Remediation Statement
Appendix I

Plot G 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 G" - one of a sequence of plots on the Whitehaven site identified as requiring further assessment in the Site Remediation Statement. This report aims 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 G lies to the west of the centre of the site and includes the former fire water basin, the treatment basin, the site of four former cooling towers and the Fatty Alcohol and Ethoxylation Plant. Plot G is bordered to the south by former acid storage tanks and to the west by the Hutbank landfill. At the time of this investigation all above ground structures have been demolished, save for the Ethoxylation Plant 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 eight trial pits were excavated. Following the trial pitting exercise a limited shallow soil boring investigation was completed at three locations which allowed the installation of three monitoring wells. Soil and groundwater samples were collected and scheduled for a suite of analyses.

Ground conditions observed comprised made ground, overlying natural clay deposits 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 subsurface structures. The natural clay deposits were generally 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. Perched groundwater was encountered at TP758G, TP761G, TP763G, TP764G TP767G, WS130G and WS766G during the investigation.

A Stage 2 controlled waters generic screening exercise was completed on all data collected from within Plot G to date. The key receptor identified for the controlled waters assessment was the Irish Sea, located approximately 1.3km south west of the site. The screening exercise identified exceedances of the Stage 2 screening criteria in soil, leachate and groundwater. The screening exercise identified exceedances in soil for naphthalene, in leachate for arsenic, chromium, copper, lead, nickel, selenium, carbazole, naphthalene, and TPH (Total Petroleum Hydrocarbons) and in groundwater for chromium, zinc, TPH, anionic surfactant (MBAS), benzo (a) anthracene, benzo (a) pyrene, dibenzo (a,h) anthracene, and fluoranthene.

A Stage 3 detailed quantitative risk assessment was undertaken on contaminants that exceeded the Stage 2 criteria. This site specific assessment modelled groundwater flow towards the coastline through an onsite dilution model (Stage 3A) and a further offsite dilution model (Stage 3B). The Stage 3 risk assessment identified a potential risk associated with zinc. However, this was discounted as a risk due to the borderline exceedance of the screening criteria and the conservatism within the model.

Stage 3 modelling could not be performed on samples taken from certain locations where analytes had exceeded at Stage 2. This was due to a lack of sampling locations surrounding the potential areas of contamination. The gap in data was from one specific area, that of the footprint of the Ethoxylation Plant. This area could not be accessed during the site investigation as the plant structures were yet to be demolished and remained in place. An area encompassing ERMSB15 and WS130 was identified as requiring further investigation due to high groundwater concentrations of TPH and anionic surfactant (MBAS). PAH concentrations above the screening criteria were measured in WS130. An area of naphthalene contamination in shallow soil in the vicinity of TP758G could not be delineated, due to insufficient data points in the area, and was therefore identified as requiring further investigation.

The following outline scope of works is recommended to assess the necessity for remedial action.

The area in the vicinity of ERMSB15 and WS130 (and TP758G)

It is proposed that up to eight trial pits and up to four boreholes are advanced to 5mbgl (or bedrock, if shallower) in order to delineate the PAH and TPH contamination. Soil samples would be taken for analysis (and at 0.5m intervals for headspace screening), and water samples would be taken from boreholes for laboratory analysis. Also, concurrently with this investigation it is proposed that an investigation into naphthalene contamination in soil is undertaken in the area around TP758G.

Following completion of this additional investigation, the Stage 3 risk assessment will be updated and the pollutant linkage assessment refined accordingly.

A Human Health DQRA was also completed considering the proposed 'right-to-roam' end use. No significant risks were identified.

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 there are no significant pollutant linkages with respect to Human Health, either in the current site use or for the proposed 'right to roam' use.

For Controlled Waters, limited additional investigation is required to investigate possible significant pollutant linkages for TPH, MBAS and PAH.

The significant pollutant linkages declared by Copeland Borough Council with respect to phosphates, arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, and VOCs/SVOCs have been shown to not exist within Plot G.

1. INTRODUCTION

1.1. General Introduction

URS was commissioned by Rhodia on 16th February 2007 to undertake an intrusive soil and groundwater investigation at the former Albright & Wilson site in Whitehaven, Cumbria (the site) as detailed in URS Proposal 1941NG1111 (dated 19th February 2007). This work was requested by Rhodia UK Limited (Rhodia) at a meeting with URS Corporation Ltd (URS) on 5th February 2007.

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

The site (including Plot G) 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 site is presented on Figure 1. The site layout and the boundary of Plot G are presented on Figure 2. TP761G and TP758G are located outside of the boundary of Plot G shown on Figure 2. The investigation in the northwest corner of Plot G was constrained due to the remaining presence of the Ethoxylation Plant, therefore TP761G and TP758G were situated at an assumed down gradient location of the Ethoxylation Plant.

1.2. Project Background

URS has undertaken a variety of investigations on the site dating back to 1995. During this period, Rhodia's operations on the site have diminished, the phosphate business has been closed down and over the past two years the remaining production operations have ceased. It is understood that at the time of issue of this report, decommissioning of above ground structures relating to former Rhodia 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 2007.

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

The scope of previous investigations across the site was developed in relation 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) contains full details of the site's history and the environmental investigations previously undertaken. The report is presented in the Site Remediation Statement (and it is herein referred to as the "Phase II report").

The Site Remediation Statement document included a requirement for additional investigation in key areas of the site to address the significant pollutant linkages identified – one of those areas identified was Plot G. Further to this requirement, URS has reported the findings of the Plot G investigation 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.

The proposal that defines the scope for the Plot G investigation (REF: 1941NG1111/MARP0001 (dated 19th February 2007) is included in Appendix A. The proposal comprises background information, project objectives, scope, approach and rationale on which the investigation has been based.

This proposal was submitted to the Environment Agency on 2nd March 2007 for comment. To date, URS has not received a response.

1.3. Site Investigation Area - Plot G

Plot G comprises an area of the site most recently occupied by the former fire water basin, the treatment basin, the site of four former cooling towers and the Fatty Alcohol and Ethoxylation Plant (operated by Huntsman). Plot G is bordered to the south by the former acid storage tank area and to the west by the Hutbank landfill. Operations in these areas have now ceased, and all above ground structures associated with these historical activities have subsequently been decommissioned and removed. At the time of the investigation (March 2007) the area was open ground with the exception of the Ethoxylation Plant which was awaiting demolition. At the time of reporting (May 2007) it is understood that the Ethoxylation Plant had been demolished.

