Remediation Statement
Appendix D

Plot B Soil and Groundwater Investigation former Albright and Wilson Works, Whitehaven, Cumbria

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EXECUTIVE SUMMARY

URS Corporation Ltd (URS) was commissioned by Rhodia UK Ltd (Rhodia) to undertake an intrusive soil and groundwater investigation at the former Albright & Wilson site in Whitehaven, Cumbria. The work comprised investigation of soil and groundwater conditions associated with an area of land identified as "Plot B" - one of a sequence of plots on the Whitehaven site identified as requiring further assessment in a Site Remediation Statement document. The report aimed to specifically address the potential significance of controlled waters pollutant linkages identified by Copeland Borough Council following their determination of the site as Contaminated Land.

Plot B comprises an area of the site most recently occupied by a surfactant manufacturing plant and a reported historical coking works. All above ground structures have been demolished and the area is now open ground. It is understood by URS at the time of reporting that the site is proposed as a public 'right-to-roam' open space land use.

A trial pitting exercise was undertaken which also allowed detailed visual assessment of the subsurface. A total of 30no. trial pits were excavated. Following the trial pitting exercise a limited shallow soil boring investigation was completed at 5no. locations which allowed the installation of 4no. monitoring wells. Soil and groundwater samples were collected and scheduled for a suite of analyses following agreement with the Environment Agency.

A summary of ground conditions observed during intrusive work comprised made ground, overlying natural clay deposits (where present) subsequently underlain by rock head. Ground cover over the majority of the site comprised concrete slab hardstanding. Made Ground generally comprised a heterogeneous mix of building rubble, ash and clinker. The depth of these horizons varied across the site and were further complicated by the presence of underground foundations, former basements and other subsurface structures. The natural clay deposits were not observed continuously beneath the site and in areas where they were not present made ground generally lay directly on rock head. Bedrock was encountered at a number of locations as a limestone or sandstone and interpreted as the St Bees Evaporite Formation.

Two groundwater units were identified beneath the site. Perched shallow groundwater was encountered in isolated areas of the made ground and drift deposits. No evidence suggested the presence of a continuous shallow groundwater body, although lateral continuity was considered likely to exist locally. Bedrock was observed to directly underlie areas of permeable made ground and drift deposits and therefore a direct vertical flow path was considered to the underlying bedrock. Deep groundwater was estimated to lie approximately 20m bgl within the underlying bedrock beneath the site.

An initial generic screening exercise was completed on all data collected from the within the Plot B boundary of the site to date. The key receptor identified for the controlled waters assessment comprised the underlying sandstone minor aquifer. The screening exercise identified exceedances of VOC, SVOC, PAH, metal and inorganic compounds in soil, soil leachate and limited shallow groundwater samples. Human health screening for the proposed open space land use was completed based on generic residential without gardens criteria, identifying exceedances of VOC, SVOC, PAH, PCB, metal and inorganic compounds in soil and shallow groundwater.

The Controlled Waters DQRA was undertaken using the CONSIM modelling software to simulate concentrations at the receptor. Given the absence of identifiable groundwater abstractions or discharge points to surface water close to the site the receptor was identified as a theoretical compliance point within the Whitehaven Sandstone minor aquifer 50m down hydraulic gradient of the identified source areas. The potential contaminants of concern (PCOC) in soil, soil leachate and limited shallow groundwater were assessed using a series of modelled pollutant linkages. These comprised horizontal migration to the receptor assuming (1) a site wide source with an unsaturated zone present, (2) a site wide source without an unsaturated zone present, and (3) a hotspot source without an unsaturated zone.

The Controlled Waters Risk Assessment identified potential risks associated with: benzene, naphthalene, ammoniacal nitrogen, trichloroethene, cyanide and phenols. However, it is considered likely that the majority of contaminants identified with the soils and shallow perched groundwater beneath the site are retained in the unsaturated zone, as a result of the presence of buried concrete structures and impermeable drift materials. Whilst the results of the conservative quantitative risk modelling for controlled waters have identified a small number of theoretical risks, on the basis of the available site information, it is considered likely that there is insufficient evidence to demonstrate a significant pollutant linkage between contaminants identified in the soils and the regional water table. Even if such a linkage did exist, based on the results of the modelling, the effects of attenuation within the aquifer would mitigate the majority of risks within 50m of the site boundary and given that addition retardation or attenuation would occur in the unsaturated zone, it is considered that residual risks would be low and acceptable.

A Human Health DQRA was also completed considering the proposed 'right-to-roam' end use. The risk assessment exposure model was developed using a standard UK CLEA residential without plant uptake scenario which was modified with site-specific parameters to more accurately represent site conditions. Site-specific assessment criteria (SSAC) were derived for each of the PCOCs assuming that all potential pathways of exposure were applicable. Following the comparison of contaminant concentrations against SSAC, those compounds which exceeded the criteria were assessed in further detail using simple statistical analysis in accordance with the guidance detailed in CLR7.

Sensitivity assessment indicates that given that the majority of the site is covered in hard standing, the only plausible pathways vapour inhalation. No risks were identified via this pathway. For an area where hard standing is not present (TP524), the source is considered both small and localised and the possibility of significant ingestion or dermal contact at this specific point is considered highly unlikely.

URS has addressed the specific controlled waters pollutant linkages identified by Copeland Borough Council in their determination of the site as Contaminated Land. URS has also addressed additional COPC and potential pollutant linkages identified during the course of the works at the site. URS concludes that whilst some theoretical risks have been identified at the site, based on the site remaining disused (as is) or becoming a public accessible amenity, with the hard standing areas remaining, actual risks to controlled waters or human health receptors are not considered potentially significant. Remedial action is not therefore considered necessary.

1. INTRODUCTION

1.1. General Introduction

URS was commissioned by Rhodia on 27 July 2006 to undertake an intrusive soil and groundwater investigation at the former Albright & Wilson Works in Whitehaven (the Rhodia site), Cumbria as detailed in URS Proposal 3033251,dated 23 June 2006, which is included as Appendix A to this report. This work was requested by John Moorhouse (Rhodia) at a meeting with Alistair Wyness (URS) on 10th March 2006.

This project focuses on the soil and groundwater conditions within an area of land identified as "Plot B" within the boundary of the site. Plot B is one of a sequence of plots on the site identified as requiring further investigation in the Site Remediation Statement[1] document, which formalises the scope, context, and timescales of investigations required on the site. This report forms Appendix D to the Remediation Statement.

The site (including Plot B) has been designated by Copeland Borough Council as statutory "Contaminated Land" under Part IIA of the Environmental Protection Act 1990. The entire site has subsequently been declared a "Special Site" and is now regulated by the Environment Agency.

The location of the former Albright and Wilson Works is presented on Figure 1. The site layout and the boundary of Plot B are presented on Figure 2.

1.2. Project Background

URS has undertaken a variety of investigations on the site, dating back to 1995. During this period, operations on the site have diminished and the phosphate business has been closed down and over the past 2 years the remaining production operations have ceased. It is understood that decommissioning of above ground structures relating to former operations at the site have now been completed. URS also understands that the only remaining structure relates to a small surfactants production facility (previously operated by Huntsman), located towards the north-eastern corner of the site and is scheduled for demolition during the latter part of 2006.

Following demolition and remediation of the site, it is understood by URS at the time of reporting that the site is proposed as a public open space land use with the minimum of site preparation expected (e.g. such as the removal of protruding trip hazards).

[1] Former Albright and Wilson Works: Site Remediation Statement. 23 June 2006. URS Corporation. (Ref 44319877/R2234.B01)

The scope of the previous investigations across the site relate to phosphate and surfactant manufacturing processes and other historic activities comprising coal and anhydrite mining, coke production, tar distillation and firelighter manufacture. A site wide investigation was undertaken in 2005 and the resulting report (ref; 44319623. Phase II Investigations and Environmental Assessments at the Former Albright & Wilson Works, Whitehaven, 23 June 2005) which contains full details of the site history and the investigations carried out. The report is presented as Appendix B to the Site Remediation Statement and it is hereafter referred to as the "Phase II report".

The Site Remediation Statement document recommended additional investigation in key areas of the site to address the significant pollutant linkages identified. Further to this, URS has reported the findings of an investigation in an area of interest identified as Plot B herein, in accordance with the Site Remediation Statement. It should be noted that the Site Remediation Statement has yet to be approved by the Environment Agency. However, the scope of this investigation has been discussed with, and agreed by the Environment Agency.

The proposal which defines the scope for the Plot B investigation (ref; 3033251, dated 23 June 2006) and the subsequent discussions with the EA has been included in Appendix A to this report. The proposal comprises background information, project objectives, scope, approach and rationale on which the investigation has been based. URS's response to comments provided by the Environment Agency on the proposal (ref; 44319877/SAB, dated 1 August 2006) are provided as an Addendum within Appendix C to this report. The comments provided by the Environment Agency and the subsequent URS correspondence have been used as the basis upon which to review and update the proposal. The amendments have been incorporated into the investigation and the reporting herein. Appendix A should therefore be referred to for detailed information on the technical basis of the investigation and assessment.

1.3. Site Investigation Area - Plot B

Plot B comprises an area of the Rhodia site most recently occupied by the 'imidazoline' and 'CAPB[2]' (surfactant) production plants. These plants were latterly operated by Huntsman however operations have now ceased. A former coke works associated with the historical operation of the Croft/Ladysmith Pit was also reportedly located in this area of the site. All above ground structures associated with these historical activities have subsequently been decommissioned and removed and the area is now open ground.

The area of interest has been identified as Plot B (Figure 2). The former layout of the site is presented on Figure 3 and the current condition of ground cover is presented on Figure 4. The plot is approximately pentagonal in shape and is located adjacent to the northern site boundary. The estimated area of the plot is 18,000 m^2.

[2] CAPB – coco amido propylbetaine

1.4. Existing Site Investigation Information

1.4.1. Introduction

Previous investigations have provided evidence that indicates the presence of potential contamination within the soils and shallow groundwater. However, due to operational constraints it was not possible to fully characterise the soil and groundwater quality with respect to risk to human health and controlled waters receptors. The following previous investigations have been undertaken within the site boundary identified as Plot B:

- URS investigation on behalf of Rhodia, ref; 44557-021, during 2001. 2No. shallow soil borings advanced as part of site wide assessment (WS114, WS165);
- ERM investigation on behalf of Huntsman ref; PPC Phase 1B/2 Site Condition Report during 2003. 1No. shallow soil boring (SB4).
- URS investigation on behalf of Rhodia, ref; 44557-033, during 2003. 17No. trial pits excavated to investigate part of an area occupied by the footprint of a former coke works (TP1-TP17) and a deep borehole (BH204) as part of a deep groundwater monitoring programme; and
- URS investigation on behalf of Rhodia, ref; 44319623, during 2005. 1No. trial pit (TP524) and 1No. shallow soil boring (WS419) advanced as part of site wide assessment.

1.4.2. Key Findings

Phase II Soil and Groundwater Investigation Interpretive Report the Former Albright & Wilson Works, Whitehaven (ref; 44557-021, 4 February 2002)

URS was commissioned by Rhodia during 2001 to undertake a Phase II Soil and Groundwater Baseline Contamination Investigation at the site. The investigation was designed primarily to provide a baseline assessment of soil and groundwater conditions with regard to current and historical contamination. The site investigation comprised the drilling of 65 shallow boreholes with 35 installed as shallow groundwater monitoring wells across the site. Soil and groundwater samples were subsequently submitted for laboratory analysis.

Two shallow soil borings were advanced in Plot B as part of site wide assessment comprising WS114 and WS165. Analysis comprised MBAS, metals, VOC, and PCB in soil and groundwater, SVOC in soil only and PAH and TPH in groundwater only. Following a generic screening exercise and human health Detailed Quantitative Risk Assessment (DQRA) based on a continued industrial land use it was considered that no concentrations represented a potentially significant risk to the identified human health receptors in Plot B.

No assessment was made for controlled waters. It was considered that further work was required to determine the extent of any impact to receptors, although leachability results on soils indicated a limited potential for soil impacts.

PPC Phase 1B/2 Site Condition Report (June 2003)

This report was produced by ERM on behalf of Huntsman in support of a PPC permit application for the surfactant manufacturing facilities, formerly the imidazoline and CAPB plants. The objective of the assessment was to undertake site investigation works to obtain soil and groundwater data to be able to make a statement of the site condition based on the recommendations from an initial Phase 1a desk study report. In the development of the site conceptual model, which enables source-pathway-receptor linkages to be defined, it was identified that there were a number of potential compounds associated with the manufacture of surfactants which may be of potential concern. These comprised; caustic soda, ethoxylated alcohol, hydrochloric acid, Kathon CG, monochloracetic acid, sodium chloroacetate and tertiary amine.

A soil boring (SB4) was located adjacent to a drum storage compound, in an area where surface staining was observed and where tanker offloading points were located. No visual evidence of impact was noted during drilling at this location although a sweet odour was noted at 0.85m bgl. Analysis for total petroleum hydrocarbons (TPH) and surfactants (as Methylene Blue Active Substances) and pH was undertaken on the soil sample from this location. The reported concentrations comprised TPH below the method reporting limit (<10mg/kg), MBAS at 3mg/kg and 7.9pH.

