Remediation Statement Appendix E Plot C Site Investigation

Former Albright and Wilson Facility, Whitehaven, Cumbria.

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EXECUTIVE SUMMARY

URS was commissioned by Rhodia on 21st April 2006 to undertake an intrusive soil and groundwater investigation at the former Albright & Wilson site in Whitehaven, as detailed in URS Proposal 130306/SAB/FXW/AJW (dated 13th March 2006).

Surface water drainage attenuation ponds are being constructed in two phases in the southern part of the Whitehaven site. The southern most pond (South Pond) has been completed in the first phase of works. The second phase, North Pond, is yet to be constructed. The purpose of both ponds is to drain the southern catchment area of the site (which includes Plot C which is the subject of this report) into Sandwith Beck, providing flood storage and preventing local flooding on the site. Sandwith Beck is a small stream situated on the southern boundary of the site. The North Pond area is within the area determined as contaminated land by Copeland Borough Council and this report fulfils a requirement for additional investigation included in the remediation statement as a condition of the planning permission for the construction of North Pond.

The objectives of the investigation were to gain an understanding of the soil and groundwater quality within the vicinity of the proposed North Pond and to determine whether special construction is required. Specifically this relates to the potential requirement for a liner to prevent the ingress of contaminated groundwaters to the pond and from there to the Sandwith Beck. A further objective was to investigate and assess risk from a "TPH Hotspot" (with both TPH and naphthalene sources) identified in the investigation undertaken in 1995 in order to meet the Environment Agency's requirements under Part 2A. Prior to the start of investigation works the scope and supporting rationale for the site investigation was submitted to the Environment Agency for comment.

Ten trial pits were advanced to a maximum depth of 5 m below ground level (bgl) and eleven boreholes advanced to a maximum depth of 8 m bgl; of these ten were installed as monitoring wells for ground water. Soil samples were submitted for laboratory chemical analysis of an analytical suite agreed with the EA (including: total petroleum hydrocarbons, volatile and semi volatile organic compounds, metals, surfactants, phosphorous, phosphate and others). Groundwater and leachate samples were also submitted for analysis of an EA approved suite including the same analytes as for soils.

The intrusive investigation identified Made Ground deposits from 1 to greater than 8 meters in thickness, and heterogeneous though commonly containing one or more layers of concrete. Other made ground comprised discarded phosphate, ash, clinker, and gravel fill. Drift deposits comprising Boulder Clay were also encountered at depths between 2.5 and 8 m bgl. The underlying geology was not proven. During inspection of the arisings occasional black staining and hydrocarbon odours were noted within the vicinity of the "TPH Hotspot".

Groundwater was encountered within the drift at elevations between 75.6 and 81.7 m above ordnance datum with a profile that is below the proposed base of the excavation for the North Lagoon.

Laboratory chemical analysis identified elevated concentrations of VOCs (including toluene, ethylbenzene, xylene, 1,2,4-Trimethylbenzene, 1,3,5-Trimethylbenzene, naphthalene) in made ground deposits at 3.2 m bgl in A117, elevated concentrations of PAHs were identified within made ground at sampling locations in the vicinity of the North Pond. Concentrations of TPH were identified in soil samples from across the investigation area, but not within the leachates or the groundwater submitted for testing. Pockets of various metals were identified with elevated chromium, lead, nickel phosphorus and vanadium identified within the footprint of the North Pond and arsenic in A111. Surfactants were identified in samples collected from across the investigation area.

Copeland Borough Council determined the site as contaminated land based on a series of general pollutant linkages. URS has further developed the Conceptual Site Model for Plot C based on the information available from subsequent operations and is based on the following potential pollutant linkages:

- **Potential Sources** – Former raffinate operations (Ufex Plant); former cement operations; former laboratories; former oil storage; former warehouse operations; decommissioning operations; Ufex and Hutbank Landfills[1], TPH hotspot.
- **Potential Pathways** – Infiltration of rainwater though contaminated soil and subsequent leaching and migration; migration of rainwater through the drainage system, dissolution and/or mobilisation of contaminants; lateral flow of contaminated shallow groundwater; lateral flow through ponds to controlled waters; overland flow of rain/storm waters; leaching and vertical migration of shallow groundwaters to deep groundwater; transport of deep groundwater to surface receptors via complex geological pathways; dermal contact; ingestion; inhalation of dust and vapours.
- **Potential Receptors** – Sandwith Beck (Controlled Waters (CW)); Deep Groundwater in the St Bees Shale, Whitehaven Sandstone, and St Bees Evaporites (CW); Shallow Groundwater in drift and made ground (CW); Byerstead Spring, Bellhouse Gill and the Coast (CW); Future Site Users (human health).

A detailed quantitative risk assessment (DQRA) for human health identified concentrations of arsenic in trial pit A111 at 0.5m bgl to represent a significant risk to human health.

The DQRA for controlled waters identified potential risks from copper and anionic surfactants in soils to the Sandwith Beck, which due to the timescale for simulated concentrations to exceed EQS values (5000 and 15000 years respectively) were concluded not to represent a significant risk. The DQRA also considered groundwater in the St Bees Evaporites as a receptor, and no significant risks were predicted.

Both TPH and naphthalene were modelled at Tier 2/3 in the controlled waters DQRA, and neither was predicted to generate a risk. Therefore is it concluded that the "TPH hotspot"

[1] Note that the Copeland Council determination of the site was not based on sources originating from Ufex and Hutbank landfills

does not represent a significant source. This conclusion is based on having obtained additional data, and also on having used a more realistic and site specific model.

Risk to the North Pond of contaminated groundwater entering the pond though flowing through the made ground was also assessed. Groundwater was found to be approximately 1 m below the proposed base of the pond even when considering seasonal or future fluctuations of the groundwater levels. Therefore the risk of contaminated groundwater entering the North Pond is considered to be low.

