to the south of the Reclamation site); and
- third party land (*i.e.* the possibility of contamination migrating off-site onto third party via contaminated groundwater).

It should be noted that there is little if any potential for the on-site contamination to impact upon human health in the off-site community as no plausible pathway exists, hence this has been discounted as a potential receptor. It is recognised, however, that there may be dust emissions during construction works but the air quality impact assessment demonstrates that this is highly unlikely to travel off-site or breach air quality standards (designed to protect human health).

Potential Pollutant Pathways

The following potential pollutant pathways have been identified at the site:

- Migration of land gases into buildings and service conduits;
- Migration of contaminants to shallow groundwater bodies and aquifer and to surface water via leaching and run-off, or transmission along conduits;
- Inhalation, ingestion or skin contact with contaminated soils or waters (although generally risks to construction workers or maintenance workers should be manageable by standard health and safety procedures); and
- Leaching and capiliary rise into landscaped areas.

A conceptual model for the site, presenting the identified sources of contamination, pathways and receptors is detailed in tabular form in *Table 14.5(b)* below and graphically in *Figure 14.8*.

The following discussion provides a discussion of the risk assessment for the site, based on the current understanding and whether plausible pollutant linkages are present.

Table 14.5(b) – Conceptual Model

Source	Pathway	Receptor	Pollutant Linkage Assessment
Chemical Contamination, e.g. Metals, PAHs, hydrocarbons, trace VOCs, sulphide, major ions and ammonia in the ground and groundwater beneath the site.	Ingestion, inhalation, skin contact Leaching and capiliary rise	**Human (current and future)** Site users: Ingestion and contact – **Low to Moderate Risk** Inhalation (vapours) – **Low to Moderate Risk** Approximately 40% of the site area is currently unsurfaced, which is used for lorry/trailer parking and container storage. This also includes the reclamation mound, however, no current activities are undertaken on the mound. The redevelopment proposals include the hardsurfacing of the majority of the site to be hardstanding, with the exception of small pockets of landscaped areas. The reclamation mound will remain the same. **Ecosystems** Landscaping species risk of damage – **Low to Medium Risk** Off-site aquatic habitat damage – **Low to Medium Risk for brooks** Off-site terrestrial habitat damage – **Low Risk**	No pollutant linkage has been identified over the majority of the site from routine current use or proposed future use of the site in relation to human exposure to soil and groundwater contamination. However, there is a potential pollution linkage from direct contact with the surface soils and dust from inhalation in unsurfaced areas. Construction or maintenance workers may come into contact with contaminated soils but exposure should be manageable by appropriate health and safety procedures. In landscaped areas a clean break layer of top-soil will be placed to a thickness of at least 0.5m on top of the current ground levels to avoid cross contamination and impacts on planting.
	Groundwater and surface water	**Controlled Waters** Groundwater (on-site) – **Medium Risk** (due to contamination found) Groundwater (off-site) – **Low to Medium Risk** (from interconnectivity of water bodies) Surface water – **Medium Risk** (due to contamination found in groundwater and proximity of Steward's Brook and Ditton Brook which may be contiguous with this. These is also the potential for contaminated run-off drainage)	Potential for migration of contaminants into groundwater exists and contamination arising from the galligu is impacting on water quality. Significant migration of TPH contamination does not appear to have occurred across the site. There is potential for localised migration of hydrocarbon contaminants in perched groundwater to the nearby surface watercourses (Stewards' Brook) via the drainage system.
Land Gas (methane and carbon dioxide).	Inhalation, asphyxiation and explosion.	**Human (current and future)** Site users **– Low Risk**	Land gases were generally detected below guideline concentrations (with the exception of one monitoring location where a slightly elevated level of methane was recorded). No significant flows were detected.

Potential Risks to the Current or Future Site Occupiers

With the exception of the reclamation mound, the area to the north of the reclamation mound, and the southern section of the West Bank Dock site, the majority of the site's external surfacing is predominantly concrete or tarmac, of varying quality. It is considered that there is some potential for human exposure to contaminated materials through direct skin contact, inhalation or ingestion in these unsurfaced zones and particularly the northern area of the Reclamation site and southern section of the West Bank Dock site.

If excavations are undertaken there is a significant potential for human exposure to contaminated ground in the main body of the reclamation mound, although there are no current activities undertaken on this part of the site.

