Remediation Statement
Appendix H

Plot F 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 F"- 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 F is located towards the north eastern end of the site, in an area most recently operated by Huntsman as part of their surfactants business. This parcel of land is predominantly derelict with only one small building structure still existing (the Huntsman Site Office).

The northern end of Plot F was formerly occupied by an above ground tank farm reportedly used for the storage of fuels, which have since been removed. During 2003, a remediation was conducted in the vicinity of these tanks. The aim of this remediation was to address the historic spillage of heavy fuel oil in the vicinity of the tanks. These works were completed in 2004. During the March 2007 investigation, a trial pitting exercise was undertaken which allowed assessment of the subsurface of Plot F (which included part of the 2003 remediation area). A total of six trial pits were excavated and soil samples taken for inspection and analysis. Two existing shallow groundwater wells (previously installed by Environmental Resources Management, ERM) were also sampled. The soil and groundwater samples collected were scheduled for a suite of analyses.

Ground conditions observed comprised made ground, overlying natural clay and silt deposits subsequently underlain by rock head. Ground cover over the majority of the site comprised a limestone gravel. A limited area within Plot F was covered with tarmac hardstanding. Made ground generally comprised a heterogeneous mix of bricks, with some ash and clinker. The natural drift deposits of clay and silt were observed in the majority of locations. The thickness of these horizons and depth encountered varied across the area. Bedrock was encountered at a number of locations, which comprised fine to medium sandstone, and at one location a siltstone with angular clasts within it. In the six trial pits excavated during this investigation, bedrock was found at between 2.1 and 2.8 meters below ground level.

A Stage 2 controlled waters generic screening exercise was completed on all data collected from the within the Plot F boundary to date (this included data from previous investigations). The key receptor identified for the controlled waters assessment comprised groundwater within the Whitehaven Sandstone. The screening exercise identified potential exceedances of Total Petroleum Hydrocarbons (TPH), and VOCs in soil, soil leachate or shallow groundwater.

A Stage 3 detailed quantitative risk assessment was undertaken using a model constructed in ConSim v2.02. This modelled the flow of contaminants from the source area (shallow horizons within Plot F) vertically downwards to the groundwater table within the Whitehaven Sandstone, and then a lateral migration of contaminants towards the theoretical compliance point set at 100m and 250m (the site boundary), down hydraulic gradient. The controlled waters risk assessment identified potential risks associated with leachable aromatic TPH fractions in the range C10-12 and aromatic TPH fractions C12-16 and C16-21 in the groundwater. These risks are considered to be marginal and theoretical,

and remediation to reduce these risks further is considered to be not practical and acheivable given the low concentrations of TPH measured in soil and groundwater. However, observations made during the site investigation suggested the potential presence of free phase product in the shallow perched groundwater horizons, directly on top of the bedrock in Plot F; it was not possible to confirm this by sampling from trial pits.

Monitoring boreholes are required in the following areas:

Area 1- the area in the vicinity of TP752F: Further limited investigation for TPH; and

Area 2- the area in the vicinity of TP756F: Further limited investigation for TPH.

Following completion of this additional investigation,an assessment will be made on the potential presence (and extent) of free product in these areas. If free product is found, URS will provide Rhodia with options of appropriate remediation technologies to address its removal.

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.

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

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 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 F" within the boundary of the site. Plot F is one of a sequence of plots on the Whitehaven site identified as requiring further investigation in a Site Remediation Statement[1] document. This report formalises the scope, context, and timescales of investigations required on the site.

The site (including Plot F) 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 F 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, Rhodia's operations on the site have diminished, the phosphate business has been closed down and over the past 2 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 northeastern 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 were developed in relation to phosphate and surfactant manufacturing processes and other historic activities comprising: coal and anhydrite mining; coke production: tar distillation; and firelighter

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

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 hereafter 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 F. Further to this requirement, URS has reported the findings of the Plot F 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 F 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 F

Plot F is located towards the north-eastern end of the site, in an area most recently operated by Huntsman as part of their surfactants business. This parcel of land is predominantly derelict with only one small building structure (the Huntsman Site Office) still existing. The northern end of Plot F was formerly occupied by above ground storage tanks reportedly used for the storage of fuels, which have since been removed. The dye and perfume shed (part of the surfactant manufacturing process) was located towards the northern end of Plot F, immediately to the north of the above ground storage tanks.

The area of interest has been presented in Figure 2. The former layout of the site is presented on Figure 3. The plot is approximately rectangular in shape. The estimated area of Plot F is 2,200m^2.

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 vicinity of Plot F are as follows:

- URS investigation on behalf of Rhodia (ref; 44557-021) during 2001: three shallow soil borings (WS108, WS109 and WS111) advanced as part of site wide assessment;

- URS investigation on behalf of Rhodia (44557-046) during 2003 and 2004; and

- URS investigation on behalf of Rhodia (ref; 44319904) during 2006: continued on-going monitoring of six deep groundwater wells and four off-site surface water locations. None of the six deep wells were located within the boundary of Plot F. Quarterly groundwater monitoring has been conducted since February 2004; previous report references are 44319646 and 44557-045.

In addition, an ERM investigation was conducted towards the end of 2006 on behalf of Huntsman. Two shallow groundwater monitoring wells were installed. With permission from Huntsman, URS sampled these wells as part of the Plot F investigation. The wells were named ERM1 and ERM2 by URS.