Additional Investigation at the Former Albright & Wilson Works, Whitehaven

(Ref; 44557-033, 8 August 2003)

In correspondence from Copeland Borough Council to URS during July 2002, concern of the potential for an area of the Rhodia site to have been contaminated by cyanide arising from 'foul lime' or 'spent oxide' from the historic use of a coke works was stated. A trial pitting exercise was therefore carried out to identify and obtain samples of any residues from the former coke works operations. Seventeen trial pits were excavated and soil samples submitted for laboratory analysis for an ICRCL gasworks suite. At the request of the Environment Agency, selected samples were also submitted for Volatile and Semi Volatile Organic Compounds (VOC, SVOC) to assess the presence of contamination which could have arisen from the former use of this area for IBC[3] storage. Visual and olfactory indicators of contamination potentially associated with the coke works were observed in four trial pits. Distinct underground structures typical of former coke works such as tar and/or liquor wells and gas purification areas were not observed in the trial pits, although underground pipes were noted, one of which contained solidified viscous black tar. Relatively elevated concentrations of sulphate and Polynuclear Aromatic Hydrocarbons (PAHs), including phenanthrene, fluoranthene and naphthalene were detected in some of the trial pits. The presence of naphthalene was reported to be potentially related to historic firelighter manufacture in this part of the site. No evidence of the impact of possible spills or leakages to ground from IBCs were found during the exercise.

[3] IBC – individual bulk container

In addition to the trial pitting, several samples of groundwater were taken from the shallow monitoring well network across the site and analysed for the ICRCL gasworks suite. The total cyanide concentration of 1,670 µg/l detected in WS115 situated down inferred hydraulic gradient of the former coke works exceeded the generic screening value of 50 µg/l. Shallow groundwater in the vicinity of the trial pitted area of the former gasworks was inferred to flow towards the west.

Phase II Investigations and Environmental Assessments at the Former Albright & Wilson Works, Whitehaven (ref; 44319623, 23 June 2005)

The principal aim of this investigation was to develop a comprehensive understanding of the contaminated land liabilities associated with the site and future licensing requirements for Rhodia's proposed forthcoming divestiture. It was identified that Rhodia were proposing to divest the site to potential purchasers for a recreational 'right to roam' end use. However, also that Rhodia required an understanding of the corrective action and costs associated with leaving the site as "derelict" land, with no public access allowed. As such, the assessments carried out by URS for the study were based upon both these proposed end uses. Following a collation of all historic and the recent analytical data, Detailed Quantitative Risk Assessments (DQRA) were performed to assess potentially significant risks to Human Health and Controlled Waters receptors, based on the future end use for the site.

Two locations were investigated in Plot B during the investigation and comprised WS419 and TP524. The location at TP524 was investigated to better determine strata after a borehole refusal at WS419. Analysis comprising MBAS, metals, major cations and anions, VOC, SVOC, PAH, TPH and PCB were completed from the sample at TP524. No exceedences of the Stage 3 human health or controlled waters criteria were noted. However, exceedences of Stage 3 criteria for PAH were noted in soil at locations investigated during the URS 2003 (44557-033) former coke work investigation.

It was noted that investigation in the former coke works area and beneath the Imidazoline Plant could not be completed in sufficient detail due to continuing Huntsman operations and it was stated that further investigation would be required following cessation of Huntsman operations.

1.5. Report Format

For ease of reference, the remainder of this report has been structured as follows:

- Section 2 details the objectives of this study
- Section 3 includes a review of the current site conditions and environmental setting, derived from pre-existing information
- Section 4 describes the site-specific ground conditions encountered and observations made during the Study.
- Section 5 describes the Conceptual Site Model
- Section 6 summarises the assessment of risk to human health.
- Section 7 summarises the assessment of risk to water resources
- Section 8 presents a complete list of the pollutant linkages potentially present on site, updated to include the findings of this investigation
- Section 9 presents the remediation strategy, in which the actions to address the significant pollutant linkages are explained.

In addition, the following Appendices are attached to the report:

Appendix A	Proposal for Site Works (Plot B)
Appendix B	Field Methodology
Appendix C	Borehole & Trial Pit logs
Appendix D	Analytical Schedules, Tabulated Results, Laboratory Certificates & Historical Analytical Data
Appendix E	Human Health Detailed Quantitative Risk Assessment
Appendix F	URS GAC Advice Note
Appendix G	Controlled Water Detailed Quantitative Risk Assessment
Appendix H	ConSim Model Inputs

2. OBJECTIVES

The project objectives listed below are in line with the *Assessment Actions* detailed in the Site Remediation Statement where the area is referred to as "Plot B".

The key objectives of the investigation were therefore to undertake the following;

- To assess the potential extent and significance of contamination in shallow soil and groundwater in the specified area of interest;
- To provide additional data on potential further compounds not previously detected but which may be considered to be present;
- To provide comprehensive and robust data to allow conceptualisation and characterisation of the site area as far as possible;
- To revisit existing data and to supplement this with additional information from the proposed investigation;
- To revise and develop the current Conceptual Site Model;
- To review all the data gathered from the assessments undertaken in the area of interest and to review this against the existing controlled waters and human health site specific risk based screening levels;
- To provide a preliminary evaluation of the need for, and scope of, potential remedial options (if considered appropriate) together with an estimation of potential remedial methodologies and costs.

2.1. Site Investigation Design

The site investigation design was submitted to the Environment Agency for comment prior to commencement of works. It was approved by Peter Bardsley of the Penrith office. Details of the investigation design and rationale are presented in the proposal and subsequent correspondence between URS and the Environment Agency provided in Appendix A to this report.

3. SITE DESCRIPTION AND ENVIRONMENTAL SITE SETTING

3.1. Introduction

The Former Albright and Wilson Works (the site) is located in a coastal setting, on a hill approximately 2 km south of Whitehaven Town Centre. To the north east are residential estates (Woodhouse and Kells) and to the south is the village of Sandwith. The remainder of the site is surrounded by agricultural land. Plot B occupies an area of approximately 18,000m^2 and is located adjacent to the northern site boundary.

The plot is located on banked terraces that reduce in elevation to the west. The main part of the site is located on the first level and most recently comprised the imidazoline and CAPB surfactant manufacturing plant. Also in this area is located the footprint of the reported historical coking works. All above ground structures have been removed and the area is now open ground with surface cover comprising concrete or crushed hardcore. This area is separated from an adjacent concrete roadway to the west by a grassed embankment and a retaining wall. The elevation of the roadway lies approximately 2m below the existing and former plant ground level. To the west of the roadway, and at a successively lower level of approximately 1m, lies an area of rough grass. No known significant previous historical uses are understood to have occurred in this area, although an above ground pipeline was once present.

From observations noted during the site work, it is likely that 'cut and fill' earthworks have been completed during the development of this area to create the banked levels.

3.2. Plot B Historical Operations

Plot B comprises open ground with extensive surface cover comprising concrete or crushed hardcore where a reported former coke works and an imidazoline and CAPB surfactant manufacturing plant were once located. In addition, other uses in this area of the site comprised a substation, laboratory, offices, engineering workshop, joinery workshop and a vehicle washdown area. No known significant previous historical uses are understood to have occurred on the grassed area of the plot.

3.2.1. Coke Works

As part of previous URS work completed for Rhodia during 2003 (ref; 44557-033) a summary of the historical development of the site was completed according to changes in on-site processes. With reference to Plot B and its surrounding area, it was found that mining of coal took place from Croft Pit until 1902 when a name change to Ladysmith Pit coincided with extension of workings. Coke was reportedly produced at Ladysmith from 1912. Priestman's Collieries acquired leases of the mine and in 1932 a subsidiary erected a small tar distillation plant near the old alabaster works. From 1935-1937 the coke plant worked intermittently and in 1938 the coke plant finally closed. During 1943 Marchon moved into the disused coke ovens and by-products processing buildings at the former Ladysmith pit. Marchon initially manufactured firelighters from mixture of sawdust, naphthalene and black fatty residues from the oil industry.

The exact location of the coke works is currently unknown however an outline of the likely area is shown on Figure 3.

3.2.2. Imidazoline / CAPB[4] Plant Process

It is understood by URS that the imidazoline and CAPB plant were processing operations that manufactured similar anionic surfactant compounds. The unit comprised the manufacture of two types of mild surfactants (CAPB/imidazoline) via a batch process where intermediates derived from the reaction of amines with fatty acids (coconut or lauric) were reacted with monochloroacetic acid.

During production of the amine intermediates vapours were vented to a water scrubber tower where the scrubbed gases (nitrogen and air) were passed via a stack to atmosphere. Water was produced as a by-product and contained low concentrations of amine which was collected, and following analysis to confirm amine content was <3%, was discharged to drain. Where a more concentrated amine/water condensate was obtained, it was recovered for re-use or collected for subsequent amine recovery.

The amines produced (alkyl imidazolines / alkyl amidoamines) were converted to the required surfactant by reaction with monochloroacetic acid, caustic soda solution and water. By-product vapours produced were passed into the scrubber tower and the manufactured surfactant was transferred to storage vessels. Raw materials are understood to have comprised amines, coconut and lauric fatty acids, caustic soda, sodium benzoate, monochloroacetic acid and sulphuric acid.

The above ground structures in these production areas were removed during 2006. The former layout of these areas and the above ground storage tanks and vessels are shown on Figure 3.

It was noted during the site investigation that a cellar was present below the main building of the imidazoline process building. This had subsequently been infilled with building rubble and hardcore during the demolition process.

[4] CAPB – cocoamidopropylbetaine

3.2.3. Other Areas

In addition to those historical uses outlined above a number of ancillary activities took place in this area of the site associated with the on-going site operations. In summary, these comprised a laboratory and offices located adjacent to the CAPB plant and were associated with the quality assessment of the surfactant product and the control and operation of the plant. An electrical substation was also located within this area and within the imidazoline plant.

An area used for the storage of finished surfactant products were located in IBCs on concrete hardstanding in an area adjacent and to the south of the imidazoline plant. A joiners workshop was located along the western boundary of the main site area and an engineering (Ladysmith) workshop was located in the south eastern corner of the site. The maintenance in the Ladysmith workshop reportedly comprised both mechanical and electrical and contained oils and hydrocarbon based lubricants. A reported wash area for tanks containing surfactant materials comprising detergents, amines, alcohols and oxylates and was located in the south eastern area of the site.

During the site walkover it was reported by Huntsman personnel that a former mine plant may have been located in an area between the laboratory and the CAP B plant. It was reported that this area *may* have been used as a 'multi-purpose' facility comprising development and laboratory trials of potential amine and surfactant products.

3.3. Environmental Setting

The environmental setting has been previously established during URS's Phase II investigation, a summary of which is presented in the sections below. The full Phase II investigation is available as an appendix to the Remediation Statement.

3.3.1. Geology and Hydrogeology

The geology and hydrogeology of the site is complex and is described in full in Section 2.3 of the Phase II Investigation. In summary, the main formations encountered in Plot B comprise:

- Made Ground: the man made or disturbed ground formed when the site was developed. Generally granular fill is considered to promote preferential groundwater flow both vertically and horizontally, however this has been complicated by concrete foundations, likely engineering earthworks, and other subsurface features. This was found to overlie natural deposits as described below.

- Glacial Till (Boulder Clay) (the "drift"): present as firm silts or soft clays across parts of Plot B. The absence of drift in some parts is likely to be due to excavation to bedrock during the construction of foundations and/or earthworks.

- St Bees Evaporite Formation (late Permian): present as either pink grey crystalline limestone or as yellow sandstone at a number of locations across Plot B. This formation is classified as a non aquifer by the Environment Agency.

- The Brockram Formation (early Permian): comprising coarse, well cemented, clast supported breccias, typically only 1 – 2m in thickness is shown to sub crop beneath the northern part of the site in BGS Geological Maps. This formation underlies the St Bees Evaporite Formation at shallow depth beneath Plot B, although its was not encountered in the exploratory holes advanced during this investigation. This formation unconformably overlies the Whitehaven Sandstone Formation. This formation is classified as a minor aquifer by the Environment Agency.

- The Whitehaven Sandstone Formation (Westphalian C to D, Carboniferous): comprising medium to coarse grained purple to purple-brown sandstones which are cross bedded throughout with thin interbeds of mudstones and siltstones bedded with sandstones and siltstone. This formation is classified as a minor aquifer by the Environment Agency.

URS considers there are two main groundwater systems:

- Perched shallow groundwater was encountered in parts of Plot B within the made ground and drift deposits at depths ranging from 0.9 – 4.1 mbgl. It is considered that there is no evidence to suggest the presence of a continuous shallow groundwater body beneath the site, although lateral continuity is likely to exist locally. Lateral shallow groundwater connectivity is complicated by building foundations, concrete supports for storage tanks, engineering groundwork and other subsurface features (e.g. drainage system).

  Bedrock has been observed to directly underlie areas of permeable made ground and drift deposits and therefore there is also likely to be vertical flow directly into the underlying bedrock.