The area of interest has been identified as Plot G (Figure 2). The former layout of the site is presented on Figure 3. The plot is approximately rectangular in shape and is located west of the centre of the site. The area of the plot is approximately 6,200m^2.

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

1.4. Existing Site Investigation Information

1.4.1. Introduction

The findings of previous investigations have indicated the potential presence of contamination within the soils and shallow groundwater. However, due to operational constraints during these investigations it was not possible to fully characterise the soil and groundwater quality with respect to risk to human health and controlled waters receptors. The investigations that have previously been undertaken within the identified boundary, of Plot G, are as follows:

- URS investigation on behalf of Rhodia, ref; 44557-021, during 2001. 3No. shallow soil borings advanced as part of site wide assessment (WS130, WS131 and WS132);

- ERM investigation on behalf of Huntsman ref; PPC Phase 1B/2 Site Condition Report during 2003. 1No. shallow soil boring (SB15);

- URS investigation on behalf of Rhodia, ref; 44319623, during 2005. 1No. trial pit (TP516) and 1No. shallow soil borings (WS418) advanced as part of site wide assessment; and

- URS investigation on behalf of Rhodia, ref; 44319904, during 2006. Continued ongoing monitoring of 6 deep groundwater wells, and four offsite surface water locations (none of the deep groundwater wells are located in Plot G). Quarterly groundwater monitoring has been conducted since February 2004; previous report references are 44319646 and 44557-045.

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.

Three shallow soil borings (WS130, WS131 and WS132) were advanced in Plot G as part of site wide assessment. One soil boring was not installed as a groundwater monitoring well (WS132), and the installed well at WS131 was found to be dry. Analysis in soils comprised metals, TPH, VOCs, SVOCs, phosphates and pH. WS132 was not included in the soil analysis. Groundwater analysis included metals, TPH, VOCs, SVOCs, phosphate, pH and surfactant.

In WS130, a plastic odour was noted in the Made Ground along with plastic and sulphurous odour in the groundwater. The groundwater was also noted to have a thick, oil like consistency and slight foam. Groundwater analytical results detected relatively elevated concentrations of TPH and surfactants. In WS131, black staining and a slight odour were noted in the natural ground. Soil analytical results detected relatively elevated concentrations of selected heavy metals and TPH.

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 G.

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.

The data obtained during the 2001 investigation has been considered in the Human Health and Controlled Waters risk assessments produced in this report.

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.

One shallow soil boring (SB15) was advanced in Plot G and installed as a shallow monitoring well as part of a site wide assessment. Analysis in soils and groundwater comprised TPH, surfactants, pH and metals.

In SB15, no visual or olfactory evidence was noted in the Made Ground. Elevated concentrations of surfactants and TPH were identified in the soil analytical results. Significantly lower concentrations of surfactants and TPH were identified in the groundwater at SB15.

The data obtained during the 2003 investigation has been considered in the Human Health and Controlled Waters risk assessments produced in this report.

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, Rhodia also 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.

One trial pit (TP516) and one soil boring (WS418) were advanced in Plot G as part of site wide assessment. Analysis in soils comprised surfactants, metals, major cations and anions, VOCs, SVOCs, PAHs, TPH, PCB, TOC and PSD. The soil boring was not installed as a groundwater monitoring well.

In TP516 a sulphurous smell was noted in the Made Ground. In WS418 a diesel odour and black staining were noted in the Made Ground. In TP516 and WS418 soil analytical results revealed elevated concentrations of TPH, metals and naphthalene, which exceeded the controlled waters risk assessment criteria.

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 G.

The data obtained during the 2005 investigation has been considered in the Human Health and Controlled Waters risk assessments produced in this report.

Groundwater Monitoring at the Former Albright & Wilson Works, Whitehaven (ref: 44557-045, 44319646, 44319904, February 2004 to date)

The aim of this project has been to provide long term monitoring of the geochemistry of the deep groundwater underlying the Whitehaven site and local surface waters. The aim of this project has been to determine trends in the chemistry of the analytes found in the groundwater, some of which are known to be derived from site processes. The locations assessed are considered to be representative of the potential receptors in the underlying geological formations and surface water features fed either by site runoff of issue from the local geology. These include: The Byerstead Spring; groundwater in the Whitehaven Sandstone; groundwater in the St Bees Evaporites, Groundwater in the St Bees Shales; Groundwater in the Middle Coal Measures; Sandwith Beck; and Bellhouse Gill.

Assessment of the condition of the water emanating from the Byerstead Spring has been undertaken sporadically since 2002. Surfactant concentrations have decreased since 2002, and have been below 1200µg/l in the past six monitoring rounds. It is thought that once surfactant production ceases completely on the site (a small surfactants business, operated by Huntsman, still operates onsite, but is due to close), a further decrease is likely to be seen in concentrations of surfactant detected at the Byerstead Spring.

Concentrations of dissolved phosphorus at the Byerstead have shown a substantial decline since monitoring began. This is thought to coincide with the cessation of the Phosphate works in December 2001.

The concentration of the analytes at the Byerstead Spring can be affected (diluted) by an increased volume of water emerging at the spring. For example, the low concentration of

MBAS detected in the Byerstead sample in November 2005 (950µg/l), was taken during a prolonged period of heavy rainfall (over a period of days before), and it was noted that the discharge from the spring appeared greater than normal. It is thought that there are several sources for the analytes detected at the Byerstead Spring, the two most prevalent of which are the site itself and the flooded mine systems in the area.

The geological and geochemical data obtained during the monitoring regime has been considered in this report.

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 G) and correspondence
Appendix B	Field Methodology
Appendix C	Borehole & Trial Pit logs
Appendix D	Analytical Schedules, Tabulated Results, Laboratory Certificates, and Historic 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	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 G".

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 review 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 revise the current Conceptual Site Model;
- To provide a preliminary evaluation of the need for, and scope of, potential remedial options (if considered appropriate) together with an indication of potential remedial methodologies.

2.1. Site Investigation Design

The site investigation design was submitted to the Environment Agency for comment prior to start of works. Details of the investigation design and rationale are presented in the proposal. To date URS has not received a response from the Environment Agency.

3. SITE DESCRIPTION AND ENVIRONMENTAL SITE SETTING

3.1. Introduction

The site is located in a coastal setting, on the 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 G occupies an area of approximately 5500m^2 (0.55 hectares) and is located to the west of the centre of the site. Plot G slopes gently towards northwest.