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 were advanced in Plot F as part of site wide assessment, one soil boring (WS111) was not installed as a groundwater monitoring well. Analysis in soils comprised metals, TPH, VOCs, SVOCs, TOC, PSD, pH and leachate (metals and SVOC). Analysis in groundwater comprised metals, TPH, VOCs, SVOCs, phosphate, pH and surfactant.

In WS108, black staining and a hydrocarbon odour was noted in the Made Ground, along with a strong diesel odour in the groundwater. Soil analytical results detected relatively elevated concentrations of Mercury and total TPH. Groundwater analysis detected elevated concentrations of Surfactant and total TPH. In WS109 no visual or olfactory evidence was noted in the soil or groundwater. Groundwater analytical results detected relatively elevated concentrations of Boron and Phosphate. In WS111 no visual or olfactory evidence was noted.

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 F.

No assessment was made for controlled waters. It was considered that further work was required to determine the extent of impact to receptors.

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

Remedial works in the vicinity of the fuel oil above ground storage tanks (Ref: 44557-046, September 2003 to May 2004)

The northern end of Plot F was formerly occupied by an above ground tank farm reportedly used for the storage of fuels, which have since been removed. During 2003, a remediation was conducted in the vicinity of these tanks. The aim of this remediation was to address the historic spillage of heavy fuel oil in the vicinity of the tanks. These works were completed in 2004. Remedial works included excavations and subsequent sampling of trench side walls (samples Stage 3W, 3X, 3Y and 3AA), and installation of boreholes WS108, WS109, BH302 and BH303. Figure 2 shows the area where these works were conducted.

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

This project continues 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 or 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 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 following decommission, a further decrease is likely to be seen in concentrations of surfactant detected at Byerstead Spring.

Concentrations of dissolved phosphorus at Byerstead Spring 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 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 potentially significant pollutant linkages are explained.

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

Appendix A	Proposal for Site Works (Plot F) 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 F".

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 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 start of works. Details of the investigation design and rationale are presented in the proposal included in Appendix A. To date URS has not received a response from the Environment Agency.

3. SITE DESCRIPTION AND ENVIRONMENTAL SITE SETTING

3.1. Introduction

The Former Albright and Wilson Works) is located in a coastal setting, on the hill approximately 2 km south of Whitehaven Town Centre. To the northeast 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 F occupies an area of approximately 2200m^2 (0.22 hectares) and is located in the northeast corner of the site.

3.2. Plot F Current and Historical Operations

Plot F comprises an area of the site formerly occupied by the dye and perfume shed (part of the surfactant manufacturing process), and an above ground storage tank farm (reportedly to have been used for the storage of fuels, which has now been demolished to ground level), and an existing office building. Much of the ground remains covered by limestone gravel resting on a geotextile sheet and tarmac hardstanding.

3.3. Environmental Setting

The environmental setting for the site has been previously established during URS's Phase II investigation (ref; 44319623. Phase II Investigations and Environmental Assessments at the Former Albright & Wilson Works, Whitehaven, 23 June 2005). A summary of the setting, specific to Plot F, 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
- Glacial Till (Boulder Clay) (the "drift"): present across the area in limited thickness, although absent in some parts of the site, overlying either
- St Bees Evaporite Formation (late Permian): present as either pink grey crystalline limestone or as yellow sandstone at a number of locations across the site. This formation is classified as a non-aquifer by the Environment Agency. This unit is not thought to be present in Plot F.
- 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 unit is thought to be

present in parts of Plot F. 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 interbeds of mudstones and siltstones bedded with sandstones and siltstone. This sandstone is classified as a minor aquifer by the Environment Agency. This unit is thought to be present in Plot F.

3.3.2. Surface Waters

No surface water bodies are present within the boundaries of Plot F or within its immediate vicinity. However, the Plot F area is serviced by a storm water drainage system which was designed to drain the water within Plot F towards the coast. It is currently proposed that the drains on the whole of the site will be blocked and allowed to silt up and that the groundcover within Plot F will be left in its current state.

Once the drains are no longer able to remove significant volumes of water it is assumed that there will be a greater component of overland flow corresponding to the natural watershed that drains the Plot F Area. However, given that Plot F is relatively flat lying, the distance surface water can travel is likely to be limited. It is considered that infiltration of surface water is likely to 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 F area:

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

- *Deep groundwater and subsequently Coastal Waters*: The groundwater within the Whitehaven Sandstone is likely to receive infiltrating shallow groundwater in Plot F due to the shallow depth to bedrock. Once into the Whitehaven Sandstone, it is likely that lateral groundwater flow will occur through the sandstone, towards the Irish Sea. The Whitehaven Sandstone is classified as a minor aquifer by the Environment Agency.

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:

- Former Heavy Oil ASTs. Spillages and leaks of hydrocarbon oil. Contaminants of concern include petroleum hydrocarbons, SVOCs and VOCs;

- Former Huntsman Operations Plant. Spillages, leaks and disposal to ground of raw and finished products. Contaminants of concern include surfactants, VOCs, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons, nitrates and ammonia; and

- Concentrations of contaminants within imported materials used for ground raising and reclamation (Made Ground), e.g. ash and clinker fill, which may contain VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates. Mercury has also been found in the boundary of Plot F. The source of this analyte is unknown.