- Deep groundwater flow is complicated and poorly understood. Deep groundwater is present at a depth of approximately 20 mbgl within the Whitehaven Sandstone, and flow beneath Plot B is considered to be broadly towards the Irish Sea (i.e. to the north and west).

  The St Bees Evaporite Formation has been affected by dissolution beneath certain parts of the site as a whole, primarily as a result of historic acid leakages and spillages affecting the site's drainage network and by historic mine workings. Dye tracing was undertaken in the 1990s by releasing dye into the drains in Plot B. The results indicated travel times in the order of seven hours to the Byerstead spring which discharges into the Irish Sea approximately 1.5km south west of the site. This ties in well with results from dye released into drainage in the area to the south or south east of Plot B, which also indicated a travel time of seven hours to the Byerstead spring.

The area to the south/south east of Plot B was formerly occupied a large acid concentrator and a large void within the St Bees Evaporite Formation has been identified beneath the former concentrator.

It is therefore considered that at the time of the dye tracing survey, drainage within Plot B flow across the area of Plot B to the area to the south/south east of the Plot where the solution feature was been identified within the St Bees Evaporite Formation and that the drainage from Plot B entered the solution feature there and not within Plot B.

The St Bees Evaporite Formation where identified within Plot B was dry and based on cross sections is likely to be less than 5m in thickness. It is therefore considered that the principal pathway for infiltrating water within Plot B will be vertically towards the deep groundwater table in Whitehaven Sandstone Formation and not laterally towards to the solution feature out with Plot B.

3.3.2. Surface Waters

Sandwith Beck and Pow Beck are located to the south of the site approximately 180m and 500m from the southern boundary respectively. Approximately 500m further east lies Bellhouse Gill which flows north easterly to meet another watercourse to create Pow Beck. Bellhouse Gill is thought to be connected to the site through a deep groundwater pathway, which passes through flooded mine adits before emerging as a spring near Bellhouse farm.

A watershed is present on the site with approximately two thirds of the site draining south towards Sandwith Beck and the northern third draining towards the coast to the north. Plot B is located in the northern area of the site and therefore is not considered to be in continuity with the identified surface water receptors.

The site has a drainage system for the collection and removal of surface water and the drainage systems below Plot B routes surface water to the west to the coast. The current proposal for the future of site drainage is to allow the extensive network of pipes to gradually silt up and collapse over time, as in the absence of operations they are not necessary.

3.4. Potential Receptors

Based on the environmental site setting and previous conceptual site models developed in the Phase II assessment URS considers the following to be the receptors potentially to be at risk from potential contamination within Plot B:

- *Deep groundwater*: The groundwater within the underlying Whitehaven Sandstone. This forms part of the Upper Carboniferous Lower Coal Measures unit, which is designated by the Environment Agency as a minor aquifer. The compliance point has been set at a theoretical point within the Whitehaven Sandstone at a distance of 50m down hydraulic gradient from the source area.

- *Human visitors*: Given that the proposed end-use for Plot B and the Site as a whole is recreational with open access to the public it is considered by URS that members of the public represent a potential receptor.

It s considered that the Byerstead spring is not a potential receptor as there is no evidence of direct connectivity between groundwater in the Whitehaven Sandstone beneath Plot Band the solution features in the overlying St Bees Evaporite Formation.

It should be noted that Copeland Borough Council determined the site as contaminated land on the basis of the pollutant linkages with regard to controlled waters receptors. Based on data provided from previous investigations at the site, detected contaminant concentrations were not considered to pose a significant potential risk to the identified human health receptors. (Full details of the risk assessment previously carried out are given in the Phase II report). However, based on the additional data provided from the most recent investigation it was considered prudent to revise and update the existing site-wide human health risk assessment to an area-specific review for Plot B.

Other potential receptors considered but not included in the assessment are presented below;

- *Shallow groundwater*: It is considered highly unlikely that shallow groundwater where present would be used for potable supply, or could sustain high enough yields to be used as such if the water quality was deemed good enough. Thus, in identifying a potentially sensitive controlled waters receptor, shallow groundwater where present is considered to represent a pathway for migration rather than a sensitive receptor.

- *Surface Waters:* Sandwith Beck, Pow Beck and Bellhouse Gill are located south of the site, however due to the watershed beneath the Rhodia site it is not considered that they are hydraulically connected to groundwater beneath Plot B and are therefore not considered further.

- *Coastal Waters*: The site lies close to the Irish Sea, which is situated approximately 1.3km to the west, a distant receptor of Plot B. It is considered likely that the majority of water in Plot B is discontinuous perched groundwater. However, in the event that water migrates downwards, it is likely that groundwater within Plot B will ultimately discharge to the coast. It is likely that deep groundwater within Plot B will move through deep strata westwards towards the coast. However, the risk assessment assumes a compliance point of 50m from the point of source, and assesses the risks at this point (as a conservative worst case). All points further away from this are likely to produce lower concentrations (due to greater dispersion, dilution etc), and hence are not considered further.

3.5. Potential Current and Historical Sources of Contamination

Based on observations during the most recent work and review of work undertaken during the previous Phase II investigation a number of potential current and historical sources of contamination have been identified. These are shown on Figure 3 and are listed below.

Historic on-site sources of potential soil and groundwater contamination:

1) Imidazoline plant – spillages and leaks from former above ground storage tanks (ASTs), reactors and blend vessels containing raw and finished products of acids (acetic, amphoacetate), fatty acid (lauric), alcohols (ethoxylated), amines (ammonium, nitrate, nitrogen) and anionic surfactants (measured as MBAS – methyl blue active substances). Spillages and leaks from ASTs containing hydrocarbon fuel and other leaks from associated drains and pipelines;

2) CAPB plant – spillages and leaks from former ASTs and individual boxed containers (IBCs) containing raw and finished products of caustic, amines (dimethylamidopropylamine, amino ethyl ethanol amine, ammonium, nitrate, nitrogen), acid (hydrochloric, sulphuric), fatty acid (coconut) and anionic surfactants (MBAS). Leaks from associated drains and pipelines;

3) Former coke works – hydrocarbon spillages and leaks from the production process. Waste materials deposited straight to ground, or buried within the subsurface. Leaks from associated drains and pipelines;

4) IBC product storage area – spillages and leaks of raw and finished products. Leaks from associated drainage;

5) Ladysmith engineering workshops – spillages and leaks of hydrocarbon oils and lubricants. Leaks from associated drains and pipelines;

6) Historical laboratories – leaks, spills or releases to ground of acids, alcohols, amines and other potential materials;

7) Electrical substations – located in both the imidazoline plant and adjacent to the CAPB plant. leaks or releases of insulating oils and lubricants;

8) Joinery workshop – spillages and leaks of hydrocarbon oils and lubricants;

9) Tank wash area – leaks, spills or releases to ground of acids, alcohols, amines and other potential materials;

10) Former amine plant – leaks, spills or releases to ground of acids, alcohols, amines and other potential materials;

11) Imported material to land raise – imported materials used for ground raising and reclamation (*e.g.* ash and clinker fill).

Other potential unknown sources – Naphthalene and phosphates. Firelighters were historically manufactured from a mixture containing naphthalene and it is possible the residual fingerprint of this contamination may be present in this area of the site. In addition, the site has processed phosphate over a long period of time. Phosphates have been detected at elevated levels in previous investigations across the Rhodia site. Given the extensive presence of phosphates, it is suggested that they are also tested for in Plot B.

4. FIELD OBSERVATIONS AND GROUND CONDITIONS ENCOUNTERED

4.1. Introduction

This section reviews the soil and groundwater conditions observed during the fieldwork and summarises the field evidence of impact identified as a result of visual/olfactory observations and/or the results of field screening. Interpretations are based on observations noted during the excavation of 30 trial pits and five boreholes (four of which were installed as monitoring wells) across Plot B during this investigation (Figure 4). The rationale for the sampling regime is presented in Appendix A and the field techniques employed during this investigation are detailed in Appendix B. Exploratory hole logs are presented in Appendix C. Exploratory hole locations are shown on Figure 4

Plot B is located on two terraced levels, a higher level comprising the former industrial works separated by an approximate two metre high wall and grassed embankment from the roadway and grassed area on the level below. Historically, industrial works located within Plot B have included a coking works, a foundry, a joiners shop, and more recently an imidazoline plant, the CAPB Plant, electrical substations, laboratories and storage tanks. In preparing the site for its historical use it is considered likely that engineered earthworks have taken place to develop the site to its current condition. However, on review of the ground conditions observed and the laboratory certificates of analysis no patterns of ground conditions have emerged to facilitate the discussion of Plot B by dividing it into sub-areas, and as such, it is described as a single area.

4.2. Soil Conditions

The ground conditions underlying the Plot B area are derived from the inspection of the arisings resulting from excavations and soil borings advanced during this investigation. A summary of the ground conditions encountered is provided in Table 4.1 below.

Table 4.1 – Summary of Typical Geological Profile Encountered

Unit	Description	Depth Encountered (m)	Maximum Thickness (m)
Made Ground	Reinforced concrete hardstanding	0 – 1.6	1.6
	Hardcore	0 – 2.1	2.1
	Loose, silty black or brown sand and gravel with brick, concrete and/or plastic	0.25 – 1.1	1.3
	Loose, black or brown sand and gravel with many man made components (fill)	0 – 2.7	>2.0
	Soft, orange red or black brown silt and clay with occasional gravel and cobbles	0.6 – 3.0	1.7
	Black silt layers with ash and clinker, or pockets or lenses of black ash and clinker	0.2 – 2.7	1.7

Unit	Description	Depth Encountered (m)	Maximum Thickness (m)
	Concrete foundations	1.2 – 2.7	Not proven
Natural Ground (Drift)	Glacial Till (Boulder Clay) Deposits typically comprising: Firm red brown silt or soft dark brown clay with occasional gravel, cobbles and lenses of sand. Occasionally contains layers of loose, yellow brown silty, sand and gravel	0.4 – 5.2	5.2
Natural Ground (Bedrock)	St Bees Evaporites, typically comprising: Pinky grey, fine to medium crystalline deposit	1.8	Not Proven
	Siltstone, comprising: Firm, friable, red brown siltstone with occasional gravel and lenses of sand	1.6 – 2.5	0.9
	Sandstone, comprising: Thickly or thinly bedded yellow brown fine grained sandstone	1.6 – 4.0	Not Proven
	Brockram: A poorly sorted conglomerate	1.6-2.5	Not proven

Geological field observations are presented in Figure 5. A geological map is presented as Figure 6 and a geological cross section in Figure 7. The geological sequence observed is summarised below.

Made Ground

The Made Ground varied in thickness from 0.4m at TP671B to greater than 3.1m at TP664B and appears to be slightly thicker in former production/tank/basement areas in the eastern section of Plot B. Made Ground also appears to be thicker in the western section of Plot B, possibly associated levelling of this area during construction of the plant.

Reinforced concrete hardstanding (0.15 – 1.6m in thickness) was encountered in most of the investigation locations, forming the foundations and floor slabs of the former plant buildings. Concrete was thickest in the area of trial pits TP653B and TP652B in the area of a former roadway; and a former tank farm respectively. The concrete hardstanding was usually found to be underlain by a layer of hardcore (typically 0.3m in thickness), though this was not identified in TP653B and TP652B and was observed to be resting directly above bedrock in TP653B.

Where concrete hardstanding was not present, the surface layer consisted of hardcore, fill or topsoil. These locations were found to be around the west, east and north edges of Plot B, surrounding the former industrial works.

Beneath the surface layer, the Made Ground typically comprised one or more of the following:

- Silty or clayey, black or brown sand and gravel, with brick, concrete and/or plastic;
- Soft, black or orange/red brown silt and clay with occasional gravel and cobbles. This is likely to be reworked drift;

- Black or brown sand and gravel with many man made components including brick, concrete, plastic, wood, wire, cable, pipe, corrugated iron, clinker, ceramic, tubing, glass, fabric and tiles ('Fill Material'). This was found towards the outer boundary of the former plant area, where concrete was not typically present at the surface (2.0m thick at TP654B, > 2.5m at TP656B, 1.2m at TP659B, 1.1m at TP664B, and 2.0m at TP675B), and at two locations on the lower terrace grassed area (3.2m at TP677B and 1.2m at TP679B);

- Clinker was found to be widespread over Plot B, as discreet pockets within the Made Ground. At TP664B a 0.5m thick lens of clinker, fibres, brick and rootlets was observed within the drift (2.0m bgl). It is considered likely that the clinker was transported here through a former drain; and

- Concrete foundations at depth (at 1.5m in TP651B, 2.0m in TP652B, 2.0m in TP654B, 2.5m in TP656B, 1.2m in TP659B, and 2.2m in TP667B). Based on observations made at the time of investigation these were considered to be associated with former buildings, storage tanks or roadways.

Site observations indicate former basements may have been infilled during demolition with, brick walls observed during the excavation of TP679B, and at TP652B. It is considered likely that a basement existed beneath the former imidazoline plant, as fill material was found above concrete foundations at depth. These and the presence of contaminated perched groundwater prevented further excavation.