3.2. Plot G Current and Historical Operations

The most recent structures in this area were the former fire water basin, the treatment basin, the site of four former cooling towers, and the Ethoxylation Plant. At the time of this investigation the buildings had been demolished to ground level, except the Ethoxylation Plant and some stockpiles of demolition rubble which remain. Approximately half of the ground surface remains covered by concrete hardstanding, relating to floor slabs from the former buildings, foundations and cover from former process areas. The remainder is open ground with grass/topsoil cover.

3.3. Environmental Setting

The environmental setting for the site has been previously established during URS's Phase II investigation, a summary of the setting, specific to Plot G 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 comprise:

- Made Ground: the made ground (the man made or disturbed ground formed when the chemical works was built), overlying the drift deposits

- Glacial Till (Boulder Clay) (the "drift"): is present across the area except in the most north eastern investigated location of Plot G, overlying

- St Bees Evaporite Formation (late Permian): present as either pink grey crystalline limestone or as yellow sandstone at a number of locations across Plot G. This formation is classified as a non aquifer by the Environment Agency. These lithologies are known to have suffered dissolution through historical losses of acid to ground in certain locations in the vicinity of Plot G. The location of the known voids in the vicinity of Plot G are as follows:

- One void is located in close proximity to WS130 near the north western corner of Plot G; and

- Two voids are known to exist approximately 60m to the northwest of Plot G located within a former tank farm

- 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, although it 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) comprises medium to coarse-grained purple to purple-brown sandstones, which are cross-bedded throughout with thin intercalations of mudstones and siltstones bedded with sandstones and siltstone. This sandstone is classified as a minor aquifer by the Environment Agency.

3.3.2. Surface Waters

Plot G area is serviced by the site drainage system, which was designed to drain the water within Plot G north to the outfall in the Irish Sea. It is currently proposed that the drains on the whole of the site will be allowed to silt up and that the groundcover within Plot G will be left in its current state.

Once the drains are no longer able to remove significant volumes of water there will be a greater component of overland flow corresponding to the natural watershed, which drains Plot G towards the south. The north and south ponds will intercept this drainage to prevent flooding in Sandwith Beck. In addition, it is considered that infiltration of surface water may also increase, potentially adding to the volume of water entering either perched ground water or the aquifers present in the geological sequence.

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 likely to be at risk from potential contamination within the Plot G area:

- *Human beings*: Given that the proposed end-use for the Plot G area and the site as a whole is to be a recreational area for open access to the public it is considered that members of the public represent a potential receptor.

- *Deep groundwater and subsequently Coastal Waters*: The groundwater within the St Bees Evaporites/St Bees Evaporite Formation is likely to receive infiltrating

rainwater in Plot G. The St Bees Evaporite Formation, which is classified as a non aquifer. Once into the St Bees Evaporite Formation, it has been demonstrated by dye testing experiments that the groundwater migrates rapidly through enhanced conduits towards the coastline (and is likely to emerge at the Byerstead Spring), which is situated approximately 1.3km to the southwest of the site.

3.5. Potential Current and Historical Sources of Contamination

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

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

- Fatty Alcohol and Ethoxylation Plant: spillages, leaks and releases to ground of raw and finished products from above ground storage tanks (AST), reactors and various other site processes. Contaminants of concern are considered to include Surfactants, VOCS, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons and nitrates.

- Acid Storage. Leaks, spills or releases to ground of acid. Contaminants of concern are considered to include phosphates, sulphates, nitrates, ammonia and heavy metals; and

- Concentrations of contaminants within imported materials used for ground raising and reclamation (e.g. ash and clinker fill) which may contain VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates.

4. FIELD OBSERVATIONS AND GROUND CONDITIONS ENCOUNTERED

4.1. Introduction

This section reviews the soil and groundwater conditions observed during the fieldwork and also 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 the eight trial pits and three boreholes advanced across Plot G during this investigation.

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 logs are presented in Appendix C. Exploratory locations are shown on Figure 4.

Recent activities on Plot G include the site of the former firewater basin, the treatment basin, the site of four former cooling towers, the Fatty Alcohol Plant and the Ethoxylation Plant. Due to the presence of structures, the locations of TP758G, TP761G and TP752G were moved west from the original sampling density location as specified in the proposal to accommodate the lack of access near the Ethoxylation Plant. TP765G was moved south to account for a steep slope. However, no patterns of ground conditions have emerged to facilitate the discussion of Plot G by dividing it into sub-areas, and as such, it is described as a whole area.

4.2. Soil Conditions

The ground conditions underlying the Plot G area are derived from the inspection of the arisings resulting from excavations advanced during the 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 to Top of Stratum (m)	Maximum Thickness (m)
Made Ground	Reinforced concrete hardstanding	0 – 0.6	0.6
	Hardcore	0 – 0.4	1.45
	Brown sand and gravel with many man made components (fill material)	0.3 – 0.9	2.2
	Brown or Black slightly sandy clay with occasional gravel and cobbles	0. – 3.7	1.7
	Black ashy gravel with clinker, coal, wood , cement clinker and brick.	0.4 – 1.6	0.4
Natural Ground	Glacial Till Deposits typically comprising soft brown sandy clay with occasional gravel and cobbles.	1 - 3	2.6

Unit	Description	Depth to Top of Stratum (m)	Maximum Thickness (m)
	Glacial Till Deposits typically comprising stiff red brown clay with occasional gravel and cobbles.	2 - 3	2.1
Bedrock	St Bees Evaporite Formation: typically comprising grey – yellow, weathered, Limestone.	1.5-5.0	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.

4.2.1. Made Ground

The Made Ground varied in thickness from 0.6m at TP758G to 3.7m at TP765G with no obvious spatial correlation. Reinforced concrete hardstanding was generally encountered in the area surrounding the Ethoxylation Plant, which at the time of investigation was yet to be demolished. Surrounding these plant areas, the land appears not to have been recently used for industrial works, and the surface layer mainly comprises hardcore.

The Made Ground typically comprised one or more of the following:

- Fill material: brown sand and gravel with occasional brick and/or concrete. At TP759G, TP762G, TP763G, TP764G, TP765G and WS766G the fill also contained wood, plastic, glass, cement clinker and clinker. This is thought to be associated with the backfilling and levelling operations in Plot G;

- Reworked drift: brown or black slightly sandy clay with occasional gravel and cobbles; and

- Ash: Black ashy gravel with clinker, coal, wood, cement, clinker and brick. Observed in TP765G, TP761G and TP758G this horizon appears to be localised in the vicinity of the Ethoxylation Plant to the north of Plot G. This is thought to be associated with historic backfilling and levelling operations in the area.