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 6 trial pits advanced across Plot F during this investigation.

Historically, activities located within Plot F have included the dye and perfume shed associated with the surfactant manufacturing process. More recently Plot F has been occupied by an office building in the southeast of the area and an above ground storage tank farm (ASTs) in the northern half of Plot F, which has reportedly been used for the storage of fuels. However, no patterns of ground conditions have emerged to facilitate the discussion of Plot F by dividing it into sub-areas, and as such, it is described as a whole area. Figure 4 presents the ground cover on Plot F at the time of the investigation.

4.2. Soil Conditions

The ground conditions underlying the Plot F 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.

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 2.

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 – 0.2	0.3
	Gravel of Limestone on a geotextile sheet	0 - 0.2	0.2
	Brown sand and gravel with man made components (fill material)	0.2 –1	0.8
	Black ashy silty gravel with pockets of brown silty clay and with man made components	0.2 – 1	1
Natural Ground	Glacial Till Deposits typically comprising firm orange – brown silty clay with occasional gravel and cobbles.	0.7 – 1.1	1.1
	Glacial Till Deposits typically comprising firm red – brown clayey silt with occasional gravel and cobbles	1- 1.8	2.05

Unit	Description	Depth to Top of Stratum (m)	Maximum Thickness (m)
	Red – brown fine sand with gravel and cobbles of sandstone	2.1 – 2.5	0.8
Bedrock	Red – brown weathered sandstone	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.

4.2.1. Made Ground

The Made Ground varied in thickness from 0.45m at TP751F to 1.1m at TP755F. The Made Ground comprised largely of one or more of the following:

- Fill material: generally brown sand and gravel with occasional brick; and
- Ash: generally black or brown silty gravel with pockets of brown silty clay and occasional brick, ash, coal and clinker.

A gravel of limestone resting on a geotextile sheet covers the majority of Plot F. Reinforced concrete hardstanding (0.1 – 0.2m thick), underlain by grey limestone gravel, was encountered at TP752F and TP753F in a service and road access area of for Plot F.

4.2.2. Natural Ground

Glacial Till (Drift/ Boulder Clay)

Drift deposits were encountered over most of Plot F with a maximum proven thickness of 2.25m observed in TP751F.

Drift was not observed in one location due to difficulties in the excavation of TP753F (underground services). In one location (TP756F), the excavation was not advanced beyond 1.8m so as to prevent potential migration of shallow contamination to deeper horizons (given the ingress of contaminated water into the base of the trial pit from above 1.8m).

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

- firm orange – brown silty clay with occasional gravel and cobbles;
- firm red – brown clayey silt with occasional gravel and cobbles; and
- red – brown fine sand with gravel and cobbles of sandstone.

Natural Ground (Bedrock)

Bedrock was encountered during this investigation. At TP755F, the lithology observed was red weathered sandstone. This unit is considered to represent the Whitehaven Sandstone Formation.

At TP752F, it is thought that the Brockram Formation may have been encountered. However, due to the ingress of groundwater into the base of the trial pit, no detailed examination of the bedrock could occur.

The estimated vertical and lateral extent of these units is illustrated on Figures 6 and 7.

4.3. Groundwater Conditions (within trial pits and monitoring wells)

Groundwater strikes were observed during the excavation of the trial pits in TP751F, TP752F, TP754F and TP755F with a rapid ingress of water in TP756F. Groundwater was additionally identified within monitoring wells ERM1 and ERM2. The observed groundwater is thought to be perched as it is generally found within the weathered sandstone layer above the sandstone bedrock. Groundwater does not appear to be continuous across Plot F.

There are two groundwater wells located in Plot F: ERM1 and ERM2. These were installed by ERM in 2006. These wells were dipped and sampled by URS on 12th March 2007. The groundwater levels are listed in Table 4.2 below.

Table 4.2 Summary of Groundwater Monitoring

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 Contamination. (Y/N)
ERM1	12/03/2007	95.244	1.992	2.235	93.252	N
ERM2	12/03/2007	95.178	2.186	3.153	92.992	N

maOD – Meters above Ordnance Datum; mbgl- meters below ground level. BH302, BH303, WS108 and WS109 could not be located during the March 2007 sampling round.

It is considered groundwater flow direction is likely to follow dip and topography to the west/south west. As groundwater migrates out of Plot F and towards the western site boundary, it will encounter a north-south trending fault. At the fault, it is thought that the geological sequence has been downthrown on the western side. The water may migrate downwards into the fault plane, before continuing to migrate laterally following the path of least resistance/highest permeability towards the coastline; this may be within old mine adits, the partially dissolved St. Bees Evaporite Formation, or continue within the Whitehaven Sandstone 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.

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
TP751F	Black staining, HC and sweet odour.	NVO	-
TP752F	HC and sweet odour and staining, PID 34.3ppm at 0.25m bgl. Black water within trial pit (potentially free product)	HC staining and odour, sweet odour and oily sheen.	Black staining through bedrock matrix
TP753F	NVO	NVO	-
TP754F	NVO	-	-
TP755F	NVO	NVO	-
TP756F	Perfume odour, sheen, slight foam on ingress water. Black water within trial pit. (potentially free product)	NVO	-

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

Contamination potentially derived from Site Processes

The nature of the observed contamination suggests the source of the potential contamination is not associated with the Made Ground present, and is instead likely to have been derived from site activity:

- A hydrocarbon and a sweet odour were observed in the Made Ground at TP751F and TP752F and in the drift geology at TP752F. In TP752F an elevated PID reading of 34.3 ppm was observed at 0.25m bgl, together with back staining in the drift and bedrock matrix. The trial pits are located near the former oil storage tanks.