Where hardstanding exists this eliminates the exposure pathway and under the development proposals the area of hardstanding will be increased substantially. Furthermore the landscaping scheme will also provide a barrier between site occupiers and the contaminated soils.

The presence of hardstanding over the remaining parts of the site will also limit the potential dust generation and gas accumulation within the buildings (although little in the way of gas and vapour was identified during the investigation).

In effect the proposed development will lessen the risk of exposure of site users to contaminated soils once fully operational as there will effectively be an impermeable physical barrier (hardstanding and managed landscaping) between the contaminants and site users.

Potential Risks to Construction Workers

The planned redevelopment activities will involve excavation and earthworks *(i.e.* laying new services, cut and fill operations, maintenance of existing services and piling activities during the construction phase) and may bring construction workers into direct contact with contaminated ground materials (soils and groundwater) through direct skin contact, inhalation and ingestion. These risks are considered to be low to moderate. The excavation and stabilisation of the galligu entrained within the Reclamation Mound will be disturbed during construction activities, however this will be covered under the works H&S Plan and Mobile Plant Licence. The proposed realignment of Stewards Brook will also involve the engineering of a new channel through areas of the site, which are likely to encounter contaminated soils. The construction phase environmental protection and health and safety management plan for the site will ensure that appropriate measures are adopted to minimise and control the levels of exposure and to ensure all site workers are adequately informed of the risks to themselves and the environment (see Proposed Remediation Strategy at the rear of this section).

Potential Risks to the Groundwater - General

The shallow groundwater encountered at the site, appears to be perched within the made ground. The made ground is underlain by alluvial drift deposits, which are further underlain by Glacial Till and then Fluvio-glacial Sands and Gravels, which are all water bearing and would be sensitive to mobile site derived contamination. Equally, the possibility exists that the underlying major sandstone aquifer is in hydraulic continuity with the groundwater encountered within the alluvial deposits and may thus also be sensitive to site derived contamination. The site investigation has focused on assessing shallow soil and groundwater conditions and has not been designed to include the assessment of the groundwater within the underlying Sandstone Group. However, the glacial clay overlying the sandstone is likely to restrict the vertical migration of mobile contaminants into the sandstone to an extent, although the clay layer is not reported to be continuous across the site. Overall, the risk to groundwater from site derived contamination is considered to be moderate as there is the potential for contaminants to leach from the soils into the groundwater bodies, which may be interconnected.

The current hardstanding cover on site will reduce the potential impact of leached contaminants to migrate downwards and impact upon the quality of the groundwater within the shallow horizons, but the hard cover is poor in places and does not form an effective barrier to infiltration of rainwater through the site. The proposed development will have a much greater area of hard cover and Stewards Brook following re-alignment and engineering will thus reduce the potential for percolating rainwater to leach contaminants from the unsaturated zone into the saturated zone.

The current coverage of hardstanding equates to around 65% of the site are. Once the development proposals are complete, this will have increased to 82%.

It is recognised, however, that during the construction phase more soils will be exposed and there may be a temporary increase in infiltration rates during this period depending upon weather conditions.

Potential Risks to the Surface Waters

The closest watercourses to the site are Stewards' Brook, which flows between the Reclamation site and the West Bank Dock site (in part) and the Ditton Brook, which flows adjacent to the south-western boundary of the Foundry Lane site and to the southern boundary of the Reclamation site. There is potential for the migration of contaminants in perched and shallow groundwater into the Brooks directly where they are contiguous and via the drainage system or run-off. Both brooks have been classified by the EA under the General Quality Assessment (GQA) scheme as water quality Grade E, i.e. of poor water quality. Steward's Brook flows through the golf course located to the north and adjacent to the HEDCO landfill in the south both of which leach contaminants into the Brook. As a controlled water, however, this represents a sensitive receptor to contaminants regardless of its prevailing quality and provides a pathway for off-site migration.

The proposed re-alignment of Stewards Brook will involve excavation into the site to form the proposed channel. As this will be fully engineered to take account the flow characteristics, the re-engineering of the proposed route will significantly reduce the potential for the surface water within the brook to interact with the surrounding contaminated soils and thus significantly reduce the overall contaminant loading to the brook.

Given that the proposals for the Reclamation Mound are to remove a substantial amount of the galligu for treatment using lime stabilisation with the resultant area being capped and designed as a car park. This will increase clean surface water run-off and reduce the potential for leachate generation within the mound to emanate and impact Stewards Brook.