4.2.2. Natural Ground

Glacial Till (Drift/ Boulder Clay)

Drift deposits were encountered over most of Plot G with a maximum proven thickness of 4.6m observed in WS766G. Drift was not observed in TP767G due to difficulties in the excavation of the trial pit due to ingress of water. No drift was present at TP765G as the Made Ground was observed to lie directly on top of bedrock.

Where encountered, the drift typically comprised Glacial Till deposits, which included:

- Soft brown sandy clay with occasional gravel and cobbles.
- Stiff red brown clay with occasional gravel and cobbles.

Natural Ground (Bedrock)

Bedrock was encountered at four locations in Plot G between 1.5m bgl (WS129) and 5m bgl (TP762). The lithology observed was as follows:

- Pale grey and yellow pink fine grained limestone with occasional dissolution voids. These voids observed in the bedrock are of the millimetre scale and are considered to have formed by natural weathering of the limestone and not as a result of dissolution caused by site derived contaminants. Large voids in the bedrock thought to be caused by on site activities are discussed in section 3.3.1.

This unit is considered to represent the St Bees Evaporite Formation (late Permian). The extent of this unit is illustrated on Figures 6 and 7.

4.3. Groundwater Conditions

Groundwater strikes were observed during the excavation of the trial pits in TP758G, TP761G, TP763G, TP764G, TP767G, WS766G and in the existing borehole WS130G.

The observed shallow groundwater appears to be perched as it is predominantly found in the Made Ground directly above the clay drift deposits. Of the three monitoring wells installed in the drift deposits (WS760G, WS766G and WS768G), underlying the Made Ground, groundwater was found to be present in only one well (WS766G). For this reason, it is considered likely that no continuous shallow groundwater body is present within the drift deposits. The spatial distribution of the groundwater strikes in the Made Ground does not suggest that there is a definite continuous perched groundwater body within the Made Ground in Plot G.

There are five groundwater wells located in Plot G; WS130, WS766G, WS768G and WS760G. WS131 was not located during the groundwater-monitoring round conducted during this investigation and WS768G and WS760G were found to be dry. WS130 and the recently installed WS766G were sampled between 7th and 8th March 2007. Due to the low permeability drift deposits that WS766G was installed in, this well was repeatedly purged dry during sampling, and it was therefore necessary to return to this well five times until sufficient sample to complete the full suite of laboratory analysis was collected. Observed groundwater levels are detailed in Table 4.2 below.

Table 4.2 – Summary of Groundwater Elevation

Installed Well	Date of sample	Relative Level of top of well (maOD)	Depth to water (m bgl)	Total Depth (m bgl)	Relative water level (maOD)	Observed Contam. (Y/N)
WS130	07/03/2007	84.2	0.232	0.880	83.918	N
WS766G	07/03/2007	87.0	3.551	5.995	83.456	N
WS768G	08/03/2007	85.3	Dry	3.851	Dry	N
WS760G	08/03/2007	84.9	Dry	2.835	Dry	N

The potential pathways for water migrating from Plot G to surface water receptors is considered to be through either the (potentially limited) movement of groundwater within shallow drift/made ground, or movement of water across the ground surface. The nearest surface water body to Plot G is north pond (approximately 200m south of Plot G). North Pond is a surface water attenuation pond, which feeds into a second attenuation pond (South Pond) before migrating into Sandwith Beck.

The potential for Plot G derived contaminants to migrate into north or south ponds (and subsequently Sandwith Beck) is considered to be unlikely; since

- the surface water is likely to infiltrate to ground prior to reaching the ponds.
- shallow groundwater that may be present between Plot G and the ponds is likely to migrate vertically into the shallow bedrock (St. Bees Evaporites).

The potential pathway for the migration of shallow groundwater and leachate into the St. Bees Evaporites (and subsequent flow to the coastline) is considered to be a potentially significant source-pathway-receptor linkage.

The St. Bees Evaporites have undergone dissolution in the vicinity of Plot G probably due to the loss of acids directly to ground in areas of former acid storage. This has resulted in the creation of large solution features/voids, which may also be present beneath Plot G. It is considered that the dominant groundwater transport mechanism within this unit (in parts of Plot G) is likely to be within these voids, where streams may flow.

It is considered groundwater flow direction is likely to follow dip to the west/south west towards the coast. As groundwater migrates out of Plot G, it will encounter a north-south trending fault. At the fault, the geological sequence has been downthrown on the western (coastal) side. The groundwater may migrate downwards into the fault plane, before continuing to migrate laterally following the path of highest permeability towards the coastline; this may be within old mine adits or workings, fractures within the bedrock or within the St Bees Evaporite Formation.

At the coastline, the groundwater is likely to be forced to the surface when it meets the saline water interface. One point known to contain site-derived waters is a spring, which

emerges on Saltom Beach, known as the Byerstead Spring. Dye tracing has shown that site derived water can reach the Byerstead Spring in less than 10 hours.

It is also likely that some of the rainfall incident on the area will be removed as surface runoff through transport in the site drainage system.

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 within the solid material. This evidence is presented below in Table 4.3, which summarises areas of potential contamination and likely sources and is shown on Figure 8.

Table 4.3 Field Observations of Contamination

Location	Made Ground	Drift	Bedrock
TP758G	Water with black oily sheen, strong hydrogen sulphide odour and tar coated railway sleepers	NVO	NVO
TP759G	NVO	NVO	-
WS760G	NVO	NVO	NVO
TP761G	NVO	NVO	NVO
TP762G	Strong sulphur odour	NVO	NVO
TP763G	Water with black oily sheen	Black staining and chemical odour	-
TP764G	NVO	NVO	-
TP765G	Strong HC / kerosene odour	NVO	NVO
WS766G	Slight HC odour	NVO	NVO
TP767G	NVO	-	-
WS768G	Staining, slight solvent odour	NVO	-

HC (hydrocarbon); NVO (no visual or olfactory evidence of contamination); PID (photo ionisation detector); - (not observed)

Contamination was predominantly observed in the Made Ground.