- At TP756F a perfume odour was observed in the Made Ground. Flecks of foam were noted on the groundwater.

No visual or olfactory evidence of contamination in trial pits and groundwater wells

No visual or olfactory evidence of contamination was encountered in trial pits TP753F, TP754F and TP755F. These are located to the south of Plot F, away from the dye and perfume shed and the former storage tanks.

4.5. Geochemical Results

The analytical results (enclosed as a CD) are provided in Tables 1 to 20 in Appendix D along with laboratory certificates and analytical schedules.

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 and five groundwater samples were submitted for VOC analysis:

- seven soil samples reported concentrations greater than the laboratory method detection limit (MDL);
- no VOCs were detected in the water samples.

Elevated concentrations of VOCs are summarised in the Table 4.4 below:

Table 4.4 – Elevated Concentrations of VOCs (Soil)

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	0.009	0.39	1	Made Ground (1)
1,3,5-Trimethylbenzene	0.008	0.018	1	Made Ground (1)
Benzene	0.009	0.022	1	Made Ground (1)
Ethylbenzene	0.004	0.007	1	Made Ground (1)
M,P-Xylene	0.014	0.03	3	Made Ground (2), Drift (1)
O-Xylene	0.010	0.022	1	Made Ground (1)
P-Isopropyltoluene	0.011	0.21	1	Made Ground (1)
Toluene	0.005	0.015	2	Made Ground (1), Drift (1)

The samples with elevated VOCs are all located in the northern, inner (TP752F) and western (TP753F) parts of Plot F.

VOC analysis was not carried out on soil leachates as the leaching methodology is considered to be unsuitable for assessment of VOCs.

Metals

12 soil samples and seven groundwater samples were submitted for metal analysis. Seven soil samples were submitted for NRA leachate preparation and subsequent analysis. Elevated concentrations are summarised in the Tables 4.5 to 4.7 below:

Table 4.5 – 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	3	22	4	Made Ground (3), Drift (1)
Cadmium	0.3	1.2	2	Made Ground (2)
Chromium	11	85	4	Made Ground (4)
Copper	6	180	4	Made Ground (4)
Lead	8	720	3	Made Ground (3)
Mercury	0.6	30	1	Made Ground (1)
Nickel	5.9	90	4	Made Ground (4)
Zinc	24	300	4	Made Ground (3), Drift (1)

Table 4.6 – Elevated Concentrations of Metals (Soil 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	9	4	Made Ground (4)
Boron	10	80	2	Made Ground (1), Drift (1)
Chromium	1	3	1	Made Ground (1)
Copper	1	52	2	Made Ground (2)
Lead	1	3	1	Made Ground (1)
Nickel	1	17	2	Made Ground (2)
Zinc	3	80	3	Made Ground (3)

Table 4.7 – Elevated Concentrations of Metals (Water)

Metal in water	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Arsenic	1	7	1	Groundwater (1)
Boron	16	138	2	Groundwater (2)

Metal in water	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Chromium	1	2	2	Groundwater (1), Seepage water (1)
Copper	1	11	3	Groundwater (2), Seepage water (1)
Lead	1	2	1	Groundwater (1)
Nickel	2	17	2	Groundwater (1), Seepage water (1)
Zinc	3	57	3	Groundwater (3)

High concentrations of metals have been found within soil, soil leachate and groundwater samples collected from the northern part of Plot F. The majority of these were reported in soil samples collected from the Made Ground. As is typical with any historic industrial facility: gravel, brick, ash, coal and clinker have been used as fill during levelling ground works on the site. These fill materials may act as sources of metals and consequently increase metal concentrations in shallow horizons.

Elevated soil metal concentrations were also observed in the underlying drift. Relatively high concentrations of arsenic and zinc were observed within TP755F (clay) at 1.1m and copper in TP754F at 1.3m (silt). Both trial pits are located at the eastern part of Plot F.

Leachable arsenic was detected in high concentrations in most of the sample locations with the highest concentrations observed in TP753F. High concentrations of leachable boron were detected in the drift in TP751F at a depth of 1.1m.

The majority of elevated groundwater metal concentrations were observed in the northern part of Plot F.

Anionic Surfactants

Four soil, one leachate and five groundwater samples were analysed for Anionic Surfactants. Samples collected from the drift deposits (silt) at 1.1m (TP751F) show an elevated concentration of 120 mg/kg, while concentrations of the other leachate samples were below the MDL. The concentrations of anionic surfactants in groundwater reached relatively high concentrations in three samples with a maximum concentration of 4500 µg/L detected in WS108 in January 2005. The majority of surfactants were detected within the northern part of Plot F.

Semi Volatile Organic Compounds (SVOCs)

Out of the 12 soil samples analysed for SVOCs, 9 samples were reported to have concentrations above laboratory MDL.