As already stated, the development proposals will involve substantially increasing areas of hard surfacing on the site which will serve to both greatly reduce rainwater infiltration (and thus flushing and leaching of contaminants) and will also provide a "clean" barrier between incident rainfall and the contaminated soils, thus leading to uncontaminated surface run-off. In addition, the site drainage system will effectively be replaced with a new high integrity drainage system, removing another potential contaminant migration pathway.

Ground Gas Assessment

Based on the field gas monitoring data obtained to date, elevated methane concentrations have been detected within BH15, which are above the BRE guideline at which there is a need to consider possible measures to prevent gas ingress into new buildings. No significant amounts of putrescible material were observed within this location and the source of this methane may be the degradation of natural organic matter within the Alluvium. In addition, elevated carbon dioxide was identified in BH51 and WS6, at concentrations where gas measures may be required in new buildings. However, concentrations of carbon dioxide reduced during the interim period between monitoring visits suggesting that the rate of generation or release is slow. Furthermore, the flow rates are not considered to be representative of land gases being positively generated on site, at any significant rate. On the whole the risk of gas ingress to buildings and structures is considered to be low. Furthermore, the soils in these areas will be substantially disturbed and replaced and post ground preparation, therefore, a significant gas presence is highly unlikely in these areas.

The proposed construction techniques and moisture exclusion measures associated with the new buildings, and their very large volumes and open nature should preclude the need for specific gas protection measures, given the general absence of gas across the site.

Risk to Underground Services and Buried Concrete

Consideration will be given to the construction of services, particularly water pipes, where they are to be laid within the contaminated Made Ground. Provision may need to be made for lining or sealing the service trenches where they pass through contaminated areas. Advice will be sought from the relevant statutory authorities prior to the design and construction of service runs.

With respect to buried concrete, on the basis of the chemical analysis for sulphate, chloride and pH, the ground conditions may be harmful and corrosive to concrete. The concrete type will be specified in accordance with the requirements of AC-2/3 of BRE Special Digest 1: 2000.

Potential Risks to Groundwater Associated With Piling and Ground Preparation

Due to the type and nature of the development it is envisaged that floor loads will be high, settlement criteria stringent and roof spans large such that foundation loads will be significant. In light of this and the weak and variable nature of the soils found across the site it is proposed that some of the built structures are founded upon piles. The contaminated nature of the near surface deposits and the potential for creating pathways to the underlying soils and aquifer as a consequence of the piling operation is recognised and understood and piling methods will be chosen on the basis of risk assessment as well as structural performance.

From the information available from the site investigation it is currently anticipated that various piling techniques may need to be employed across the site including both displacement and non-displacement types, in addition to surface based ground treatment (e.g. cement stabilisation). During the detailed design phase it is intended that final ground treatment and/or pile designs will be determined and agreed through discussion and liaison between the EA, the Structural Engineer and the specialist Piling and Groundworks Contractors taking due regard of structural performance and the avoidance of contamination migration.

Ideally, the piling technique will comprise friction Piles, which are designed to bed into stiff boulder clay over a sufficient length (depth) to ensure that the frictional forces between the Pile and the surrounding clay exceed the downward force of the buildings load, and thus provide a stable support for the building. Given the size of the buildings and loads that could be involved, the Structural Engineers have calculated that such piles would need to be located in excess of 15m thickness of such boulder clay across the site, but the Site Investigation has demonstrated that this situation does not exist on the development site. As such, it is likely that the Piles will have to be founded on the sandstone rock head that underlies the made-ground and drift deposits. This may necessitate piles ranging from between 14m to >45m depth across the site due to the sandstone rock head dipping sharply from east to west.

Environmental Implications of Piling

In Environmental Impact terms, the principal concerns with Piling are:

- Piling equipment can generate both noise and vibration that could be evident off-site;
- Certain Piling methods can bring spoil (some of which may be contaminated) to the surface and other methods may drive contaminated soil down into deeper horizons where it would not have previously existed; and
- Any Piling method that passes through contaminated ground or groundwater into underlying uncontaminated strata creates a potential pathway for downward migration of contaminants (i.e. can cross-contaminate previously uncontaminated ground or groundwater) by allowing contaminated water to drain along the sides of the pile into deeper strata.