As to be expected from the long industrial history of the site, the contamination is irregularly distributed over Plot G. The contamination encountered at Plot G consisted of the following:

- Tar was noted alongside railway sleepers in TP758G, located by the Ethoxylation Plant, at a depth of 0.5m within the Made Ground;
- At TP763G, located by a former cooling tower, a chemical odour was noted in addition to black staining and water with a black oily sheen;
- At WS768G, located by a former cooling tower, a slight solvent odour was noted in addition to black staining at a depth of 0.8m in the Made Ground;
- At WS418 a diesel odour was noted from approximately 1.1m to 1.5m bgl within the Made Ground;
- Water with a black oily sheen and a strong hydrogen sulphide odour was observed in TP758G located by the existing Ethoxylation Plant;
- A sulphur odour was observed in TP762G located by the Ethoxylation Plant;
- Hydrocarbon odours were observed in WS766G and in TP765G together with a kerosene odour. These trial pits are located to the east of the site by the Ethoxylation Plant and a former cooling tower.

During the most recent investigation at Plot G, no elevated PID concentrations were recorded. However, in previous investigations elevated PID measurements were recorded in WS130 at 2.8m bgl (169ppm) and SB15 from 0.5m to 2.4m bgl (max. reading at 0.6m - 458ppm).

4.5. Geochemical Results

The analytical schedules and results of chemical analyses are provided in detail in Table 1 and Tables 3 to 23 included in Appendix D to this report (enclosed as a CD). 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)

Thirteen soil samples were scheduled for VOC analysis. Of the samples analysed, four had reported concentrations greater that the laboratory method detection limit (MDL). The majority of these were from samples taken from Made Ground including, WS418 at 1.25m, TP758G at 0.5m and TP516 at 0.45m. The sample at 3.5m bgl at TP765G was taken from drift. There is no spatial correlation of these exceedances across Plot G.

VOC analysis was not carried out on soil leachates.

Four groundwater samples were scheduled for VOC analysis. Three compounds had reported concentrations greater that the laboratory method detection limit (MDL).

Metals

Fifteen soil samples were scheduled for metals analysis and 17 for NRA leachate preparation and analysis. Elevated concentrations are summarised in the Tables 4.4 and 4.5 below:

Table 4.4 – 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	4	24	8	Made Ground (7), Drift (1)
Boron	5	13	3	Made Ground
Cadmium	0.5	21	5	Made Ground (4), Drift (1)
Chromium	11	748	2	Made Ground (1), Drift (1)
Copper	10	185	8	Made Ground (7), Drift (1)
Lead	9	334	4	Made Ground
Nickel	2.5	114	5	Made Ground (4), Drift (1)
Selenium	1.2	4.54	4	Made Ground (3), Drift (1)
Zinc	33	1660	3	Made Ground (2), Drift (1)

Table 4.5 – Elevated Concentrations of Metals (Soil Leachate)

Metal in leachate	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Arsenic	2	33	4	Made Ground
Boron	40	210	5	Made Ground
Cadmium	0.6	2	2	Made Ground
Chromium	23	54	2	Made Ground
Copper	2	69	4	Made Ground (3), Drift (1)
Lead	2	53	2	Made Ground
Nickel	3	170	4	Made Ground

Metal in leachate	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Selenium	2	22	6	Made Ground
Zinc	6	140	7	Made Ground (4), Drift (3)

No obvious spatial correlation of elevated metal concentrations in soils or leachable metal concentrations is evident from the data acquired across Plot G. 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 site and these are typically considered to be a likely source for the increase of concentrations of metals in shallow horizons. Elevated concentrations of metals in soil were also observed in drift. Relatively elevated concentrations of arsenic, cadmium, chromium, copper, nickel, selenium and zinc soil concentrations were observed in clay at WS131. The leachate analysis identified elevated leachable metal concentrations mainly in made ground, in particular, elevated concentrations for most metals were reported in made ground and on the horizon between made ground and drift in TP764G and in made ground in TP763G. These two trial pits were located between the existing cooling towers.

Elevated arsenic, boron, chromium, lead, nickel, selenium and zinc were also reported in water samples taken from sampling wells across Plot G.

Anionic Surfactants

Three water samples were scheduled for surfactant analysis. The minimum reported concentration was 50µg/l in WS418, and the maximum reported concentration was 1100µg/l in WS766G.

Semi Volatile Organic Compounds (SVOCs)

Fourteen soil samples were scheduled for SVOC analysis. Of these, nine returned concentrations above the laboratory MDL. The majority of these detections were in the Polycyclic Aromatic Hydrocarbon (PAH) group of analytes in samples collected from Made Ground at 0.5m in TP758G, 0.45m in TP516, 1.5m in TP762G, 1.6m in TP765G, 0.5-0.8m in WS130, 1.5m in WS766G and 1.05m in WS768G. There appears to be no spatial correlation between these results across Plot G. Only one of the 16 samples submitted for NRA leachate preparation and analysis contained concentrations of SVOCs above the MDL, the majority of the detections were in the PAH group of analytes. Elevated concentrations were observed in Made Ground at 0.5m in TP758G.

Total Petroleum Hydrocarbons (TPH)

Very few of the 17 soil samples and 12 leachate samples submitted for NRA leachate analysis and preparation exceeded the MDL for Total Petroleum Hydrocarbons (TPH). Three soil samples, TP516 at 0.45m, TP758G at 0.5m and WS418 at 1.15m, exceeded

the MDL for Aromatic Hydrocarbons in the range C10 to C35. The maximum value for total hydrocarbons for soils was 1,500mg/kg from 1.5m at WS766G. Only one of the samples (TP758G at 0.5m) submitted for leachate analysis exceeded the MDL for leachable TPH in the range C12 to C21 and for Total Aromatics (C6-C35).

Additional Analytes

Three soil samples and one leachate sample were scheduled for Polychlorinated Biphenyls (PCB) analysis. There were no concentrations of PCBs in soil or leachate above the MDL.

Further additional analytes include: ammoniacal nitrogen, cyanide, nitrate, phosphate, sulphate, sodium and total organic carbon. Table 4.6 summarises the elevated concentrations reported for these analytes.

Table 4.6 – Elevated Concentrations of Additional Analytes

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
Ammoniacal Nitrogen	<mdl	-	-	-
Cyanide	<mdl	<mdl	-	-
Nitrate	6	-	2 (Made Ground)	-
Phosphate	<mdl	14000	-	8 (Mixture)
Sulphate	63900	1200000	2 (Made Ground)	13 (Made Ground)
Sodium	695	-	2 (Made Ground)	-
Total Organic Carbon	0.42	-	3 (Mixture)	-

Summary

Based on the analytical results of this site investigation, it is considered that the majority of samples with relatively elevated concentrations are located within the Made Ground, and that there is little spatial correlation of reported elevated concentration across Plot G.