Out of the four samples submitted for leachate SVOC analysis, concentrations above laboratory MDL were reported in one sample.

There were no SVOCs detected in the five groundwater samples submitted for analysis.

Elevated SVOC concentrations are summarised in Tables 4.8 and 4.9 below.

Table 4.8 – Elevated Concentrations of SVOCs (Soils)

SVOC in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
2-Methylnaphthalene	0.1	1.3	2	Made Ground (2)
4-Methylphenol	0.1	0.2	1	Drift (1)
Acenaphthene	0.1	0.8	1	Made Ground (1)
Anthracene	0.1	5.2	1	Made Ground (1)
Benzo(a)anthracene	0.1	9.7	2	Made Ground (2)
Benzo(a)pyrene	0.1	6.3	2	Made Ground (2)
Benzo(b)fluoranthene	0.1	7.3	2	Made Ground (2)
Benzo(g,h,i)perylene	0.1	2.9	2	Made Ground (2)
Benzo(k)fluoranthene	0.1	3.3	2	Made Ground (2)
Butylbenzylphthalate	0.1	0.8	1	Made Ground (1)
Carbazole	0.1	1.9	1	Made Ground (1)
Chrysene	0.1	6.8	2	Made Ground (2)
Dibenz(a,h)anthracene	0.1	1.1	1	Made Ground (1)
Dibenzofuran	0.1	0.6	1	Made Ground (1)
Fluoranthene	0.1	22	2	Made Ground (2)
Fluorene	0.1	1.8	2	Made Ground (2)
Indeno(1,2,3cd)pyrene	0.1	3.2	2	Made Ground (2)
Naphthalene	0.1	0.2	2	Made Ground (2)
Phenanthrene	0.1	15	2	Made Ground (2)
Pyrene	0.1	15	2	Made Ground (2)

Table 4.9 – Elevated Concentrations of SVOCs (Soil 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	1	2	1	Made Ground (1)

The majority of SVOC detections were in the Polycyclic Aromatic Hydrocarbon (PAH) group of analytes in samples collected from Made Ground. High SVOC concentrations in the southern part of Plot F were measured mainly in the samples collected from TP754F (at 0.4m) and for TP755F (0.2m). Elevated concentrations were also detected in samples collected from drift clay deposits in the northern part of Plot F BH302 (0.5m) and BH303 (0.8m). A high concentration of leachable 2,4-Dimethylphenol of 2 µg/l was detected in the Made Ground in TP752F located in the centre of this Plot.

Total Petroleum Hydrocarbons (TPH)

21 soil, 3 leachate and 7 water (6 groundwater, 1 seepage water) samples were submitted for TPH analysis. 20 soil samples were analysed for TPH using the risk-based evaluation (RBE) method. 15 soil samples were analysed for TPH using criteria working group (CWG) method. TPH was reported at concentrations exceeding the MDL in 12 soil, 1 leachate and 1 water samples. Elevated concentrations detected in the CWG analysis are summarised in Tables 4.10 to 4.12.

Most fractions detected using CWG method in the samples taken from the Made Ground in TP752F (0.2m) were found in high concentrations. Elevated concentrations of total hydrocarbons were observed in the Made Ground in TP752F and WS108.

High concentrations of total aliphatics (C6-C40) (2200 mg/kg) and total aromatics (C6-C40) (2000 mg/kg) were observed in the samples taken from the drift deposits (gravel) found in TP752F (2.5m). Both represent the maximum detected concentrations within the Plot F investigation area.

Elevated concentrations of leachable aromatic (990 µg/L) and aliphatic (660 µg/L) TPH fractions (EC8-C10) were observed in the Made Ground in TP752F (0.2m).

A water sample of TP756F (seepage water) was found to contain elevated concentrations of TPH (EC12-16) aromatic and (EC16-21) aliphatic.

Table 4.10 – Elevated concentrations of TPH CWG (Soil)

TPH in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
TPH (>EC6-7) Aromatic	0.01	0.03	1	Made Ground (1)
TPH (>EC7-8) Aromatic	0.01	0.02	1	Made Ground (1)
TPH (>EC8-10) Aromatic	0.01	2.9	1	Made Ground (1)
TPH (>EC10-12) Aromatic	0.01	2.7	1	Made Ground (1)
TPH (>EC12-16) Aromatic	0.1	98	4	Made Ground (3), Drift (1)
TPH (>EC16-21) Aromatic	0.1	550	5	Made Ground (2), Drift (3)
TPH (>EC21-35) Aromatic	0.1	2200	4	Made Ground (6), Drift (4)
TPH (>EC5-6) Aliphatic	0.1	0.65	4	Made Ground (3), Drift (1)
TPH (>EC6-8) Aliphatic	0.01	0.52	1	Made Ground (1)
TPH (>EC8-10) Aliphatic	0.01	1.9	1	Made Ground (1)
TPH (>EC10-12) Aliphatic	0.01	1.8	1	Made Ground (1)
TPH (>EC12-16) Aliphatic	0.1	1100	4	Made Ground (3), Drift (1)
TPH (>EC16-21) Aliphatic	0.1	3173	4	Made Ground (3), Drift (1)
TPH (>EC21-35) Aliphatic	0.1	3900	2	Made Ground (2)
Benzene	0.01	0.03	1	Made Ground (1)
Toluene	0.01	0.02	1	Drift (1)