The noise and vibration issues associated with Piling are discussed in *Section 12* (*Noise and Vibration*). With respect to ground contamination issues, it is recognised that in many locations on the site, the Piling locations will coincide with varying degrees of contaminated ground and groundwater. What has not been determined at this stage is the specific Piling technique that will be used and where these will be required.

This will be influenced by a number of factors including:

- Feasibility of surface cement stabilisation techniques;
- Depth to rock head;
- Required bearing strength;
- Presence or absence of contaminated soil along the Pile profile;
- Presence or absence of contaminated groundwater along the Pile profile;
- The specific nature of the contamination that may be present;
- Proximity to retained structures (i.e. structures that could be damaged by vibration), and
- Cost.

Once Planning Consent has been granted for this development then the Client will commission further investigation of the proposed Pile locations, and commence technical discussions with piling contractors to define appropriate Piling methodologies and an overall strategy. It is likely, however, that the Piling techniques selected will be a combination of augered Piling and displacement piling; each of which has potential impacts associated with it, and these are discussed below. These techniques will be used where surface based ground stabilisation is not feasible.

Auger Piling

This involves using a rotary boring (auger) technique whereby a screw auger is slowly progressed through the ground whilst, at the same time, bringing the material it has bored through to the surface. Notwithstanding the obvious implication of the open borehole providing a direct pathway from contaminated horizons into uncontaminated horizons (which applies to any Piling technique) there is also the issue of exposure to contaminated soils and vapours (e.g. VOC's from hydrocarbon contamination or hydrogen sulphide from galligu). The most sensitive receptor for this being the Piling Rig Operators. Furthermore, this technique creates a waste material requiring management and disposal (regardless of whether or not it is contaminated). If the material is contaminated then there is also the potential for contaminated run-off from this exposed material draining into on-site drainage systems or previously uncontaminated ground. The technique aim would be to screw an auger into the ground to the required depth and then to pump concrete down the hollow auger stem as the auger is slowly withdrawn. Reinforcement is then pushed into the wet concrete.

Displacement Piles

This typically involves physically driving a preformed concrete Pile into the ground to the required depth. Again, there is the potential for this to create a cross-contamination pathway from contaminated to uncontaminated horizons, but also this technique can physically drive contaminated soils down into deeper horizons, albeit in relatively small quantities dictated by the cross-sectional area of the Pile. Significant advantages of this technique over augered Piling, however, are that no contaminated material is brought to the surface, thus Worker exposure and waste disposal problems are avoided, and there is no need for the pouring and setting of concrete.

The relative merits of the Piling techniques on their associated environmental implications are summarised in the box below.

PILING TECHNIQUE	ADVANTAGES	DISADVANTAGES
AUGER PILING This involves open drilling of a hole to the required depth, which is then filled with liquid concrete as the auger is withdrawn.	Does not physically transfer material from contaminated horizons to uncontaminated horizons, and instead brings all materials to the surface where they can be managed/disposed of.	1. The Pile can provide a direct migration pathway between contaminated and uncontaminated horizons. 2. This technique can generate large volumes of waste material, some of which may be contaminated presenting Worker exposure and waste disposal issues. 3. The open hole can provide a direct pathway for potentially hazardous gases (e.g. H_2S and VOC) to migrate to the surface (Worker exposure issue). 4. During periods of heavy rainfall, the open hole can provide a direct pathway for substantial volumes of water to flow into contaminated horizons and carry contamination down to previously uncontaminated horizons.
DISPLACEMENT PILING This involves driving a precast concrete Pile directly into the ground.	There is no open hole and the Pile can be installed directly without bringing any material to the surface.	1. The Pile can provide a direct migration pathway between contaminated and uncontaminated horizons. 2. This method can drive solid contaminants and contaminated soil directly into underlying uncontaminated strata and groundwater.

It should be noted that, in addition to the Piles providing a pathway for contaminated water to seep downwards into underlying strata, there is also the potential to allow underlying uncontaminated groundwater that may be under confined conditions (i.e. sub-artesian) to rise-up into contaminated ground.