Natural Ground (Drift)

Drift deposits were only observed in the central area of Plot B. In the other areas, drift was not observed either because the Made Ground directly overlay bedrock (TP653B, TP658B, TP669B, TP672B and TP677B), or because the presence of contaminated groundwater, unstable Made Ground or concrete foundations prevented further excavation.

Drift deposits were observed up to a maximum thickness of 5.2m, however the base of the drift deposits were not proven at all locations, potentially indicating a greater thickness in some areas. Drift deposits appear to increase in thickness towards the southwest of the site, with most locations in this section of Plot B having greater than 2m present. In the northeast section the drift tends to be thinner, possibly due to excavations for foundations, former landscaping, or natural pinching out.

Where observed, the drift typically comprised Glacial Till (Boulder Clay) deposits, which included:

- Firm, red brown silt with occasional gravel, cobbles, and lenses of yellow fine sand (found at most locations);

- Soft, black and dark brown mottled clay or silt and sand (found at most locations); and

- Yellow and brown silty sand, sand and gravel (found at locations to the south and west of Plot B).

Natural Ground (Bedrock)

Bedrock was encountered at eleven locations across Plot B between 1.6m bgl and 5.2m bgl, with the depth to bedrock steadily increasing to the southwest. The lithologies observed were as follows and all are considered to be representative of the St Bees Evaporite Formation:

- Pink grey, fine to medium crystalline limestone (1.8m bgl at TP658B) or weathered, grey white coarse gravel of limestone (5.2m bgl at WS555B);

- Siltstone comprising firm, friable, red brown siltstone with occasional gravel and lenses of sand (1.6m bgl at TP666B); and

- Sandstone comprising thickly or thinly bedded, yellow brown, fine grained sandstone (at depths ranging from 1.6m bgl to 4.0m bgl at TP653B, TP666B, TP669B, TP670B, TP671B, TP672B, TP673B, TP674B, TP677B, and TP678B). The surface of this was observed to be weathered at TP653B, TP666B and TP671B.

4.3. Groundwater Conditions

Perched groundwater was encountered within the made ground and the drift deposits during the excavation of the trial pits and dipping of the monitoring wells in Plot B. The locations where groundwater was encountered are summarised in Table 4.2 and monitored groundwater levels monitored on 30th August 2006 are summarised in Table 4.3 (and Table 1 in Appendix D). The extent of groundwater within Plot B is illustrated on Figure 6. Field methodologies are presented in Appendix B.

Table 4.2 – Summary of Encountered Groundwater

Location	Depth Encountered (mbgl)	Strata	Comments
TP651B	0.6 (drain)	Made Ground	Water ran into pit through old drain.
TP654B	0.9	Made Ground	Pit filled with water. Strong chemical odour
TP659B	1.0	Made Ground	Pit rapidly filled with water. Oily sheen on surface
TP660B	1.0	Made Ground	Pit rapidly filled with water. Diesel on surface
TP663B	1.6	Sand (Drift)	Water steamed into pit through silt & sand layer.
TP664B	2.0	Silt (Drift)	Water present in silt lens. Strong chemical odour
TP667B	1.7	Made Ground	Sludge filled pit at 1.7m
TP668B	4.1	Silt (Drift)	Water seeping in at base of pit. Oily sheen on surface
TP670B	2.5	Sand (Drift)	Wet at base of pit
TP672B	3.2	Made Ground	Water seeping through black silt layer. Strong HC odour
TP675B	1.0	Made Ground	Pit rapidly filled with water. Black, oily sheen
WS552B	3.129	Silt (drift)	Groundwater encountered during dipping round. Oily sheen on surface
WS553B	2.5	Made Ground	Oil encountered during dipping round. Oily sheen, moderate odour

Table 4.3 – Summary of Groundwater Monitoring

Monitoring Well	Depth to Groundwater (mbtc)	Groundwater elevation (mAOD)	Comments
WS551B	dry	-	Dry
WS552B	3.129	88.991	Brown, silty, slight oily sheen
WS553B	2.760	89.540	Dark brown, moderate hydrocarbon odour
WS554B	not installed	-	Monitoring well not installed
WS555B	dry	-	Dry, strong chemical odour from open well
WS114	lost	-	Unable to locate
WS165	2.555	-	NVO, unable to sample

mbtc- meters below top of casing

Where perched water was encountered within the made ground it was typically observed within permeable fill material overlying impermeable foundations along the eastern boundary of Plot B, at TP654B (0.9m), TP675B (1.0m), TP659B (1.0m) and TP660B (1.0m). It is considered likely that the extent of the perched water is continuous across this area of the site, and probably limited vertically by the presence of concrete or foundations (observed at TP654B at 2.0m and TP659B at 1.2m).

Localised groundwater was encountered both within the made ground and the drift in the north part of Plot B in TP663B (1.6m), TP664B (2.0m), TP667B (1.7m), TP672B (3.0m), WS552B (3.1m) and WS553B (2.5m). Water was observed entering the trial pits through permeable lenses or layers of silt or sand. Standing water was measured in WS552B and WS553B during the dipping and sampling of the monitoring wells. This groundwater is considered to be present in localised permeable lenses within the Made Ground or the Glacial Till deposits and is unlikely to be continuous over large areas. It is noted that a potential source of localised groundwater could be old drains.

Permeability

Based on field observations Made Ground appeared to be of relatively high permeability, with ready movement of water through sand, gravel and/or hardcore. These fill materials were also identified at most locations advanced on Plot B.

The majority of the drift encountered appeared dry, with isolated wet or damp patches usually in sandy lenses. Where encountered, the sand layers were mostly wet. During the dipping of the monitoring wells, water was observed in WS552B, and a very small amount in WS553B whist the other wells were dry. This suggests that the drift is of relatively low permeability, with the potential to transmit water through localised sand layers and lenses.

Bedrock was generally observed to be dry. In places, evidence of water movement was present e.g. black staining in sandstone at TP653B.

4.4. Field Observations of Contamination

Field observations (visual and olfactory evidence) and Photo Ionisation Detector (PID) readings were recorded to provide information on the location and nature of potential contamination. This evidence is presented below in Table 4.4, which summarises areas of potential contamination and likely sources, which are in turn discussed below.

Table 4.4 – Field Observations of Contamination

Location	Made Ground	Drift	Bedrock	Groundwater
TP651B	Strong HC odour	-	-	NVO
TP652B	NVO	-	-	-
TP653B	NVO	-	PID 11.0ppm at 2.3m, moderate chemical odour and black staining	-
TP654B	PID 90.1ppm at 2.0m, strong chemical odour	-	-	Strong chemical odour
TP655B	NVO	Anaerobic odour	-	-
TP656B	PID 38.2ppm at 1.0m & PID 14.1ppm at 2.3m	-	-	-

Location	Made Ground	Drift	Bedrock	Groundwater
TP657B	NVO	NVO	-	-
TP658B	NVO	-	NVO	-
TP659B	PID >1000ppm at 1.0m, strong chemical odour, contains clinker and tar	-	-	Oily sheen on surface
TP660B	PID 597ppm at 1.5m, chemical odour	-	-	Oily sheen on surface
TP661B	PID 51.6ppm at 0.4m	NVO	-	-
TP662B	PID 145ppm at 0.5m, moderate chemical odour, black oil leaking from broken pipe	-	-	-
TP663B	NVO	NVO	-	NVO
TP664B	PID 36.9ppm at 2.0m, strong chemical odour, contains clinker and fibres	-	-	Strong chemical odour
TP665B	PID 165ppm at 0.9m, strong chemical odour, contains fibres and tar	PID 132ppm at 1.3m, contains black tarry lenses	-	-
TP666B	NVO	PID 42.6ppm at 0.7m and 32.3ppm at 1.5m, moderate chemical odour	PID 76.9ppm at 2.2m, 867ppm at 2.5m and 430ppm at 3.5m, moderate to strong chemical odour	-
TP667B	Chemical and phenol odours, contains clinker	-	-	NVO
TP668B	PID 209ppm at 1.0m, strong chemical odour, contains clinker	PID 121ppm at 2.5m and 57.1ppm at 3.9m, patches of black staining and oily sheen	-	Oily sheen on surface
TP669B	PID > 1000ppm at 0.5m, strong chemical odour, contains clinker	-	-	-
TP670B	NVO	Rare pockets of black staining	-	-
TP671B	NVO	PID >1000ppm at 1.5m and 562ppm at 2.2m, black staining and moderate chemical odour	PID 224ppm at 4.0m	-

Location	Made Ground	Drift	Bedrock	Groundwater
TP672B	Black staining, strong HC odour, contains clinker	-	PID 58.8ppm at 3.5m, strong HC odour	Strong HC odour
TP673B	NVO	PID 81.7ppm at 2.5m, oily sheen, moderate HC odour	-	-
TP674B	PID 479ppm at 0.8m	PID 705ppm at 1.6m and 128ppm at 3.0m, black lenses of moderate HC odour	-	-
TP675B	PID 53.7ppm at 2.3m, oily sheen, contains clinker	-	-	Black colour, oily sheen
TP676B	Contains clinker	NVO	-	-
TP677B	PID 33.3ppm at 1.6m, oily sheen, faint HC odour, contains clinker	-	-	-
TP678B	NVO	NVO	NVO	-
TP679B	Contains ash	-	-	-
TP680B	NVO	Black staining, slight HC odour	-	-
WS551B	PID 22ppm at 0.5m	NVO	-	-
WS552B	NVO	NVO	-	Oily sheen on surface
WS553B	PID 348ppm at 2.5m, black staining and strong odour	-	-	Oily sheen, moderate odour
WS554B	Sulphurous odour	-	-	-
WS555B	NVO	Strong odour	-	-

HC hydrocarbon
NVO no visual or olfactory evidence of contamination
PID photo ionisation detector
"-" Not observed

Made Ground Contamination

Contamination was noted in the Made Ground at many locations within Plot B. The source of this is mostly likely to be residual, from the deposition of the Made Ground and former site operations. The different types of contamination identified are as follows:

- Ash and clinker were observed in TP659B, TP664B, TP667B, TP668B, TP669B, TP672B, TP675B, TP676B, TP677B, TP679B, WS553B and WS554B. These deposits appear to be more common in the centre of Plot B, and tend to be found either in a 0.1m – 0.6m thick layer near the top of the Made Ground, or associated with thick layers of fill material;

- Elevated PID readings were noted in the Made Ground in: TP654B*, TP656B, TP659B*, TP660B*, TP661B, TP662B**, TP664B*, TP665B, TP668B, TP669B*, TP674B, TP675B*, TP677B, WS551B and WS553B;

- Chemical odours were observed in: TP651B, TP654B*, TP659B*, TP660B*, TP662B (considered likely to relate to a broken pipe), TP664B*, TP667B (phenol), TP668B, TP669B*, TP672B*, TP677B (hydrocarbon), WS553B and WS554B; and

- Black staining was present in TP672B* and WS553B

Based on field observations it is considered likely that the source contamination which may be associated with the black staining and the elevated PID results is derived from the transport of contaminants to these locations by infiltrating rainwater or old drains/historic spillages rather than residual concentrations relating from fill materials.

Contaminated Groundwater

Groundwater with an oily sheen on the surface and/or hydrocarbon odours was observed in the Plot B areas follows:

- Localised perched groundwater at TP664B (2.0m) and TP672B (3.2m) was found in black Made Ground and noted to have a strong hydrocarbon odour. It is considered likely that this may relate to a former channel or drain that has been infilled with contaminated material;

- Perched groundwater in Made Ground at TP654B, TP659B, TP660B and TP675B was observed to be black, with a strong chemical odour and an oily sheen on the surface. This was found in the eastern section of Plot B, and is considered likely to be laterally continuous between these locations with, vertical continuity limited by the presence of concrete foundations. The Made Ground was noted to also have evidence of contamination, however it was not possible to tell whether the source was from the Made Ground, or from the Perched Groundwater; and

- Perched groundwater in drift deposits at WS552B was noted to have an oily sheen on the surface of the water; and water sampled from WS553B was noted to be very oily and had a moderate chemical odour.

Natural Ground

A band of trial pits, running north south down the centre of Plot B were noted to have pockets or lenses of wet, black staining within the drift and/or bedrock, chemical odours, and/or elevated PID readings. This type of contamination was observed as follows:

- Wet lenses or pockets of black staining were observed in Drift at TP665B*, TP668B*, TP670B, TP671B, TP674B* and TP680B;

- Chemical odours were noted in Drift at TP666B, TP671B, TP673B (hydrocarbon), TP674B*, TP680B (hydrocarbon) and WS555B*;

- Elevated PID readings were noted in Drift at TP665B*, TP666B, TP668B*, TP671B, TP673B and TP674B*;

- Wet, black staining of Bedrock was observed at TP653B;

- Chemical odours were noted in Bedrock at TP653B, TP671B, TP672B* (hydrocarbon) and WS553B; and

- Elevated PID readings were noted in Bedrock at TP653B, TP666B, TP671B and TP672B*.