Table 4.11 – Elevated concentrations of TPH CWG (Soil Leachate)

Leachable TPH	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
TPH (>EC10-12) Aromatic	10	990	1	Made Ground (1)
TPH (>EC10-12) Aliphatic	10	660	1	Made Ground (1)

Table 4.12 – Elevated concentrations of TPH CWG (Water)

TPH in water	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
TPH (>EC12-16) Aromatic	10	140	1	Seepage water of TP756F
TPH (>EC16-21) Aromatic	10	100	1	Seepage water of TP756F
TPH (>EC12-16) Aliphatic	10	14	1	Seepage water of TP756F
TPH (>EC16-21) Aliphatic	10	37	1	Seepage water of TP756F

Additional Analytes

Two soil and two groundwater samples were submitted for Polychlorinated Biphenyls (PCB) analysis. No elevated concentrations were detected. Further additional analytes include: ammoniacal nitrogen (6 soil, 3 groundwater); anionic surfactant (4 soil, 1 leachate, 5 groundwater); asbestos (1 soil); bicarbonate alkalinity (3 groundwater); calcium (3 groundwater); chloride (6 groundwater); fluoride (3 groundwater); iron (3 groundwater); magnesium (3 groundwater); nitrate as N (1 soil); ortho-phosphate (6 soil, 3 leachate, 6 groundwater); potassium (3 groundwater); sodium (4 groundwater); sulphate (4 soil - water soluble, 3 leachate - leachable, 6 groundwater – water soluble); total cyanide (6 soil, 3 leachate, 6 groundwater); and total organic carbon (2 soil).

The elevated concentrations reported for these analytes are summarised in Tables 4.13 to 4.15.

Table 4.13 – Elevated Concentrations of Additional Analytes (Soils)

Analyte in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Ammoniacal Nitrogen	15	34	3	Made Ground (1), Drift (2)
Anionic Surfactant	50	120	1	Drift (1)
Nitrate as N	1	4	1	Drift (1)
Sulphate Water soluble	170	6800	1	Made Ground (1)
Total Organic Carbon	0.4	5.5	1	Drift (1)
Total Sulphate	510	780	1	Drift (1)

Table 4.14 – Elevated Concentrations of Additional Analytes (Soil Leachate)

Leachable analyte	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Phosphate (Ortho)	180	1400	1	Drift (1)
Sulphate	8000	75000	2	Made Ground (1), Drift (2)

Table 4.15 – Elevated Concentrations of Additional Analytes (Water)

Analyte in water	Minimum reported concentration (µg/L)	Maximum reported concentration (µg/L)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Anionic Surfactant	50	4500	3	Groundwater
Bicarbonate Alkalinity	2000	250000	1	Groundwater
Calcium	5	270000	1	Groundwater
Chloride	1000	32000	2	Groundwater
Fluoride	500	1800	1	Groundwater
Iron	5	15550	2	Groundwater
Magnesium	5	10800	1	Groundwater
Nitrate as N	300	3800	2	Groundwater
Phosphate (Ortho)	80	250	1	Groundwater

Analyte in water	Minimum reported concentration (µg/L)	Maximum reported concentration (µg/L)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Potassium	200	13200	1	Groundwater
Sodium	200	61500	2	Groundwater
Sulphate Water soluble	3000	841000	2	Groundwater

Elevated concentrations were not observed either in soil leachate nor water samples during the most recent sample rounds.

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. The contamination is thought to be predominantly towards the central, northern and western side of Plot F.

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 in Appendix A. These comprise the following**;**

Table 5.1a – Summary of potential Sources

Potential Sources	Contaminants of Concern
Former Heavy Oil AST	Petroleum hydrocarbons, SVOCs and VOCs
Former Huntsman Operations Plant	Surfactants, VOCs, SVOCs, heavy metals, phosphate, sulphate, petroleum hydrocarbons, nitrates and ammonium.
Unidentified source	Mercury
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 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 points where the integrity of the drainage lines may have been compromised.
Controlled Water 2 (CW2)	Vertical movement of dissolved or liquid contaminants from shallow groundwater to groundwater within the Whitehaven Sandstone. Movement from shallow groundwater to groundwater in the Whitehaven Sandstone 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.
Controlled Water 3 (CW3)	Lateral flow of deep groundwater within the sandstone aquifer to the defined compliance point.
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: Compliance Point in the Whitehaven Sandstone.	Groundwater migrates through the Whitehaven Sandstone. The receptor has been designated as groundwater within the Whitehaven Sandstone at a compliance point 250m downgradient of Plot F (the site boundary). Beyond this compliance point, groundwater continues to migrate towards the Irish Sea.