Mitigation of Piling Impacts

As a precursor to the Construction project and in conjunction with the proposed further investigation that will take place once Planning permission has been granted, the Client will undertake a Piling Risk Assessment in accordance with the EA Methodology for such set out in their publication - *Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance of Pollution Prevention*. Based upon the investigation of Pile locations and the Piling Risk Assessment, the Client and its Contractors will confirm with the Environment Agency which of the proposed Piling locations presents a potentially significant risk of cross-contamination between contaminated and uncontaminated horizons. A detailed Method Statement will be then agreed setting out the Piling technique and protection methods that will be employed. It is likely that this will include:

- Augered Piling to bring the contaminated material up to the surface where it can be managed and controlled;

- Pre-emptive or simultaneous advancement of solid casing, which will isolate the material being excavated from the surrounding material and prevent groundwater seepages into the borehole, and

- In-situ casting of the Piles with secondary sealing of the made-ground/natural ground interface so that groundwater can not be transmitted downwards along the outside edge of the formed Pile.

Where the proposed Piling location does not coincide with significantly contaminated ground and the Piling Risk Assessment demonstrates that there is negligible risk of cross-contamination then it is likely that preformed displacement Piles will be used.

The rotary auger Piling will bring materials to the surface from each horizon that it passes through. It is proposed that these Pile horizons are monitored and periodically sampled to enable them to be characterised and, where possible, segregated. This will enable the contaminated material and uncontaminated material to be defined and segregated for management and handling in accordance with Site-wide Waste Management Strategy (see *Section 18 - Waste Management*).

The full details of the Piling strategy and techniques will be determined in conjunction with suitably qualified Piling Contractors and confirmed with Halton Borough Council and the Environment Agency well in advance of Piling works commencing on site.

14.6 SUMMARY AND CONCLUSIONS

The nature and level of contaminants identified at the site although substantial are not considered to pose a significant health risk to current occupants (i.e. industrial end-use). The soil contamination identified does, however, represent an ongoing source of groundwater contamination and furthermore, the areas of unsurfaced ground increases the leaching potential of any soluble contaminants from the unsaturated into the saturated zone. This will be significantly reduced as a direct result of the proposed redevelopment, as the majority of the site will become hardstanding with pockets of controlled drained landscaped areas. It is clear that groundwater quality is being locally impacted, although this does not appear to be site wide. Given the site setting and hydrogeological conditions and the substantial off-site contamination sources that exist, on-site groundwater remediation is very unlikely to have noticeable effects.

In terms of the proposed planned redevelopment of the site, some remedial works in relation to soils will be required prior to the building construction phase. The following recommendations are made with respect to additional works and issues to be addressed prior to redevelopment (and assume an industrial/commercial end use):

- prior to the redevelopment of the site, there is a significant amount of material currently being stored on site which will require off site disposal. This includes all waste drums, which are of unknown composition, waste scrap metal and the numerous, redundant storage tanks, which will be decommissioned prior to disposal;

- the above ground oil/diesel storage tanks, which are currently in-situ, both on the Foundry Lane and West Bank Dock site will subsequently be emptied, decommissioned and removed prior to the redevelopment works commencing. This will be undertaken by an appropriately qualified contractor and a visual assessment will be made of the local ground conditions upon their removal i.e. evidence of surface staining. It is clear from the soil and groundwater samples obtained from WS6, located adjacent to the tank farm area, that localised hydrocarbon contamination has taken place and therefore an allowance will be made for soil sampling and testing of the excavation, and potentially for the removal of contaminated soil;

- prior to the construction phase, (upon site clearance), further investigation will be undertaken in those areas that were previously inaccessible, most notably within, for example, the bulk oil storage facility area within the West Bank Dock site;

- there are potential asbestos-containing materials present within some of the buildings on site. An asbestos survey has been undertaken at the site, which will aid in the assessment of asbestos removal costs and plan for any asbestos removal work prior to the demolition of the buildings;

- quantitative risk assessment will be undertaken using appropriate UK defined risk models to define site specific target values for soils for those parameters identified as being of concern *i.e.* TPH, PAHs, arsenic, lead etc. This will enable an assessment of remediation requirements to be carried out;

- assessment of the potential impact to the shallow groundwater from contaminated materials at the site using established risk assessment tools. This would be agreed with the regulatory bodies in advance of any detailed modelling and would forma part of the overall remediation strategy for the site;

- once site specific target values have been defined, further investigatory works are likely to be required to further delineate areas of contamination identified as requiring remediation. At this stage a detailed remediation plan will be drawn up for agreement with the appropriate regulatory authority (LA/EA);

- where future areas of landscaping are proposed as part of the planned redevelopment, it is likely that a clean ‘break layer’ of top-soil will be required to a thickness of at least 0.5m on top of the current ground levels, which will subsequently protect the vegetation from potentially phytotoxic effects of contaminants such as copper and zinc and to protect humans that may be exposed via landscape maintenance activities;

- a gas monitoring programme will be developed in order to further assess the gas regime at the site. BH15 located on the Foundry Lane site was the only borehole which recorded slightly elevated levels of methane, although this was recorded within the natural alluvial deposits, rather than the fill material and may be a result of the degradation of natural organic material, which may be present within the glacial clay.