* Elevated PID readings, chemical odours and/or black staining was also observed in the Made Ground at these locations, hence the source could potentially be from this, rather than the perched groundwater.

Trial pits where no visual or olfactory evidence of contamination include: TP652B, TP655B, TP657B, TP658B, TP663B and TP678B. These trial pits are generally located in the centre of Plot B, where a road formerly existed between the imidazoline plant and the CAPB plant.

4.5. Geochemical Results

The analytical schedules and results of chemical analyses are provided in detail in Tables 2a, 2b and Tables 4 to 11 included in Appendix D to this report. The laboratory certificates are also included in Appendix D to this report.

This section introduces an initial understanding of the distribution of key analytes detected in the soil, leachate and groundwater on the site. The term 'elevated' refers to the comparison between a reported analyte concentration compared to an average concentration for that compound calculated from all data across the investigation area. An assessment of whether the analyte concentration represents a "significant risk" to either controlled waters or human health receptors is made within Sections 6 and 7 in this report.

Volatile Organic Compounds (VOCs)

VOCs were detected at concentrations greater than the laboratory method detection limit (MDL) in each of the 17 of the samples submitted for analysis. No samples were scheduled for leachate analysis. Elevated concentrations of VOCs are summarised in the Table 4.5 below:

Table 4.5 – Elevated Concentrations of VOCs

VOC in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
1,2,4-Trimethylbenzene	0.015	14.890	3	Made Ground
1,2-Dichlorobenzene	0.009	41.340	1	Bedrock
1,2,5-Trimethylbenzene	0.030	7.930	3	Made Ground
Benzene	0.003	99.180	2	Made Ground
Cis-1,1,2-Dichloroethene	0.002	3.074	1	Drift
Ethylbenzene	0.004	6.880	2	Made Ground
Isopropylbenzene	0.009	0.350	3	Made Ground
M,P-Xylene	0.001	111.28	2	Made Ground
Naphthalane	0.085	5,734.64	3	Made Ground
O-Xylene	0.001	31.270	2	Made Ground
P-Isopropyltoluene	0.028	0.260	1	Made Ground
Propylbenzene	0.035	0.330	2	Made Ground
Sec-Butylbenzene	0.150	0.380	1	Made Ground
Styrene	2.054	19.220	1	Made Ground
Tetrachloroethane	0.013	0.018	1	Drift
Toluene	0.001	60.90	2	Made Ground
Trichloroethene	0.007	8.520	2	Drift

It should be noted that these elevated concentrations were reported from five samples: Made Ground from TP660B (1.5m), TP665B (0.9m) and TP672B (3.5m), drift (silt) from TP671B (1.5m and 2.2m) and bedrock (sandstone) from TP653B (2.3m). TP653B and TP660B are located on former roadways, and TP665B, TP671B and TP672B are located beneath former processing facilities.

For the most part, elevated readings PID readings (>10ppm) occur where the laboratory analysis identified VOC compounds. However, at TP661B and TP666B, a relatively small amount and number of VOC compounds have been detected but elevated PID readings were recorded.

Four groundwater samples were submitted for VOC analysis, two grab samples from the perched groundwater in the Made Ground (TP659B and TP675B), and two samples from the perched groundwater encountered in monitoring wells WS552B and WS553B. Furthermore, a Trip Blank and a Blank (labelled 'A') were submitted for analysis. VOC compounds were detected in each of the samples submitted with the exception of the Trip Blank. VOC concentrations in the groundwater sample submitted from WS553B were reported at up to three orders of magnitude greater than the other samples.

Metals

Seventeen soil samples were scheduled for metals analysis, and 18 samples scheduled for NRA leachate preparation and analysis. Elevated concentrations are summarised in Table 4.6 and Table 4.7 below:

Table 4.6 – Elevated concentrations of Metals (Soils)

Metal in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Arsenic	2	86	4	Made Ground (4)
Barium	5	1583	5	Made Ground (2), Drift (2), Bedrock (1)
Beryllium	1	4	1	Made Ground (1)
Boron	1	8	3	Made Ground (1), Drift (1), Bedrock (1)
Cadmium	1	9	1	Made Ground (1)
Chromium	1	47	7	Made Ground (3), Drift (3), Bedrock (1)
Copper	3	269	4	Made Ground (4)
Lead	17	559	4	Made Ground (4)
Mercury	1.9	518	1	Made Ground (1)
Nickel	3	119	5	Made Ground (2), Drift (2), Bedrock (1)
Vanadium	11	46	6	Made Ground (4), Drift (2)
Zinc	35	416	8	Made Ground (6), Drift (2)

Table 4.7 – Elevated Concentrations of Metal (Leachate)

Leachable Metal	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Arsenic	1	13	4	Made Ground (2), Bedrock (2)
Barium	6	398	6	Made Ground (3), Drift (2), Bedrock (1)
Boron	15	282	4	Made Ground (2), Drift (1), Bedrock (1)
Chromium	1	3	1	Made Ground (1)
Copper	1	78	4	Made Ground (2), Bedrock (2)
Lead	1	47	2	Made Ground (2)
Mercury	0.09	0.76	1	Made Ground (1)
Nickel	1	139	4	Made Ground (2), Drift (1), Bedrock (1)
Selenium	1	3	1	Made Ground (1)
Vanadium	1	38	3	Made Ground (3)
Zinc	4	332	3	Made Ground (3)

The majority of elevated concentrations of metals were reported in soil samples collected from within the Made Ground. As is typical with any historic industrial facility, ash and clinker were used as fill during levelling ground works on the Whitehaven site and these are typically considered to be a likely source for the increase of concentrations of metals in shallow horizons. The locations with elevated concentrations of metals in the Made Ground are generally found in the northeast corner of Plot B, in the former plant areas.

Elevated concentrations of metals in soil and leachate were also observed in Drift and Bedrock. In soil these were observed in clay at TP655B (barium, chromium, nickel, vanadium and zinc), silt and sand at TP674B (barium, boron, chromium, nickel, vanadium and zinc), and in sandstone at TP666B (barium, boron, chromium and nickel). Leachate analysis identified elevated metal concentrations in silt at TP657B (barium and nickel), silt at TP668B (boron and nickel), silt and sand at TP674B (barium), sandstone at TP653B (arsenic and copper) and sandstone at TP666B (arsenic, barium, boron, copper and nickel). The reported concentrations of barium, boron, chromium and vanadium are considered to lie within a similar range to natural background rock concentrations reported by the British Geological Survey (BGS. 1992 Regional geochemistry of the Lake District and adjacent areas. Keyworth, Nottingham) and are therefore not considered to be site derived.

Three water samples were submitted for metal analysis: WS552B, a Blank (labelled A) and a Trip Blank. Metals were detected in the WS552B (arsenic, boron, nickel and zinc) and in the Blank (arsenic, boron, copper, nickel, selenium and zinc).

Anionic Surfactants

Thirty two soil samples were scheduled for surfactant analysis in soil, eleven samples contained surfactants at concentrations above the MDL (six in samples from Made Ground, four in samples from Drift, and one in a sample from Bedrock), fifteen samples did not contain detectable amounts of surfactants, and six samples could not be analysed due to high clay content. The minimum reported concentration was 0.8mg/kg in Made Ground at 3.2m in TP677B, and the maximum reported concentration was 180mg/kg in Made Ground at 0.5m in TP662B.

Leachate analysis was undertaken on 62 soil samples. Surfactants were detected at concentrations exceeding the MDL in 37 samples. The minimum concentration reported was 60µg/l and the maximum 56,000µg/ (from Made Ground at 0.4m in TP661B. Six concentrations are considered elevated, five from the Made Ground (TP651B 0.7m and 1.3m, TP661B 0.4m, TP662B 0.5m and TP669B 3.5m), and one from the bedrock (sandstone at 3.5m inTP666B).

Two water samples were analysed for surfactants, WS552B and a trip/field blank. A concentration of 4,700µg/l was reported for WS552B, and surfactants were not detected in the blank.

Elevated concentrations of surfactants in soil and leachate appear discontinuously across the entire area of Plot B.

Semi Volatile Organic Compounds (SVOCs)

Twenty three soil samples were scheduled for SVOC analysis and ten for polycyclic aromatic hydrocarbons (PAH). SVOCs and/or PAHs were detected in 27 of these samples. Of these, six samples from the Made Ground reported concentrations of up to five orders of magnitude greater than the others, and account for all elevated concentrations. These are samples from TP659B (1.0m), TP660B (1.5m), TP664B (2.0m), TP665B (0.9m), TP669B (0.5m) and TP677B (1.6m), and are summarised in Table 4.8 below:

Table 4.8 – Elevated Concentrations of SVOCs (Soils)

SVOC / PAH in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Samples with elevated concentrations
2,4-Dimethylphenol	2.4	140.9	TP677B
2-Methylnaphthalene	4.5	797.9	TP659B, TP665B & TP677B
2-Methylphenol	13.3	107.5	TP677B
4-Methylphenol	30.9	268.6	TP677B
Acenaphthene	0.014	4,440	TP659B, TP660B, TP665B, TP669B & TP677B
Acenaphthylene	0.006	2,881	TP664B, TP665B & TP677B
Anthracene	0.009	4,471	TP659B, TP660B, TP664B, TP665B, TP669B & TP677B
Benzo(a)anthracene	0.024	2,975	TP659B, TP664B, TP665B, TP669B & TP677B
Benzo(a)pyrene	0.018	1,962	TP659B, TP664B, TP665B, TP669B & TP677B
Benzo(b)fluoranthene	0.041	1,364	TP659B, TP664B, TP665B, TP669B & TP677B
Benzo(g,h,i)perylene	0.03	883.5	TP659B, TP664B, TP665B, & TP677B
Benzo(k)fluoranthene	0.039	1,275	TP659B, TP664B, TP665B, TP669B & TP677B
Carbazole	0.6	374.3	TP659B, TP665B & TP677B
Chrysene	0.02	2,469	TP659B, TP664B, TP665B, TP669B & TP677B
Dibenz(a,h)anthracene	0.014	382.2	TP664B, TP665B & TP677B
Dibenzofuran	0.2	760.3	TP659B, TP665B & TP677B
Fluoranthene	0.099	8,853	TP659B, TP664B, TP665B, TP669B & TP677B
Fluorene	0.022	5,224	TP659B, TP664B, TP665B, TP669B & TP677B
Indeno(1,2,3-cd)pyrene	0.025	1,051	TP664B, TP659B, TP665B & TP677B
Naphthalene	0.04	9,246	TP659B, TP660B, TP664B, TP665B, TP669B & TP677B
Phenanthrene	0.04	12,863	TP659B, TP664B, TP665B, TP669B & TP677B
Pyrene	0.022	5,777	TP659B, TP664B, TP665B, TP669B & TP677B

SVOCs were reported above the MDL in 38 of the 64 samples for which leachate analysis was undertaken. Elevated concentrations are summarised below:

Table 4.9 – Elevated Concentrations of SVOCs (Leachate)

Leachable SVOC	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
2,4-Dimethylphenol	2	4,044	2	Made Ground (2)
2-Methylnaphthalene	1	801	10	Made Ground (6), Drift (4)
2-Methylphenol	3	1,161	1	Made Ground (1)
4-Methylphenol	2	4,449	2	Made Ground (2)
Acenaphthene	2	336	5	Made Ground (3), Drift (2)
Acenaphthylene	2	484	4	Made Ground (3), Drift (1)
Anthracene	1	31	2	Made Ground (1), Drift (1)
Carbazole	1	492	7	Made Ground (5), Drift (2)
Dibenzofuran	1	214	8	Made Ground (3), Drift (5)
Fluoranthene	1	18	3	Made Ground (3)
Fluorene	2	142	5	Made Ground (3), Drift (2)
Naphthalene	1	7,797	11	Made Ground (7), Drift (4)
Phenanthrene	2	158	6	Made Ground (4), Drift (2)
Phenol	10	376	1	Made Ground (1)
Pyrene	1	11	1	Made Ground (1)

Elevated concentrations were observed in Made Ground and within the drift deposits at a variety of depths. These locations are clustered in the area of the former CAPB plant and to the south of the former storage tank area.

Three water samples were analysed for SVOCs, WS552B, a field blank and a trip blank. SVOCs were only detected in WS552B, comprising 2-methylnaphthalene, acenaphthene, acenaphthylene, carbazole, dibenzofuran, fluorine, naphthalene and phenanthrene.

Total Petroleum Hydrocarbons (TPH)

Thirty three samples were submitted for TPH analysis; two for total TPH, and 31 for criteria working group (CWG) analysis. TPH was reported at concentrations exceeding the MDL in each of the samples submitted. Elevated concentrations were reported in Made Ground at TP651B (0.7m and 1.3m), TP654B (2.0m), TP659B (1.0m), TP660B (1.5m), TP661B (0.4m), TP668B (1.0m), TP669B (0.5m), TP672B (3.5m) and TP677B (1.6m) and TP664B (2.0m, clinker lens). In the drift, elevated TPH concentrations were reported at TP671B (2.2m), TP67B (2.5m), TP674B (3.0m), TP680B (2.0m) and WS555B (2.1m). Elevated concentrations were also reported in the Whitehaven Sandstone at TP653B (2.3m). The maximum reported concentration of total TPH is 52,292mg/kg from the ash/clinker lens at TP664B. The second and third highest total TPH concentrations were also in ash/clinker samples (TP669B and TP677B). The locations with elevated TPH concentrations are widespread across Plot B.