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 F Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
C1	Petroleum hydrocarbons, SVOCs and VOCs	Former Heavy Oil ASTs	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the Sandstone Aquifer (and subsequently the Irish Sea after it has passed through the complex geological system in the area)
C2	Surfactants, VOCs, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons, nitrates and ammonia	Former Huntsman Operation Plant	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the Sandstone Aquifer (and subsequently the Irish Sea after it has passed through the complex geological system in the area)
C3	Mercury	Unidentified source	CW1, CW2, CW3	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the Sandstone Aquifer (and subsequently the Irish Sea after it has passed through the complex geological system in the area)
C4	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	Sandstone Aquifer	Irish Sea	Potential for entry of contaminant into the Sandstone Aquifer (and subsequently 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 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 F. 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 F Source location	Pathway	Main Receptor	Additional Receptors	Description of Harm/Pollution of Controlled Waters
H1	Petroleum hydrocarbons, SVOCs and VOCs	Former Heavy Oil ASTs	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	Surfactants, VOCs, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons, nitrates and ammonia	Former Huntsman Operation 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
H3	Mercury	Unidentified source	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	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 F 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 garden scenario. A number of substances were identified which exceeded their respective generic screening criteria:

Soil

- **Metals** – arsenic, nickel, lead, mercury;
- **PAH** –benzo(a)pyrene; and
- **TPH** – assessed via TPH Criteria Working Group (TPHCWG) fractions.

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.

Therefore for the exceedances identified at Stage 2 further assessment has been completed and the significance for potential harm identified. 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.

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, it is considered that there are no significant pollutant linkages associated with human health, principally on the basis that the sources of contamination are not considered to represent significant sources.

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

[2] Residential without gardens

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 summarised below.

7.2. Stage 2 Assessment

A Stage 2 generic quantitative screening risk assessment was undertaken. The results of the Stage 2 assessment are summarised in Table 7.1.

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

Soil	Soil Leachate	Shallow Groundwater
1,2,4-trimethylbenzene	TPH C10-C12 Aromatic	TPH C12-C16 Aromatic
Benzene	TPH C10-C12 Aliphatic	TPH C16-C21 Aromatic
		TPH C12-C16 Aliphatic
		TPH C16-C21 Aliphatic

Given the presence of granular made ground, absence of low permeability drift, and shallow depth to bedrock (less than 3m), the pollutant linkage is considered plausible for all of the sources in Table 7.1. Those determinands whose concentrations exceeded the Stage 2 screening criteria have been taken forward to Stage 3 where a detailed quantitative risk assessment is carried out.

7.3. Stage 3 Assessment

The Stage 3 assessment used ConSim (v2.2) to simulate concentrations at receptors at distances of 100m and 250m from the source area. The 250m compliance point was chosen as it represents the site boundary.

The source area in the model was designated as an area of approximately 1200m^2 in Plot F; this was based on information on historical land use on the plot and the analytical results. The model input concentration for the analytes was generally the maximum concentration, as only one concentration for each was determined above the method detection limit. In one instance, a statistical estimation was used as more than one sample was recorded above the method detection limit (refer to Appendix G for details).

Because each of the samples was taken from granular material, and often wet horizons, located directly above the bedrock (the Whitehaven Sandstone), the distance between the top of the bedrock and the water table was considered to represent the unsaturated zone. Fracture flow was assumed to be the dominant mechanism for groundwater migration in the unsaturated zone. Consequently, the groundwater table (within the

Whitehaven Sandstone) was modelled as being immediately below the source area (*i.e.* as if no unsaturated zone existed). Groundwater was modelled as migrating laterally from the source area towards the 100m and 250m compliance points.

Current UK guidance requires that simulated 95th percentile concentrations be 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 below.

7.4. Summary of Risks to Controlled Waters

For simulated contaminant concentrations to pose a potentially significant risk to controlled waters at the site boundary (250m from the source), 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 3 assessment criteria have been identified.

Please note that the exceedances modelled at Stage 3 are considered marginal, and if the TPH concentrations measured fully represent the contamination present then it is considered that remediation is unlikely to be practical. However, field observations and analytical results are not fully consistent; it is possible that more significant contamination is present that the testing to date would suggest.

It is therefore recommended that the areas of TP752F and TP756F will require further investigation and assessment to determine whether or not remedial action may be required (refer to Section 9).

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

100m Compliance point						250m 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
-	-	Leachable TPH (>EC10-12) aromatic (0.013mg/L)	Leachable TPH (>EC10-12) aromatic (0.034mg/L)	-	-	-	-	IR	Leachable TPH (>EC10-12) aromatic (0.011mg/L)	-	-
-	-	IR	Leachable TPH (>EC10-12) aliphatic (0.012mg/L)	-	-	-	-	IR	IR	-	-
-	-	-	-	TPH (>EC12-16) aromatic (0.049mg/L)	TPH (>EC12-16) aromatic (0.063mg/L)	-	-	-	-	TPH (>EC12-16) aromatic (0.019mg/L)	TPH (>EC12-16) aromatic (0.027mg/L)
-	-	-	-	TPH (>EC16-21) aromatic (0.035mg/L)	TPH (>EC16-21) aromatic (0.046mg/L)	-	-	-	-	TPH (>EC16-21) aromatic (0.014mg/L)	TPH (>EC16-21) aromatic (0.020mg/L)

"IR" = Insignificant Risk: *i.e.* modelled concentration at receptor does not exceed the screening criteria, "-" = Not detected in initial sample analysis

8. REFINED POLLUTANT LINKAGE ASSESSMENT

The human health risk assessment for Plot F 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 some 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 (Section 5.4) as detailed in the Site Remediation Statement.