With regards to the construction phase, the following points have been identified:

- Preliminary consideration of the ground conditions has indicated that a piled foundation solution may be required in places, however, the pile design and method will be governed by site contamination issues. Detailed drawings of the pile design together with the detailed drawings of the locations of the intended piles together with a method statement for the chosen pile design will form part of the remediation method statement, which will be produced prior to the commencement of the redevelopment works.

- In addition to piling it is proposed that ground stabilisation techniques may be employed, which effectively involve rotavating the upper 2m of soil and the material excavated from the Reclamation Mound with specialist cement products using specialised mechanical plant. This technique will also stabilise and reduce the leaching potential of the galligu and will form a key part of the remediation strategy. Surface stabilisation either in-situ or ex-situ will be used in preference to piling wherever possible to avoid the potential piling cross contamination risk described earlier;

- consideration will be given to the construction of services, particularly water pipes, where they are to be laid within the contaminated made ground. Provision may need to be made for lining or sealing the service trenches. Advice on this will be sought from the relevant statutory authorities prior to the design and construction of service runs. With respect to buried concrete, on the basis of the chemical analysis for sulphate, chloride and pH, the ground conditions will be specified in accordance with the requirements of AC-2/3 of BRE Special Digest 1: 2000;

- as with the redevelopment of any site, appropriate health and safety procedures will be adopted and adhered to, in order to prevent site workers/developers and maintenance staff being exposed to contaminated soil;

- the remedial strategy for materials generated on the site will be three fold. Firstly, uncontaminated material and demolition rubble will as much as possible be re-used on the site under a waste management licensing exemption. Secondly, heavily contaminated material (i.e. hydrocarbon contaminated areas) will go off site as special waste to an appropriate landfill or be treated on site using licensed plant/contractors. Thirdly, the galligu chemical waste will be blended with cement to produce a usable material, thus, converting the galligu to either a simple general fill material (no structural strength required) or sub grade or sub base (which will have to achieve a specific engineering specification);

- the disposal of excavated material will comply with all applicable environmental laws. However, as contamination appears to be located in ‘hotspots’ rather than site wide, excavated material may fall into different classes of waste depending on its location. It is anticipated therefore, that screening of the excavated materials for contaminants will be undertaken, which would subsequently allow the waste to be classified for disposal purposes, which would aid in the minimisation of landfill costs;

- evidence from groundwater monitoring suggests that excavations may encounter natural groundwater within the alluvial deposits or perched water within the made ground. Therefore, provisions will be made for the pumping of any groundwater from the excavations. In addition, the pumped water will be disposed of according to all applicable environmental laws. Associated impacts to surface waters are discussed in *Section 17*;

- the quantity of imported fill that may be required cannot be determined at this stage as it is dependent upon the volume of material that can be re-used on site (e.g. stabilised galligu, demolition rubble and uncontaminated soil). This will be determined during the construction design phase that will immediately follow the granting of planning permission. Full consultation will be undertaken with the EA and HBC to agree in detail a proposed method for re-using site materials and to ensure the appropriate exemptions/licenses are obtained;

- the use of plant equipment on site may possibly lead to the potential for the release of contaminants to ground, such as fuel oils, coolants and lubricants. To avoid the accidental leakage of fuel oils and/or lubricants, all machines will be maintained to a safe and efficient working condition at all times. In most cases, leakage of oil is avoidable through regular checks for signs of wear and tear on plant and tanks. Refuelling is identified by the Environment Agency guidelines (Pollution Prevention Guidance Note 5) as the greatest risk of pollution during site work construction. Therefore, together with other routine maintenance, all servicing and refuelling will be carried out in a designated area away from sensitive soil and groundwater receptors;
- Japanese Knotweed has become established on the site, with small stands identified in the north-western section of the Foundry Lane site together with a small stand located within the north-eastern section of the West Bank Dock site.