Twenty of the 31 samples analysed for leachable TPH reported concentrations above the MDL. Elevated concentrations were reported in Made Ground (TP654B, TP659B, TP660B, TP668B, TP669B, TP672B, TP675B and TP677B), Drift (TP664B, TP668B and TP674B) and bedrock (TP653B). The maximum reported concentration is 27,680µg/l, found in Made Ground at TP669B (0.5m). These are mostly located in the area of the former imidazoline and CAPB plants.

One water sample (WS552B) was analysed for TPH. A reported concentration of 164µg/l was reported with the dominant fractions C12 – C21 (aliphatic and aromatic).

Additional Analytes

Eight samples were scheduled for Polychlorinated Biphenyls (PCB) soil analysis and nine for leachate analysis. PCBs were detected in soil in only one sample, (TP675B, 2.0m) and were not detected in the leachate analysis.

Ten samples were scheduled for phenol soil and leachate analysis. Phenols were detected above the MDL in eight soil samples, with one concentration considered elevated (13.21mg/kg at 1.5m in TP660B). Leachable phenols were detected in two samples, with one elevated concentration of 940µg/l in TP660B (1.5m). The water sample WS552B contained 10µg/l of phenols (just above the detection limit).

Further additional analytes include: ammoniacal nitrogen (30 soil, 60 leachate, 1 water), chloride (1 water), cyanide (21 soil, 21 leachate, 1 water), nitrate (34 soil, 31 leachate, 1 water), phosphate (58 soil, 42 leachate, 2 water), sulphate (10 soil, 15 leachate, 1 water), sulphur (9 soil, 6 leachate), sulphide (10 soil, 5 leachate), thiocyanate (21 soil, 21 leachate, 1 water), and total organic nitrogen (31 soil, 60 leachate, 1 water). Table 4.10 below summarises the elevated concentrations reported for these analytes:

Table 4.10 – Additional Analyses Summary

Analyte	Maximum reported soil concentration (mg/kg)	Maximum reported leachate concentration (µg/l)	Number of samples with elevated soil concentrations	Number of samples with elevated leachate concentrations
Acid soluble sulphide	282	Not detected	1 (Made Ground)	-
Ammoniacal Nitrogen	1,063	530,000	4 (Mixture)	4 (Mixture)
Cyanide	4,230	61,080	1 (Made Ground)	1 (Made Ground)
Nitrate	235	11,900	5 (Mixture)	5 (Mixture)
Phosphate	18	2,700	2 (Made Ground)	7 (Mixture)
Sulphate	21,810	1,585,000	4 (Made Ground)	1 (Made Ground)
Sulphur	0.68	Not detected	2 (Mixture)	-
Thiocyanate	317	800	1 (Made Ground)	1 (Made Ground)
Total Organic Nitrogen	47.8	3,200,000	5 (Mixture)	1 (Made Ground)

The elevated concentrations of cyanide and thiocyanate were from Made Ground at TP660B (1.5m); these values far exceeded any others detected for these compounds on Plot B.

Summary

Based on the analytical results of this site investigation, it is considered that potential contamination is relatively widespread across Plot B (see Figure 8), with the majority of evidence of potential contamination being found in the upper terrace layer. Elevated concentrations of the analytes tested were found to be present in the made ground, the drift and the bedrock.

Of particular note are the pockets of clinker, [samples TP659B (1.0m), TP664B (2.0m), TP665B (0.9m), TP669B (0.5m) and TP677B (1.6m)] and the areas where perched groundwater is present in the Made Ground [samples TP654B (2.0m), TP659B (1.0m), TP660B (1.5m) and TP675B (2.0m)]. These samples contain high levels of potential contaminants including SVOCs, TPH, cyanide and thiocyanate.

In addition, elevated concentrations of PAH were detected at TP659 and TP665 which coincided with observations of black, viscous tarry contamination and at TP664, TP669 and TP677 where chemical and hydrocarbon odours were noted.

5. CONCEPTUAL SITE MODEL

5.1. Introduction

The objective of the conceptual site model is to place the environmental, geological and hydrogeological information obtained to date in the context of a risk-based setting, and produce a conceptual model of the site. The conceptual model of the site will highlight the primary sources of site contamination and the sources of exposure to potential receptors. The conceptual model assumes the site use is public open space.

The findings of this preliminary qualitative assessment will be used to define the extent and nature of the quantitative risk assessment.

Copeland Borough Council determined the site as contaminated land on the basis of the pollutant linkages listed below. These pollutant linkages are of a very general nature, and in order to present a meaningful assessment, URS has carried out a more detailed analysis, presented in the sections below.

Copeland Borough Council Pollutant Linkages
Petroleum Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Poly Aromatic Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Surfactants in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Phosphates in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Arsenic in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Boron in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Cadmium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Chromium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Copper in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Lead in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.

Copeland Borough Council Pollutant Linkages
Mercury in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Nickel in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Selenium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Zinc in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
VOC's/SVOCs in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.

5.1.1. Potential Sources

Potential contaminant sources on site associated with current and historical uses, as outlined previously in Section 3.5 and detailed in the Site Remediation Statement (23 June 2006 ref 44319877/R2234.B01) and the proposal and EA correspondence in Appendix C. These comprise the following**;**

Table 5.1a – Summary of potential Sources

Potential Sources	Contaminants of Concern
Imidazoline Plant	Anionic surfactants, sulphates, acids and fatty acids, alcohols, amines. Petroleum hydrocarbon associated with storage of heating fluid & plant operations.
CAP B Plant	Anionic surfactants, sulphates, caustic, amines, acids and fatty acids. Low volumes of petroleum hydrocarbons associated with plant operations.
Historical coke works	PAH, phenols, thiocyanate, total and free cyanide, heavy metals, petroleum hydrocarbons (arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc), sulphate, sulphur, sulphide
IBC product storage area	Anionic surfactants, sulphates, acids and fatty acids, alcohols, amines.
Ladysmith engineering workshops	Small volumes of petroleum hydrocarbon oils and lubricants.
Historical laboratories	Small volumes of anionic surfactants, sulphates, acids

Potential Sources	Contaminants of Concern
	and fatty acids, alcohols, amines.
Electrical substations	Polychlorinated biphenyls (PCBs)
Joinery workshop	Small volumes of petroleum hydrocarbon oils and lubricants.
Tank wash area	Small volumes of surfactants, sulphates, acids and fatty acids, alcohols, amines. Small volumes of petroleum hydrocarbon oils and lubricants.
Former amine plant	Surfactants, sulphates, acids and fatty acids, alcohols, amines.
Fill Materials	PAHs, petroleum hydrocarbons and heavy metals associated with ash and clinker fill. Potentially other contaminants associated with other materials.
Other Historic sources	Naphthalene, phosphate
Decommissioning Operations/ Site Drains & underground pipelines	TPH derived from leaks and spills. Asbestos, lead or other materials associated with buried demolition rubble

In their determination of the site as “contaminated land”, Copeland Borough Council listed a number of other contaminants which they considered likely to be present on the site as a result of its’ previous history. These contaminants were included in Assessment Action to ensure that the possibility of their being Contaminants of Concern is fully evaluated. Details of the sampling suite and rationale are presented in the proposal and subsequent correspondence between URS and the Environment Agency provided in Appendix C.

5.2. Potential Pathways

Copeland Borough Council's determination of the land as contaminated land refers to only two pathways – the movement of contaminants from soil to groundwater, and the migration of contaminants to controlled waters through drains. In the generation of the Remediation Statement, URS refined the understanding of the pathways. The pathways that are relevant to the land to which this report relates are listed below in Table 5.2a and are presented as a cross section in Figure 7.

Table 5.2a Pathway details

Pathway	Pathway characteristics
Controlled Water 1 (CW1)	a.) Infiltration of rainwater through contaminated soil and subsequent leaching and vertical movement to shallow groundwater. b). Migration of rainwater through the drainage system, possibly resulting in dissolution of contaminants and/or the mobilisation of contaminants within the drains, leading to discharge into shallow groundwater
Controlled Water 2 (CW2)	Vertical movement of dissolved or liquid contaminants from shallow groundwater to deep groundwater. This includes the movement of contaminants from streams running in anthropogenic (man-made) voids underneath the site within the shallow strata into deep groundwater. Movement from shallow groundwater to deep groundwater may be enhanced by engineering earthwork which is likely to have been undertaken in the development of the site (removal of drift, build up of made ground) and by faulting in certain areas or may also be retarded by the presence of concrete foundations and cellars.
Controlled Water 3 (CW3)	Lateral flow of deep groundwater within the sandstone aquifer to the 50m compliance point. Flow in a west/northwest direction towards the coast and the Irish Sea.
Human Health 1 (HH1)	Dermal contact/ingestion of contaminated soil.
Human Health 2 (HH2)	Inhalation of vapours from soil and/or groundwater.
Human Health 3 (HH3)	Inhalation of dust from contaminated soil.

5.3. Potential Receptors

Table 5.3a Receptor characteristics

Receptor	Receptor characteristics
Humans: Public using the open space	Mainly local residents, likely to use the site for dog walking and other recreation. The critical receptor (person most likely to come to harm) in the risk assessment was a female child aged 6 or under, visiting the site to play for an estimated average 119 days per year. Other more probable users would be at lower risk.
Controlled waters: Deep groundwater	Water in the Whitehaven Sandstone modelled to a 50m compliance point from beneath the site

5.4. Pollutant Linkages

For a significant 'pollutant linkage' to exist, a *source* of contamination (e.g. a leaking storage tank) must be connected to via a *pathway* (e.g. surface water) to a receptor (e.g. a nearby stream). Pollutant linkages apply to controlled waters and human health receptors.

5.4.1. Controlled Waters

The analytes that were considered to present a potentially significant risk to controlled waters were identified in Section 4.0 of the Site Remediation Statement document. Various pollutant linkages are thought to exist from these contaminant sources. Table 5.4a below shows the significant pollutant linkages considered to exist from the identified potential contaminants of concern to the identified controlled waters receptor (please note that the pathway codes refer to the pathways detailed in Table 5.2a).

Table 5.4a Particulars of Substances and Significant Harm/Pollution of Controlled Waters

Pollutant Linkage Identifier	Pollutant	Plot B Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
C1	Substances used in surfactant manufacture – amines, alcohols, acids, anionic surfactants	Imidazoline, CAP B, ASTs, IBCs, laboratories, wash down area	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer (which enters the Irish Sea after it has passed through the complex geological system in the area).
C2	Likely Substances from coke works – PAH, phenols, thiocyanate, total and free cyanide, heavy metals, TPH, sulphate, sulphur, sulphide	Historical cokework area	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer (which enters the Irish Sea after it has passed through the complex geological system in the area).
C3	Likely Substances from workshops – TPH, SVOC, PAH	Ladysmith and joinery workshops	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer (which enters the Irish Sea after it has passed through the complex geological system in the area).
C4	Likely substances from electrical substations – PCB, TPH, PAH	Imidazoline and CAP B electrical substations	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer (which enters the Irish Sea after it has passed through the complex geological system in the area).
C5	Substances associated with fill material – PAH, TPH, metals	Made ground comprising ash and clinker & other diffuse sources	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer (which enters the Irish Sea after it has passed through the complex geological system in the area).
C6	Substances associated with other historical activities – naphthalene, phosphate, trichloroethene	Diffuse (unknown)	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer (which enters the Irish Sea after it has passed through the complex geological system in the area).

5.4.2. Human Health

Copeland Borough Council determined the Rhodia site as contaminated land on the basis of the pollutant linkages with regard to controlled waters receptors. However, based on the additional data provided from the most recent investigation it was considered prudent to revise and update the existing site-wide human health risk assessment to a area-specific assessment for Plot B. Therefore Table 5.4b below shows the significant pollutant linkages considered to exist from the identified potential contaminants of concern to the identified human health receptors (please note that the pathway codes refer to the pathways detailed in Table 5.2a).

Table 5.4b Particulars of Substances and Significant Harm/Pollution of Human Health

Pollutant Linkage Identifier	Pollutant	Plot B Source location	Pathway	Main Receptor	Additional Receptors	Description of Harm/Pollution of Controlled Waters
H1	Substances used in surfactant manufacture – amines, alcohols, acids, anionic surfactants	Imidazoline, CAP B, ASTs, IBCs, laboratories, wash down area	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H2	Likely Substances from coke works – PAH, phenols, thiocyanate, total and free cyanide, heavy metals, TPH, sulphate, sulphur, sulphide	Historical cokework area	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H3	Likely Substances from workshops – TPH, SVOC, PAH	Ladysmith and joinery workshops	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H4	Likely substances from electrical substations – PCB, TPH, PAH	Imidazoline and CAP B electrical substations	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H5	Substances associated with fill material – PAH, TPH metals	Made ground comprising ash and clinker & other diffuse sources	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater

Pollutant Linkage Identifier	Pollutant	Plot B Source location	Pathway	Main Receptor	Additional Receptors	Description of Harm/Pollution of Controlled Waters
H6	Substances associated with other historical activities – naphthalene, phosphate	Diffuse (unknown)	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater

6. HUMAN HEALTH RISK ASSESSMENT

6.1. Introduction

Details of the rationale, methodology and results of the modelling undertaken for the human health quantitative risk assessment are presented in full in Appendix E and are summarised below.