The controlled waters risk assessment considered a conservative scenario where the contaminants from the source zone enter directly into the underlying sandstone aquifer via fracture flow through the unsaturated zone. The assessment thus makes no allowance for attenuation of contaminant concentrations by retardation or biodegradation within the unsaturated zone. 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. Consequently, risks are generated due predicted concentrations in the aquifer underlying Plot F being greater than they would be if the unsaturated zone were accurately characterized. However, whilst every effort has been made to develop a reasonably realistic model, there is insufficient detailed information on the precise nature of the unsaturated zone below Plot F, resulting in there being an element of conservatism in the model.

Given the complexity of the geological, and hydrogeological conditions, coupled with the spatial distribution of the modelled source area, to remove the conservative elements from the model 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 Plot F that has emerged from the investigation is that contamination posing a potential risk is limited to a relatively small area.

Whilst the assessment has identified a number of 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 the source area.

Table 8.1 – Refined Pollutant Linkage Assessment

Pollutant Linkage Identifier	Pollutant	Plot F 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	Petroleum hydrocarbons, SVOCs and VOCs	Former Heavy Oil ASTs	CW1, CW2, CW3	Theoretical compliance points	-	Potential for entry of contaminant into the Whitehaven Sandstone before lateral migration within deep groundwater.	1) Trimethylbenzene. No. Insignificant Risk simulated for both compliance points.
							2) Benzene. No. Insignificant Risk simulated for both compliance points.
							3) TPH (in leachate). Yes. For the TPH fraction Aromatic C10-C12 risks were simulated at the 100m and 250m compliance points. Despite the measured TPH concentrations generating only marginal risks at the 250m compliance point, further investigation is required to determine the potential presence of free phase product in Plot F. Refer to Section 9.1.
							4) TPH (in shallow groundwater). Yes. For the TPH fractions Aromatic C12-C16 and Aromatic C16-C21 risks were simulated at the 100m and 250m compliance points. Despite the measured TPH concentrations generating only marginal risks at the 250m compliance point, further investigation is required to determine the potential presence of free phase product in Plot F. Refer to Section 9.1.
C2	Surfactants, VOCs, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons, nitrates and ammonia	Former Huntsman Operation Plant	CW1, CW2, CW3	Theoretical compliance points	-	Potential for entry of contaminant into the Whitehaven Sandstone before lateral migration within deep groundwater.	No. Stage 2 Risk Assessment indicates no significant risk.

Pollutant Linkage Identifier	Pollutant	Plot F 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	Mercury	Unidentified Source	CW1, CW2, CW3	Theoretical compliance points	-	Potential for entry of contaminant into the Whitehaven Sandstone before lateral migration within deep groundwater.	No. Stage 2 Risk Assessment indicates no significant risk.
C4	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	Theoretical compliance points	-	Potential for entry of contaminant into the Whitehaven Sandstone before lateral migration within deep groundwater.	No. Stage 2 Risk Assessment indicates no significant risk.
H1	Petroleum hydrocarbons, SVOCs and VOCs	Former Heavy Oil ASTs	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 3 Risk Assessment indicates no significant risk.
H2	Surfactants, VOCs, SVOCs, heavy metals, phosphates, sulphates, petroleum hydrocarbons, nitrates and ammonia	Former Huntsman Operation 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 3 Risk Assessment indicates no significant risk.

Pollutant Linkage Identifier	Pollutant	Plot F 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	Mercury	Unidentified Source	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 3 Risk Assessment indicates no significant risk.
H4	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 3 Risk Assessment indicates no significant risk.

9. REMEDIATION ACTIONS

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

The majority of potential pollutant linkages have been shown to be not significant, and therefore for these analytes, no remediation actions will be necessary. Some potential linkages have been identified which will require additional investigation in order to assess their significance.

The results of the modelling have indicated that potentially significant risks may be present with regard to controlled waters. Two areas of the site: the area around TP752F and the area around TP756F will require further investigation and assessment to determine whether or not remedial action may be required.

Although the modelled concentrations at the site boundary (250m) and offsite (400m) receptors suggest that there is limited risks to ground water outside the site from Plot F, the observed black staining on the top of the bedrock at TP752F may need to be further assessed. Furthermore, additional characterisation of the nature of the contamination at TP756F is also required. The areas requiring additional investigation are presented in Figure 9.

It is proposed that one groundwater well is advanced in the vicinity of TP752F and one in the vicinity of TP756F. Soil samples shall be taken at approximately 0.5m intervals for subsequent on site headspace analysis. Up to two soil samples shall be scheduled for analysis; one shallow sample within the made ground and one deeper sample within the underlying strata (where possible). Following development of these wells, an assessment will be made as to whether the black contamination on the groundwater forms a discernible product layer. If so, then Rhodia may wish to remove this product through dewatering of the shallow horizons. Removal of free product is likely to remove the presence of an ongoing source and therefore increase the degradation rate of contamination sourced from Plot F. URS will provide Rhodia with options of appropriate remediation technologies to address its removal.

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 F*
Petroleum Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*Yes- Potential risks associated with TPH have been identified at TP752F and TP756F. 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 controlled waters receptor.	*No significant pollutant linkage (no source).*
Surfactants in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
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 linkage (no source).*
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	*No significant pollutant linkage (no source).*

Copeland Borough Council Pollutant Linkage	***Findings and Remediation Actions for Plot F***
receptor.	
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).*
VOCs/ **SVOCs** in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no pathway).*

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 (included on CD)