  Japanese Knotweed is a rhizomatous perennial, which can grow up to 2-3m in height and has bamboo-like stems that produce clusters of creamy white flowers late in the growing season. The hollow woody stems persist throughout the winter, with new growth the following spring being produced from the plant's extensive rhizome system. The dead stems and leaf litter decompose very slowly, forming a deep organic layer which prevents the germination of other plants. The plant's rhizome system can extend to a 3m depth and 4m laterally. A fragment of rhizome, as little as 0.7 grams, can produce a new plant. Control of the plant is reliant upon the death of the rhizome system, which can take a number of years with herbicide treatment. All knotweed-contaminated material will be dealt with on-site where possible so as to minimise the potential spread of the plant as a result of off-site transport for disposal. Therefore, the preferred method of control will be via the application of herbicide. However, prior to remedial works the stands of knotweed will be cordoned off to prevent disturbance by on-site vehicles/machinery and personnel.

- The Client and its advisors are in the process of developing a detailed remediation method statement based upon consultation with the EA and HBC, treatment trials and expert advice from ENVIRON and potential remediation contractors. Once the proposed development is granted planning consent a further round of investigation will be undertaken and further trials and consultation entered into to facilitate the final production of a detailed remediation strategy and method statement. This will be agreed with the EA and HBC before it is implemented.

Key aspects of the remediation strategy are discussed in more detail below.

Remediation Options

The aim of the remediation at this site is to reduce calculated risks from the identified impacts to potential receptors to levels acceptable to the Environment Agency (EA) and the Local Authority Environmental Health Department (EHD), such that the property is no longer considered to be impacted under the Contaminated Land Regulations 2006 or present a significant risk to the development.

Initial results from the qualitative risk assessment indicate that removal of the most heavily contaminated material together with treatment of the source areas is, in ENVIRON's opinion, likely to be acceptable to the Environment Agency (EA) and the Local Authority Environmental Health Department (EHD). If lesser degrees of removal are undertaken, these may also require some form of containment at the site boundary to mitigate the potential for off-site migration.

The selection of a single or combination of remedial systems is complicated due to the combination of chemical compounds within the soils and groundwater. These have different physico-chemical properties, i.e. different volatilisation rates, solubility in water, density and therefore the treatment designed for some compounds may well not extend to the treatment of all compounds present and impacting the site.

The available techniques and consideration for undertaking the remedial works include:

- Objective of the remedial action;
- Site setting (geology and hydrogeology);
- Nature and extent of the impact present;
- Technical achievability;
- Total cost (capital and O&M);
- Acceptance by the Regulators; and
- Duration of implementation.

To address these initial concerns, ENVIRON previously commissioned pilot tests for a range of parameters on the galligu waste material. The desired requirements being that the end material is sufficiently stabilised for its intended end use (which will vary dependent on the placement of the material), to be environmentally stable *i.e.* non-leachable and to render the material fit for use in line with current waste management licensing regulations. These levels will need to be agreed with the EA in advance and hence a Quantitative Risk Assessment will be required and undertaken to identify these values.

ENVIRON and the potential remediation/earthworks contractors have discussed the initial considerations with the Environment Agency Waste Management Unit and prior to undertaking any remedial works the EA will be provided with a Site Specific Working Plan to demonstrate the actions anticipated. On balance, the preferred remedial alternative is source excavation of the shallow contaminated soils required to be cut as part of the building development, and treated onsite with a stabilisation product capable of reducing the leachability to the required levels under a Mobile Plant Licence. There is also the option of treating and cement stabilising this material in-situ as part of the ground preparation works.

Generally, only moderate levels of contamination have been identified to date, in the context of an industrial usage. However, several areas of more significant contamination have been identified generally associated with the galligu in the soil and elevated concentrations within the groundwater. It should be noted that under the scope of the investigation works to date, full delineation of the extent of these areas has not been carried out. In addition, on demolition of the site infrastructure further areas of the site which have not been investigated, due to access constraints will be undertaken. ENVIRON considers that further works are required to quantify the extent of the identified hot spots and within areas currently inaccessible.

In conclusion, it is recognised that there is substantial contamination present on the site and that the proposed development will need to take account of this during the construction phase and be protected from it once developed. Furthermore the development must not exacerbate the risks and create pathways that did not exist previously.

The Client and their advisors are confident that a robust and detailed remedial strategy can be developed to achieve these aims and reduce the impact of soil contamination on the developed site.