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 A. These comprise the following**;**

Table 5.1a – Summary of potential Sources

Potential Sources	Contaminants of Concern
Fatty Alcohol and Ethoxylation Plant	surfactants, VOCs, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons, and nitrates
Acid storage tanks	phosphates, sulphates, nitrates, ammonia and heavy metals
Made Ground	VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates

In their determination of the site as "contaminated land", Copeland Borough Council listed a number of contaminants which they considered likely to be present on the site as a result of its' previous history. These contaminants were included in the Assessment Action to ensure that the possibility of there being Contaminants of Concern is fully evaluated.

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.

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 at point where the integrity of the drainage lines has been compromised by exposure to acid.
Controlled Water 2 (CW2)	Vertical movement of dissolved or liquid contaminants from shallow groundwater to groundwater within the St. Bees Evaporite Formation. Movement from shallow groundwater to groundwater in the St. Bees Evaporite Formation 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)	The potentially rapid flow of groundwater within the St. Bees Evaporite Formation via complex pathways in a west/southwest direction towards the coast and the Irish Sea. This occurs through flow in solution features in the St. Bees Evaporite Formation, interaction with faults, and through mine adits).
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: The Irish Sea.	Groundwater migrates via complex underground pathways towards the Irish Sea. It is likely to discharge via the Byerstead Fault Spring on Saltom Beach, located 1.3km away.

5.4. Pollutant Linkages

For a pollutant linkage to exist, a *source* of contamination (e.g. a leaking storage tank) must be connected 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 potentially 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 G Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
C1	Likely substances from the Fatty Alcohol and ETO Plant surfactants, VOCs, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons,	The Fatty Alcohol and ETO Plant	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.

Pollutant Linkage Identifier	Pollutant	Plot G Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
	and nitrates					
C2	Substances associated with acid include phosphates, sulphates, nitrates, ammonia and heavy metals	Acid storage tanks	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.
C3	Substances associated with fill material VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates	Made Ground comprising ash and clinker and other diffuse sources	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.

5.4.2. Human Health

Copeland Borough Council determined the 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 an area-specific assessment for Plot G. Therefore Table 5.4b below shows the potentially 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 G Source location	Pathway	Main Receptor	Additional Receptors	Description of Harm/Pollution of Controlled Waters
H1	Likely substances from the Fatty Alcohol and ETO Plant surfactants, VOCs, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons, and nitrates	The Fatty Alcohol and ETO Plant	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 contamination from acid storage tanks include phosphates, sulphates, nitrates, ammonia and heavy metals	Acid storage tanks	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	Substances associated with fill material VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates	Made Ground comprising ash and clinker and 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

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 G as detected by investigations undertaken at the site.

6.2. Stage 2 Assessment

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

Soil

- **Metals**– arsenic, chromium, nickel; and
- **PAH** –naphthalene.

6.3. Stage 2 Risk Evaluation

Prior to assessing the exceedances at Stage 3 (DQRA) further review has been made with regard to the significance of the contamination in the context of the proposed public open space end use of the site. This has comprised further assessment of the plausibility of the identified pollutant linkages and has taken into consideration factors such as the nature, extent and location of the detected contamination (i.e. the size of the source), the likely pathways for receptor exposure, receptor behaviour, condition and circumstances of the land and other factors which may prevent or enhance potential exposure.

Where appropriate, assessment has also included the use of simple statistical tests in accordance with CLR7 to derive averaging concentrations for the area to which a receptor could potentially be exposed while occupying the site.

It should also be noted that the generic assessment criteria for the Stage 2 assessment are based upon a conceptual exposure model[2] which is highly conservative for the 'right to roam' end use and is designed to be suitably protective of future site users.

[2] Residential without gardens

The evaluation of each of the Stage 2 potential sources is presented in Tables E4 and E5 in Appendix E.

6.4. Summary of Risks to human Health

In summary, naphthalene was not considered to present a plausible risk to the designated receptor due to the localised nature of the contamination (only exceedance at TP758G), the low likelihood of excavation of the contaminated soil and low likelihood of chronic exposure to the receptor. Arsenic, chromium and nickel were not considered to present a risk due to the absence of a viable pollutant linkage, i.e. all exceedances were measured in deep soil (>1m) and all contaminants are non-volatile.

Overall, it is considered that there are no contaminant concentrations detected in this area of the site which are considered to represent a significant possibility of significant harm to the identified receptors based on the proposed end-use of the site.

Therefore, should the current condition and layout of Plot G be maintained, it is considered that potentially significant risks to human health would be unlikely for a public open space scenario. Plot G 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.

7. CONTROLLED WATERS QUANTITATIVE RISK ASSESSMENT

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 is summarised below.

7.2. Stage 2 Assessment

A Stage 2 generic quantitative screening risk assessment was undertaken that incorporated the March 2007 data as well as all previous data, and compared measured concentrations to the generic screening values for the protection of controlled waters, in this case, Marine EQS values.

The results are summarised in Table 7.1.

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

Soil	Soil Leachate	Shallow Groundwater
naphthalene	arsenic	zinc
	chromium	chromium
	copper	TPH C10-C12
	lead	TPH C12-C16
	nickel	TPH C21-C35
	selenium	anionic surfactant (MBAS)
	carbazole	benzo(a)anthracene
	naphthalene	benzo(a)pyrene
	TPH C12-C16 Aromatic	dibenz(a,h)anthracene
	TPH C16-C21 Aromatic	fluoranthene

Each of the determinands whose concentrations exceeded their respective Stage 2 criterion were then assessed to determine whether the potential risk they posed was realistic. As such, the geochemical profile, geological horizons, water strikes, and field observations of contamination were all considered. For example, consider an exceedance from a sample taken in the made ground. If the underlying geology was several meters of dry low permeability clay, and a deep sample from within or below this clay did not detect this analyte, then this risk may be deemed not significant, given the pathway into the underlying evaporites (which forms part of the pollutant linkage) was not realistic. Therefore this analyte may have been discounted and not taken to Stage 3. Conversely, if contamination was found in granular wet made ground, that sat directly on to bedrock, this will have been considered potentially significant, and taken to Stage 3.