The primary objective was to assess the potential risk to human health assuming the site is opened to the general public for a right-to-roam open space usage. The screening assessment is based on the current condition of the subsurface soil and groundwater beneath Plot B as detected by investigations undertaken at the site. The URS in-house model, Human7, which is based on the algorithms detailed in CLR10 was used to run the assessment.

6.2. Stage 2 Assessment

A Stage 2 generic screening risk assessment was undertaken using a residential without garden scenario. A number of substances were identified which exceeded their respective generic screening criteria:

Soil

- **Metals, metalloids and inorganic** – arsenic, barium, lead, nickel, cyanide, thiocyanate[5], mercury;
- **PAH** – acenaphthene, acenaphthylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, phenanthrene, pyrene, and naphthalene;
- **PCB** – total as Aroclor 1254
- **SVOC** – cis 1,2-dichloroethene, carbazole, dibenzofuran
- **TPH** – assessed via TPH Criteria Working Group (TPHCWG) fractions; and
- **VOC** – benzene, toluene, xylenes, trichloroethene (TCE).

Groundwater

[5] Sum of cyanide and thiocyanate compared to acute exposure value

- **VOC** – vinyl chloride, p-isopropyltoluene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, naphthalene, styrene, xylenes, and

- **SVOC** – 2-methylnaphthalene, carbazole, dibenzofuran.

6.3. Stage 3 Assessment

Those determinands identified as exceeding the Stage 2 screening criteria were taken forward to Stage 3 detailed quantitative assessment. At Stage 3, site specific assessment criteria (SSAC) were derived for a public open space end use using the URS Human 7 model.

Soil and groundwater site data was screened against the derived SSACs. Following the comparison of contaminant concentrations against SSACs, those compounds that exceeded the criteria were assessed in further detail using simple statistical tests in accordance with the guidance detailed in CLR7. This assessment was undertaken to derive averaging concentrations for the site area to which a receptor could potentially be exposed to while occupying the site. The contaminants considered potentially significant are summarised in the table below and shown on Figure 9.

Table 6.1 – Human Health Stage 3 Summary of SSAC Exceedances

Compound	Media	Locations at which US95 concentrations exceed SSAC	Pathway Contribution to Risk (% Contribution)
Cyanide	Shallow soil	TP659	Ingestion (100%)
Benzo(a)anthracene	Shallow soil	TP14, TP524, TP662, TP669, TP08, TP665, TP659	Ingestion (82%) Dermal (18%)
Benzo(a)pyrene	Shallow soil	TP14, TP11, TP12, TP16, TP524, TP662, TP669, TP08, TP658, TP665, TP656, TP659	Ingestion (82%) Dermal (18%)
Benzo(b)fluoranthene	Shallow soil	TP524, TP669, TP08, TP665, TP659	Ingestion (82%) Dermal (18%)
Dibenz(a,h)anthracene	Shallow soil	TP14, TP524, TP662, TP669, TP08, TP665, TP659	Ingestion (82%) Dermal (18%)
Fluoranthene	Shallow soil	TP669, TP665, TP659	Ingestion (82%) Dermal (18%)
Indeno(1,2,3-cd)pyrene	Shallow soil	TP524, TP669, TP08, TP665, TP659	Ingestion (82%) Dermal (18%)
Phenanthrene	Shallow soil	TP669, TP665, TP659	Ingestion (82%) Dermal (18%)

Compound	Media	Locations at which US95 concentrations exceed SSAC	Pathway Contribution to Risk (% Contribution)
Carbazole	Shallow soil	TP665, TP659	Ingestion (81%) Dermal (1%) Inhalation (18%)
TPH C16-21 aromatic	Shallow soil	TP659, TP669*	Ingestion (85%) Dermal (14.5%) Inhalation (0.5%)
TPH C21-35 aromatic	Shallow soil	TP659, TP669*	Ingestion (85%) Dermal (15%)

6.4. Sensitivity Assessment

The assessment has been based upon on a residential without gardens exposure model. In the context of the proposed future end use of the site as a 'right to roam' open land use, it is a conservative assumption designed to be suitably protective of future site users.

Examination of Table 6.1 indicates that the ingestion and dermal pathways dominate the modelled exposure. The variables that have most effect on the calculated SSAC are exposure duration and frequency and the extent to which the pathways are plausible.

Exposure Frequency & Duration

Given the lack of guidance regarding exposure duration and frequency for public open space scenarios, URS has undertaken a sensitivity analysis considering a less conservative time weighted average value of 92 days for each of the pathways modelled (see Appendix E). This results in a 2 – 3 fold increase of the SSAC modelled for each compound but it is unlikely to result in a significant change to the key identified locations of concern in Plot B.

Exposure Pathways

Exposure is controlled by whether a pathway exists or not. A significant portion of the site is covered with hardstanding and it is considered that the condition of the site will remain in this state for the proposed future use. It may therefore be assumed that complete direct contact pathways (ingestion, dermal contact and inhalation of soil derived dust) will not be plausible in those areas where hardstanding remains in place. Where hardstanding is present, only the outdoor vapour inhalation pathway is viable in assessing potential exposure. The most significant areas of contamination are located beneath areas of this surface cover. Taking this into account and assuming a vapour inhalation pathway only, no potential significant risks were identified from the contaminants detected in soil or groundwater at the site with the exception of those detected at elevated concentrations at TP524. No hardstanding cover is present at TP524 and although PAH compounds were detected, it is considered that the exposure frequency at this individual location would be so low (in the context of Plot B and the wider site area) that a potential risk is considered unlikely to be significant.

6.5. Summary of Risks to human Health

Potentially significant health risks were identified for future open space 'right to roam' site users based on a residential without gardens conceptual exposure model. Following a review of the plausibility of potential pollutant linkages modelled during the assessment it is considered that for the majority of the site the vapour inhalation pathway only is applicable as the majority of site contamination is located beneath a layer of hardstanding. Risks via the vapour inhalation pathway were not identified for Plot B.

However, PAH compounds were detected at TP524 where no hard standing is present. Assessment of the potential frequency of exposure for dermal and ingestion pathways at this location has been undertaken and it is considered that the exposure frequency would be so low that a potential risk is considered unlikely.

Therefore, should the current condition and layout of Plot B be maintained, it is considered that potentially significant risks to human health would be unlikely for a public open space scenario. Plot B is considered suitable for use as public open space without the requirement for further action with the exception of addressing Health and Safety issues (such as the removal of protruding trip hazards etc).

The risks to potential future maintenance, remediation or redevelopment workers who may be involved in subsurface working are not specifically assessed as part of this report. URS advises that separate activity related risk assessments should be carried out as required to comply with the necessary legislation and guidance, which identifies the need for any preventative measures (such as the use of PPE) to be completed prior to such activities being carried out. The results of this human health assessment however could be used to inform decision-making on this issue.Controlled Waters Quantitative Risk Assessment

7. CONTROLLED WATERS

7.1. Introduction

Details of the rationale, methodology and results of the modelling undertaken for the Controlled Waters Quantitative Risk Assessment are presented in full in Appendix G and summarised below.

7.2. Stage 2 Assessment

A Stage 2 generic quantitative screening risk assessment was undertaken, the results being summarised in Table 7.1.

Table 7.1 – Controlled Waters Stage 2 Summary of Screening Criteria Exceedances

Soil	Soil Leachate	Shallow Groundwater
benzene	benzene	benzene
toluene	toluene	toluene
ethylbenzene		
xylenes	xylenes	xylenes
naphthalene	naphthalene	naphthalene
1,2,4-Trimethylbenzene		1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene		1,3,5-Trimethylbenzene
1,2-Dichlorobenzene		
Cis-1,2-Dichloroethene		Cis-1,2-Dichloroethene
Styrene		Styrene
Trichloroethene		Trichloroethene
	arsenic	
	lead	
	nickel	nickel
	vanadium	
	ammoniacal nitrogen	ammoniacal nitrogen
	sulphate	
	total cyanide	total cyanide
	total petroleum hydrocarbons	
	2,4-dimethylphenol	
	4-methylphenol	
	acenaphthylene	
	carbazole	
	dibenzofuran	
	fluoranthene	
	phenanthrene	
	phenol	
		Chloride
		Vinyl chloride

All of the determinands whose concentrations exceeded their respective Stage 2 criterion were taken forward to Stage 3, detailed quantitative risk assessment.

7.3. Stage 3 Assessment

The Stage 3 assessment used ConSim (v2.2) to simulate concentrations at the receptor for three different scenarios, as described below:

- **Model 1** assumed that an unsaturated zone was present beneath the site. Model 1 assumed that up to approximately 18m of unsaturated zone exists underneath Plot B. The presence of an unsaturated zone is likely to allow attenuation to occur as the contaminants migrate vertically through seepage through sandstone matrix pore space. As a result, the concentrations of analytes predicted are likely to significantly reduce as they pass through the unsaturated zone, before eventually reaching the underlying water table. Once at the water table, groundwater was modelled to migrate laterally to the 50m compliance point. The model assumed the entire site (Plot B) was the source area. The model input concentration for each analyte was a statistical prediction (in this case the US95), considerate of all concentrations of the specific analytes detected within Plot B.

- **Model 2** assumed that fracture flow was the dominant mechanism for groundwater migration below Plot B. This model effectively assumed that the groundwater table within the Whitehaven Sandstone was positioned immediately below the source area (i.e. no unsaturated zone). Groundwater was modelled to migrate laterally to the 50m compliance point. As with Model 1, this model assumed the entire site (Plot B) was the source area. The model input concentration for each analyte was a statistical prediction (in this case the US95), considerate of all concentrations of the specific analytes detected within Plot B.

- **Model 3** utilised the same approach as Model 2. It was generated to assess whether the theoretical risks generated by analytes in Model 2 using the entire area of Plot B as a source area were also a risk if considered as a hotspot.

Current UK guidance conservatively requires that simulated 95th percentile concentrations are used to assess potential risks. However, in assessing the potential significance of an identified risk, predicted travel times and 50th percentile of predicted concentrations are taken into account. Simulated 50th and 95th percentile concentrations can be interpreted as follows:

- Simulated concentrations at the 50th percentile of predicted concentrations represent 'on the balance of probabilities' the most likely simulated concentrations given the range of parameters applied.
- Simulated concentrations at the 95th percentile of predicted concentrations represent a worse case or extreme condition, resulting from a worse case combination of parameters (e.g. high permeability, high source concentrations and low degradation rate).

The results of the Stage 3 assessment are summarised in Table 7.2.

7.4. Summary of Risks to Controlled Waters

The conservatism in Models 2 and 3 must be taken into account when considering the potential risk to controlled waters posed by residual contamination within Plot B. These models assumed fracture flow was the sole mechanism for transport. In reality, it is likely that a combination of fracture flow and flow through seepage through sandstone matrix pore space is occurring, with the migration through pores allowing attenuation to occur. Furthermore, attenuation can also occur in fracture flow. The connectivity of the fractures has also not been considered since the model has assumed migrating water passes vertically through a fracture directly to the water table. It is more likely that water migrates through a complex system of fractures within the 18m between the source zone and underlying groundwater table. This will increase the residence time of the water in this system, again increasing the attenuation that can occur.

The possible pollutant linkages identified relate to the risk of soil leachate or shallow contaminated groundwater entering the Whitehaven Sandstone minor aquifer by migration from the Made Ground source and directly into the underlying aquifer. A summary of the potential risks identified at both the 50th and 95th percentile of predicted concentrations for each model using a compliance point of 50m (Plot B boundary) and 400m (site boundary) is given in Table 7.2 below.

It must be noted that Model 1 may underestimate actual risks because of the paucity of data on vertical hydraulic conductivity and the presence of fractures that could provide a rapid flow mechanism. Models 2 and 3 are considered to be conservative in so far as an unsaturated zone has not been modelled, the results being unrealistically high breakthrough concentrations. It is considered that the “real “ situation would lie somewhere in between these models, with an unsaturated zone and a degree of attenuation in the unsaturated zone, which suggests that Model 1 is closer to actual site conditions.

Taking into account the physical site conditions, it can be seen that where soils, soil leachate and shallow groundwater with high concentrations have been identified, the majority of these are present in areas where concrete hardstanding is present at the surface. In addition, shallow perched groundwater has been identified, indicating that the potential for vertical migration is limited by the presence of buried concrete slabs or clayey drift deposits, suggesting that the majority of the contamination identified within Plot B is retained in the upper parts of the unsaturated zone. There is no evidence to suggest significant volumes of contaminants are entering bedrock.