If a pollutant linkage was deemed potentially significant or could not be discounted (due to insufficient geochemical and geological evidence) they were taken forward to Stage 3, the detailed quantitative risk assessment.

The evaluation of each of the Stage 2 potential sources is presented in Section 3.5 in Appendix G. The substances that went to 3A modelling were chromium, nickel and zinc.

7.3. Stage 3A Assessment

The hydrogeological sequence of the site is complex. It has been further compounded by historic site activities, the most prevalent of which has been the deposition of acids into the ground, resulting in voids and channels being created in certain locations, some of which are considered likely to be present in Plot G.

Given the complexity of the geology in Plot G and the rapid travel times for migration sourced from Plot G, no standard model (e.g. CONSIM, which was used in Plots B and C) was considered to be appropriate. Instead, a mass balance approach was adopted in order to assess potential risks. This approach is described in detail, with examples, in Appendix G. A brief overview is given here.

Stage 3a calculates the concentrations of contaminants entering the underlying geology based on contaminated groundwater from the source zone mixing with surrounding clean groundwater prior to entry into the St. Bees Evaporites Formation. This mixing results in dilution of the contaminant concentrations. The diluted concentrations are then compared directly against their respective screening criteria. If the contaminant concentrations have been diluted below their respective Marine EQS values, they are no longer considered to represent a potentially significant risk to controlled waters. However, if they are still in exceedance, they will be entered into the Stage 3B model discussed in Section 7.4.

The following contaminants identified in Stage 2 were still found to be in exceedance of their respective screening values at Stage 3a.

Table 7.2 – Controlled Waters Stage 3a - Summary of Screening Criteria Exceedances

Soil	Soil Leachate	Shallow Groundwater
	nickel	chromium
		zinc

7.4. Stage 3B Assessment

The current model builds upon the previous modelling. Specifically, it recognises the potential for an *offsite* dilution of site derived waters. This is due to the infiltration of clean water through the St. Bees Sandstone (located down hydraulic gradient), and its subsequent vertical movement into the underlying units, which includes the St. Bees Evaporites, where the conduits containing the site derived waters are thought to exist. As the clean waters enter the conduits, they dilute the site derived waters.

The model takes the Stage 3a assessment to the next step (through generating a second dilution), by considering rainfall, surface area of infiltration into the St. Bees Sandstone, likely infiltration rates through the geological strata, and combines this with a mass of contamination (a concentration).

As the concentration reduces after this second dilution, the resultant analyte concentrations are then compared to their respective screening criteria.

The results of the Stage 3b assessment are summarised in Table 7.3. Further details regarding the methodology, limitations and assumptions are included in Appendix G.

Table 7.3 – Controlled Waters Stage 3b - Summary of Screening Criteria Exceedances

Soil	Soil Leachate	Shallow Groundwater
		zinc

7.5. Summary of Risks to Controlled Waters

The results of the Stage 3 assessment are summarised in Tables 7.2 and 7.3. With regard to the Stage 3a assessment for simulated contaminant concentrations at the adopted compliance point (in this case, the point directly below the source, where the analyte enters the evaporite sequence) to pose a potentially significant risk to shallow controlled waters, they must be in excess of defined Stage 3 screening criteria (EQS). It can be seen from Table 7.2 that a number of exceedances of the Stage 3a assessment criteria have been identified. These exceedances have been taken through to the Stage 3b assessment, where the zinc concentration remained in exceedance of the screening criteria. The concentration of zinc after the Stage 3b assessment (43µg/l) marginally exceeded the screening criteria (40µg/l). Taking into account this borderline exceedance and the conservatism within the model, in reality it is unlikely that this concentration signifies a requirement for further investigation.

One area of the site (in the vicinity of the ETO plant), focused on the area encompassing ERMSB15, WS130 and TP758G will require further investigation and assessment to determine whether remedial action may be required. TPH was detected in groundwater above the screening criteria in ERMSB15 and WS130. MBAS and PAHs were detected in groundwater above the screening criteria in WS130. Due to access constraints (the ETO plant and associated structures were pending demolition during the site investigation), the area surrounding these locations could not be fully investigated in order to assess the extent of potential groundwater contamination in this area. The area surrounding TP758G (adjacent to area outlined above) has also been identified as requiring further investigation due to a naphthalene exceedance in soil. Insufficient data points exist to permit delineation of potential naphthalene contamination in the vicinity of TP758G.

The proposed area requiring further investigation is shown on Figure 9.

8. REFINED POLLUTANT LINKAGE ASSESSMENT

The human health risk assessment for Plot G has indicated that there are no potentially significant risks with regard to a proposed end use of public open space. The controlled waters risk assessment has identified a single analyte (zinc) at the Stage 3B assessment which marginally exceeds the screening criteria, but is not considered to present a risk to the identified receptor. The following section provides a review on the plausibility of the modelled potential pollutant linkages (Section 5.4) as detailed in the Site Remediation Statement.

The controlled waters risk assessment has used a worst case assessment where by each hotspot identified is assessed against meeting the respective EQS on entry into the Irish Sea via theoretical solution features located immediately beneath each hotspot within the St Bees Evaporite Formation. The assessment assumes rapid flow within the St Bees Evaporite Formation to the Irish Sea, based on the travel times of dye tracing from the vicinity of Plot G to the Byerstead Spring being in the order of 10 hours. The assessment at Stage 3a makes no allowance for dilution or lateral/vertical attenuation within the unsaturated zone above the St Bees Evaporite Formation. Dilution is considered at Stage 3B, but this only accounts for dilution of site derived waters once they have entered into the St. Bees Evaporites.

This model considers the complex hydrogeological regime at the site, and specifically within Plot G, where potentially, a number of solution features may exist (solution features are known to exist beyond the plot boundary, approximately 10m north of WS130). However, whilst every effort has been made to develop a reasonably realistic model, there is insufficient detailed information on the precise location and nature of solution features within Plot G, resulting in there being an element of conservatism in the model.

It is considered highly likely that solution features are present within Plot G, however, it is unlikely that they are as extensive as considered by the model. The model has also assumed that the contaminants are present immediately above the solution features. Physical evidence from the site suggests that an unsaturated zone is present in most areas between the contaminated soils and the theoretical receptor. Consideration has been given to modelling a variety of situations to take this into account, but given the complexity of the geological, and hydrogeological conditions, coupled with the spatial distribution of the modelled hotspots, each model would have its own inherent conservative elements and to remove these would require an enormous amount of additional data gathering. It is doubtful whether such an exercise would add any benefit to the assessment given that the overall picture of the site that has emerged from the investigation is that there is no evidence of widespread contamination.