Overall, taking into account both the physical site evidence and the results of the risk assessment and modelling, it is considered that the potential risks to controlled waters are insignificant, if present at all, i.e. there are no significant pollutant linkages with regard to controlled waters within Plot B.

Table 7.2- Controlled Waters Stage 3 Assessment – Summary of Results

Model/ Source	50m Compliance point						400m compliance point – Site Boundary					
	Soil		Soil Leachate		Shallow Groundwater		Soil		Soil Leachate		Shallow Groundwater	
	50%ile	95%ile	50%ile	95%ile	50%ile	95%ile	50%ile	95%ile	50%ile	95%ile	50%ile	95%ile
1	IR	IR	IR	IR	IR	IR	IR	IR	IR	IR	IR	IR
2	IR	Benzene (0.098mg/L), naphthalene (0.063mg/L), TCE (0.014mg/L)	Cyanide (0.063mg/L)	Ammoniacal nitrogen (0.761mg/L),benzene (0.003mg/L), cyanide (0.314mg/L), phenol (0.0020mg/L)	IR	Ammoniacal nitrogen (0.718mg/L), benzene (0.002mg/L), naphthalene (0.237mg/L)	NM	NM	NM	NM	NM	NM
3	Benzene (0.02mg/L)	Benzene (0.303mg/L), naphthalene (0.051mg/L), TCE (0.046mg/L)	Ammoniacal nitrogen (2.875mg/L), cyanide (0.332mg/L), benzene (0.0048mg/L)	Ammoniacal nitrogen (8.664mg/L, cyanide (1.002mg/L), phenol (0.0013mg/L), benzene (0.017mg/L).	IR	Ammoniacal nitrogen (0.64mg/L), benzene (0.0038mg/L), naphthalene (0.562mg/L)	IR	IR	Ammoniacal nitrogen (0.844mg/L, cyanide (0.061mg/L)	Ammoniacal nitrogen (2.564mg/L, cyanide (0.305mg/L)	IR	IR

IR- Insignificant Risk, NM- not modelled

8. REFINED POLLUTANT LINKAGE ASSESSMENT

The human health and controlled waters risk assessments have identified those analytes that pose a theoretical potential risk to the identified receptors. The following section provides a review on the plausibility of the modelled potential pollutant linkages.

With regard to the human health risk assessment, whilst some potential risks have been identified, the pathways identified for the derivation of the Stage 3 SSACs for those analytes being identified as a potential risk at Stage 3 are ingestion and dermal contact. Given that the majority of the site is covered in hard standing, these pathways are not considered to exist. Risks have not been identified at Stage 3 for the vapour inhalation pathway. For the area where hard standing is not present (TP524), there is no visual evidence of contamination and the source is therefore considered to be very small and localised. Thus, the possibility of ingestion or dermal contact with soil at this specific point is considered highly unlikely. Overall therefore, it is considered that there are no pollutant linkages with regard to human health within Plot B.

The controlled waters risk assessment has identified a number of potential risks associated with concentrations of: benzene, naphthalene, ammoniacal nitrogen, trichloroethene, cyanide and phenols. It should be borne in mind that the model that generated these predicted risks to controlled waters is conservative in that is has assumed that there is no unsaturated zone beneath the site. The main thrust of the risk assessment assumes a groundwater table directly beneath the source zone on the site. However, groundwater is present as an impersistent perched shallow groundwater body beneath Plot B, the regional water table being some 18m below ground level. Given the complexity of the geology and hydrogeology beneath the site, it is extremely difficult to generate a wholly representative model, hence a conservative model has been used. The results of the modelling therefore need to be treated with some caution as they are an overestimate of the actual risk. A model that assumed an unsaturated zone of 18m was also used in the assessment, this model predicted no risks.

A number of factors would influence the possibility of contaminants reaching the regional water table. Downwards migration of contaminants will be influenced by rainfall infiltration. Given that the site is primarily covered in hard standing, it is evident that the majority of rainfall will dissipate as surface run off to the drainage system. This is supported by the fact that where perched groundwater has been identified, it is located on concrete bases or impermeable drift deposits, i.e. downward migration is very limited. Thus, whilst contaminants have been identified in the soils there is very little evidence of significant vertical migration.

Overall, it is considered that the majority of contaminants identified with the soils and shallow perched groundwater beneath the site are retained in the unsaturated zone, as a result of the presence of buried concrete structures and impermeable drift materials. Whilst the results of the conservative quantitative risk modelling for controlled waters have identified a small number of theoretical risks, on the basis of the available site information, it is considered that there is insufficient evidence to demonstrate a significant pollutant linkage between contaminants identified in the soils and the regional water table.

Even if such a linkage were to exist, based on the results of the modelling using no unsaturated zone, the effects of attenuation within the aquifer would mitigate the majority of risks within 400m of the source and given that additional retardation or attenuation would occur in the unsaturated zone, it is considered that residual risks would be low and acceptable.

It is therefore concluded that whilst some theoretical risks have been identified at the site, based on the site remaining disused (as is) or becoming a public accessible amenity, with the hard standing areas remaining, actual risks to controlled waters or human health receptors are not present. Remedial action is not therefore considered necessary.

Based on the data obtained in this investigation and the discussion in the section above, the following table below provides a summary of the key findings from the assessment and a conclusion on whether the identified pollutant linkages are considered to be potentially significant or acceptable.

Table 8.1 – Refined Pollutant Linkage Assessment

Pollutant Linkage Identifier	Pollutant	Plot B Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
C1	Substances used in surfactant manufacture – amines, alcohols, acids, anionic surfactants & associated breakdown products	Imidazoline, CAP B, ASTs, IBCs, laboratories, wash down area	CW1, CW3, CW4 (leaching - deep groundwater)	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer	1) No. Source not identified for these contaminants
C2	Likely Substances from coke works – PAH, phenols, thiocyanate, total and free cyanide, heavy metals, TPH, sulphate, sulphur, sulphide	Historical cokework area	CW1, CW3, CW4	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer	1) No. This linkage modelled at Stage 3 and shown to be insignificant. See previous section for details.
C3	Likely Substances from workshops – TPH, SVOC, PAH	Ladysmith and joinery workshops	CW1, CW3, CW4	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer	1) No. This linkage modelled at Stage 3 and shown to be insignificant. See previous section for details.
C4	Likely substances from electrical substations – PCB, TPH, PAH	Imidazoline and CAP B electrical substations	CW1, CW3, CW4	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer	1) PCBs. No. Source not present. 2) TPH. No. Source not present. 3) PAHs. No. This linkage modelled at Stage 3 and shown to be insignificant.

Pollutant Linkage Identifier	Pollutant	Plot B Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
C5	Substances associated with fill material – PAH, TPH metals	Made ground comprising ash and clinker & other diffuse sources	CW1, CW3, CW4	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer	1) PAHs. No. This linkage modelled at Stage 3 and shown to be insignificant. 2) TPH. No. Source not identified.
C6	Substances associated with other historical activities – naphthalene, phosphate, trichloroethene	Diffuse (unknown)	CW2, CW3, CW4	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the sandstone aquifer	1) Naphthalene. No. This linkage modelled at Stage 3 and shown to be insignificant. 2) Metals. No. This linkage modelled at Stage 3 and shown to be insignificant. 3) Phosphate. Uncertain because no screening criteria exist. 4) Trichloroethene: This linkage modelled at Stage 3 and shown to be insignificant.
H1	Substances used in surfactant manufacture – amines, alcohols, acids, anionic surfactants	Imidazoline, CAP B, ASTs, IBCs, laboratories, wash down area	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Source not identified for substances used for surfactant manufacture.
H2	Likely Substances from coke works – PAH, phenols, thiocyanate, total and free cyanide, heavy metals, TPH, sulphate, sulphur, sulphide	Historical cokework area	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Pathways incomplete for cyanide. No. Source not identified/pathways incomplete for carbazole. No. Pathways incomplete for TPH C16-C21 and C21-C35 aromatic. Source not identified/pathways incomplete for remainder of TPH fractions. No. Pathways incomplete for benzo(a)anthracene. No. Pathways incomplete for Benzo(a)pyrene.

Pollutant Linkage Identifier	Pollutant	Plot B Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
							No. Pathways incomplete for Benzo(b)fluoranthene.
							No. Pathways incomplete for Dibenz(a,h)anthracene.
							No. Pathways incomplete for Fluoranthene.
							No. Pathways incomplete for Indeno(1,2,3-cd)pyrene.
							No. Pathways incomplete for Phenanthrene.
H3	Likely Substances from workshops – TPH, SVOC, PAH	Ladysmith and joinery workshops	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Pathways incomplete for TPH C16-C21 and C21-C35 aromatic. Source not identified/pathways incomplete for remainder of TPH fractions.
							No. Pathways incomplete for benzo(a)anthracene.
							No. Pathways incomplete for Benzo(a)pyrene.
							No. Pathways incomplete for Benzo(b)fluoranthene.
							No. Pathways incomplete for Dibenz(a,h)anthracene.
							No. Pathways incomplete for Fluoranthene.
							No. Pathways incomplete for Indeno(1,2,3-cd)pyrene.
							No. Pathways incomplete for Phenanthrene.
H4	Likely substances from electrical substations – PCB, TPH, PAH	Imidazoline and CAP B electrical substations	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Sources not identified for PCBs.
							No. Pathways incomplete for TPH C16-C21 and C21-C35 aromatic. Source not identified/pathways incomplete for remainder of TPH fractions.
							No. Pathways incomplete for benzo(a)anthracene.
							No. Pathways incomplete for Benzo(a)pyrene.
							No. Pathways incomplete for Benzo(b)fluoranthene.
							No. Pathways incomplete for Dibenz(a,h)anthracene.
							No. Pathways incomplete for Fluoranthene.
							No. Pathways incomplete for Indeno(1,2,3-cd)pyrene.

Pollutant Linkage Identifier	Pollutant	Plot B Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
							No. Pathways incomplete for Phenanthrene.
H5	Substances associated with fill material – PAH, TPH, metals	Made ground comprising ash and clinker & other diffuse sources	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Pathways incomplete for TPH C16-C21 and C21-C35 aromatic. Source not identified/pathways incomplete for remainder of TPH fractions.
							No. Pathways incomplete for benzo(a)anthracene.
							No. Pathways incomplete for Benzo(a)pyrene.
							No. Pathways incomplete for Benzo(b)fluoranthene.
							No. Pathways incomplete for Dibenz(a,h)anthracene.
							No. Pathways incomplete for Fluoranthene.
							No. Pathways incomplete for Indeno(1,2,3-cd)pyrene.
							No. Pathways incomplete for Phenanthrene.
H6	Substances associated with other historical activities – naphthalene, phosphate	Diffuse (unknown)	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Sources not identified.

9. REMEDIATION ACTIONS

9.1. Summary of remediation actions required relating to Pollutant Linkages Identified specific to Plot B

Based on the findings of the refined pollutant linkage assessment it is considered that no further remediation actions will be required to address the contamination issues identified in the Plot B Area.

9.2. Summary of remediation actions required relating to Part IIA Pollutant Linkages for the overall site area

For regulatory purposes it is necessary to explain how each of the pollutant linkages listed by Copeland Borough Council in their determination of the site as statutory Contaminated Land are dealt with. Table 9.1 below summarises the findings of the investigation and the actions applicable to each pollutant linkage.

Table 9.1 – Summary of Remedial Actions

Copeland Borough Council Pollutant Linkage	***Findings and Remediation Actions for Plot B***
Petroleum Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. Pathways incomplete. No remedial action required.*
Poly Aromatic Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. Pathways incomplete. No remedial action required.*
Surfactants in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkages identified. No source identified. No remedial action required.*
Phosphates in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*Screening criteria for phosphate are currently not available based on UK or other legislation. Therefore, the risk assessment cannot determine if a potential risk exists.*
Arsenic in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. No source identified/ pathways incomplete. No remedial action required.*

Copeland Borough Council Pollutant Linkage	***Findings and Remediation Actions for Plot B***
Boron in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. No source identified. No remedial action required.*
Cadmium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. No source identified. No remedial action required.*
Chromium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. No source identified. No remedial action required.*
Copper in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. No source identified. No remedial action required.*
Lead in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. No source identified/ pathways incomplete.*
Mercury in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. No source identified. No remedial action required.*
Nickel in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage identified. No source identified/ pathways incomplete. No remedial action required.*
Selenium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkages exists, as no source identified. No remedial action required.*
Zinc in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkages exists, as no source identified. No remedial action required.*
VOCs/ **SVOCs** in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage. Pathways incomplete. No remedial action required.*

TABLES

FIGURES

PHOTOGRAPHS

Appendix A - Proposal For Site Works

Appendix B - Field Methodology

Appendix C - Borehole & Trial Pit Logs

Appendix D - Laboratory Certificates & Historical Analytical Data (included on CD)

Appendix E - Human Health Detailed Quantitative Risk Assessment

Appendix F - URS GAC Advice Note

Appendix G - Controlled Waters Detailed Quantitative Risk Assessment

Appendix H - ConSim Model Inputs

(Electronic CD)