Whilst the assessment has identified potential risks, we have considered the field and laboratory data in conjunction with the results of the modelling. This has provided a balanced view on the plausibility of pollutant linkages for each identified hotspot.

Table 8.1 – Refined Pollutant Linkage Assessment

Pollutant Linkage Identifier	Pollutant	Plot G 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	Surfactants, VOCs, SVOCs, Heavy Metals, Phosphates, Sulphates, Petroleum Hydrocarbons and Nitrates	The Fatty Alcohol and ETO Plant	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St. Bees Evaporites before rapidly migrating to the Irish Sea.	1) Naphthalene. Yes. No pathway, however calculated pore water concentration from soil concentration (at TP758G-0.5m) was 1700ug/l, which was considered a significant source. The naphthalene source area could not be defined due to insufficient data points. Additional data is required to delineate the extent of naphthalene contamination and its potential significance in this area. 2) MBAS. Yes. 5,090ug/l was detected in groundwater at WS130. Further work is required to clarify if a significant MBAS source is present in this area. 3) TPH. Yes. TPH (C10-C12, C12-C16 and C21-C35) detected above screening criteria in shallow groundwater in ERMSB15. Further investigation is necessary in this area to delineate TPH contamination. 4) PAH. Yes. Benzo(a)anthracene, benzo(a)pyrene, dibenz(a,h)anthracene and fluoranthene were detected above the screening criteria in shallow groundwater at WS130. Further investigation is necessary in this area to delineate PAH contamination. 5) Carbazole. No. No potential linkage and no significant source.
C2	Phosphates, sulphates, nitrates, ammonia and heavy metals	Acid Storage Tanks	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St. Bees Evaporites before rapidly migrating to the Irish Sea.	No. Stage 2 Risk Assessment indicates no significant risk.

Pollutant Linkage Identifier	Pollutant	Plot G 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)
C3	VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates	Made Ground comprising ash, clinker and other diffuse sources	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St. Bees Evaporites before rapidly migrating to the Irish Sea.	1) Chromium. No. Potential source identified at TP764G – 1.3m but no potential linkage. Leachate concentrations for chromium reduced to less than the Stage 2 screening criteria at Stage 3a of the controlled waters risk assessment. 2) Nickel. No. Significant source and no potential linkage. Leachate concentrations for nickel at TP764G-1.3m reduced to less than the Stage 2 screening criteria at Stage 3b of the controlled waters risk assessment. 3) Arsenic. No. No potential linkage and no significant source. 4) Copper. No. No potential linkage and no significant source. 5) Lead. No. No potential linkage and no significant source. 6) Selenium. No. No potential linkage and no significant source.
H1	Likely substances from the Fatty Alcohol and ETO Plant Surfactants, VOCs, SVOCs, Heavy Metals, Phosphates, Sulphates, Petroleum Hydrocarbons, and Nitrates	The Fatty Alcohol and ETO Plant	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	No. Stage 2 Risk Assessment indicates no significant risk.
H2	Likely contamination from acid storage tanks include phosphates, sulphates, nitrates, ammonia and heavy metals	Acid storage tanks	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	No. Stage 2 Risk Assessment indicates no significant risk.

Pollutant Linkage Identifier	Pollutant	Plot G 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)
H3	Substances associated with fill material VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates	Made Ground comprising ash and clinker and 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	No. Stage 2 Risk Assessment indicates no significant risk.

9. REMEDIATION ACTIONS

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

All of the potential pollutant linkages assessed in the risk assessment have been shown to be not significant, and for these analytes no remediation actions will be necessary. An area has been identified which, due to the lack of sampling points in that area, contamination was not assessed at the Stage 3 assessment. This area will require additional investigation in order to assess the extent of contamination (refer to Figure 9).

The following outline scope of works is recommended to investigate the ETO (Ethoxylation) Area further.

ETO Area – The area in the vicinity of ERMSB15 and WS130 (and TP758G)

It is proposed that up to eight trial pits and up to four boreholes are advanced to 5mbgl (or bedrock, if shallower) in order to delineate the PAH and TPH contamination. Soil samples would be taken for analysis (and at 0.5m intervals for headspace screening), and water samples would be taken from boreholes for laboratory analysis. Also, concurrently with this investigation it is proposed that an investigation into naphthalene contamination in soil is undertaken in the area around TP758G.

Following completion of the investigation, the Stage 3 risk assessment will be updated and the pollutant linkage assessment refined accordingly

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 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 G***
Petroleum Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*Yes- Potential risks associated with TPH in groundwater have been identified at WS130 and ERMSB15. These areas require further delineation and assessment to determine whether remedial action is required (included in the Scope in Section 9.1).*
Poly Aromatic Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined	*Yes- A potential risk has been identified from a number of PAHs in the vicinity of WS130. Further data gathering and assessment is needed to determine whether remedial*

Copeland Borough Council Pollutant Linkage	***Findings and Remediation Actions for Plot G***
controlled waters receptor.	*action is required (included in the Scope in Section 9.1).*
Surfactants in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*Yes- A potential risk has been identified from MBAS in groundwater at WS130. Further data gathering and assessment is needed to determine whether remedial action is required (included in the Scope in Section 9.1).*
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 from phosphate.*
Arsenic in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Boron in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Cadmium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Chromium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Copper in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkages identified for copper (potential linkage identified but not considered significant based on site observations, ground conditions, and geochemical results). Refer to Appendix G, section 3.5.*
Lead in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Mercury in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Nickel in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Selenium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Zinc in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).* *Zinc concentrations in groundwater at WS418 exceeded the screening criteria at the Stage 3b assessment. This was discounted due to the marginal exceedance and conservatism used in the risk assessment.*
VOCs/ SVOCs in soil, migrating from	*No significant pollutant linkage (no source).*

Copeland Borough Council Pollutant Linkage	***Findings and Remediation Actions for Plot G***
soil to groundwater and through drains impacting undefined controlled waters receptor.	

TABLES

FIGURES

PLATES

Appendix A - Proposal For Site Works

Appendix B - Field Methodology

Appendix C - Borehole & Trial Pit Logs

Appendix D - Laboratory Certificates (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 - Model Inputs