Recommended remediation actions include:

- Monitoring the North Pond, South Pond and Sandwith Beck to check contamination is not reaching the pond
- Monitoring of Bellhouse Gill and Byerstead Spring
- Additional sampling around A111

The outline of the North Pond is shown on Figure 2. Analysis indicates that the Made Ground to be excavated contains some elevated levels of metals chromium, lead, nickel and vanadium in comparison to Made Ground elsewhere on the site. There are also high levels of phosphate, although it appears to be highly insoluble. Trial pit A117, likely to be up hydraulic gradient of North Pond contained some VOC contamination. The made ground in this area is deep, and there are concrete bases at between 3-4m below ground level. Apart from the phosphate, the Made Ground contamination levels are typical of industrial fills. No risks to human health or water resources have been identified.

It is therefore considered that the material excavated from the North Pond will be suitable for use elsewhere on the site for levelling and regrading, and should be stockpiled in a suitable location away from the pond. The material will not be hazardous waste.

Given that groundwater is below the base of the proposed pond, even allowing for fluctuation in the ground water levels after site closure, it is not considered that the influx of contaminated groundwater to the North Lagoon is potentially significant pathway. It is therefore considered by URS that there is no requirement for the installation of a pond liner.

1. INTRODUCTION

1.1. General Introduction

URS was commissioned by Rhodia on 21st April 2006 to undertake an intrusive soil and groundwater investigation at the former Albright & Wilson site in Whitehaven, as detailed in URS Proposal 130306/SAB/FXW/AJW (dated 13th March 2006). This work was requested by John Moorhouse (Rhodia) at a meeting with Alistair Wyness (URS) on 10th March 2006.

This project focuses on the soil and groundwater conditions within an area of land named Plot C. Plot C is one of a number of plots on the Whitehaven site identified as requiring further investigation in two draft Remediation Statements[2] [3] which formalise the scope, context, and timescales of investigations (Assessment Actions) required on the Rhodia site. There were two remediation statements because a separate Remediation Statement for Plot C was required as a condition on the planning permission for construction of the North Pond. Plot C is now included in the Remediation Statement for the whole site, which supersedes the separate Plot C Remediation Statement.

The site including the Plot C area has been designated by Copeland Borough Council as statutory "Contaminated Land" under Part 2A of the Environmental Protection Act 1990. The entire site has subsequently been declared a "Special Site" and is now regulated by the Environment Agency.

1.2. Project Background

The location for the former Albright and Wilson Works is presented on Figure 1 and its layout on Figure 2 ("44319877, Figure 2") along with the location of the Plot C area within the wider site boundary.

URS has undertaken a variety of investigations on the Rhodia site, formerly the Albright & Wilson site, dating back to 1995. During this period, Rhodia's operations on the site have diminished and the phosphate business has been closed down and over the past 2 years, the majority of remaining production operations have ceased. At present, the site is being demolished. URS understands that only one small surfactants production facility is still active (operated by Huntsman), located towards the north-eastern corner of the site.

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

[3] Former Albright and Wilson Works, Northern Surface Water Pond and "TPH Hotspot": Remediation Statement. 6 June 2006. URS Corporation Ltd. (ref: 44319877/R2233.B02)

Following demolition and remediation of the site, it is proposed that the site should become public open space.

The scope of the previous investigations relate to the use of the site not only for phosphate and surfactant related processes, but historic activities which include coal and anhydrite mining, coke production, tar distillation and firelighter manufacture. The main site investigation was undertaken in 2005, and the resulting report contains full details of the site's history and the investigations carried out. The report is presented in the Remediation Statement (Appendix B to the Remediation Statement, and it is hereafter referred to as the "Phase II report").

Surface water drainage attenuation ponds are being constructed in two phases in the southern part of the Whitehaven site. The southern most pond (South Pond) has been completed in the first phase of works. The second phase, North Pond, is yet to be constructed.

The purpose of both ponds is to drain the southern catchment area of the site (which includes Plot C) into Sandwith Beck, providing flood storage and preventing local flooding on the site. Sandwith Beck is a small stream situated on the southern boundary of the site.

URS have also undertaken site investigation work in the area within the immediate vicinity of the south pond, adjacent to the pH adjustment plant. These works have been reported in a previous URS report (REF: 44319881-1941/ARD/SAB, dated 5th May 2006). The South Pond area is outside the area of statutory contaminated land.

The North Pond area is within the area determined as contaminated land by Copeland Borough Council. As a condition of the planning permission for the construction of North Pond, a Remediation Statement was to be prepared by the Applicant (Rhodia) and approved by the Planning Authority. This Remediation Statement was drafted by URS under a separate commission from Rhodia (REF: 44319877/ R2233.B02, dated 6th June 2006), and approval from the Planning Authority has been received. The Remediation Statement includes a requirement for additional investigation. This report details the findings of this "Plot C" investigation, in accordance with the Remediation Statement. It should be noted that the Remediation Statement has yet to be approved by the Environment Agency. The scope of this investigation has been discussed with, and agreed by the Environment Agency.

The "TPH hotspot" area is an area of potential contamination identified during the Phase II site investigation works undertaken by URS in 2005, and illustrated on Figure 12 of that report. The area lies immediately north of the Ufex landfill, and is east of the footprint of North Pond. It was identified in 2005 as an area which potentially poses a risk to human health and groundwater.

The scope of works for both the North Pond area and the TPH Hotspot area were aimed at gaining sufficient data to enable a remediation strategy to be prepared. This remediation strategy is presented in Section 9 of this report.

1.3. 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.

The results of the chemical analysis carried out, including the screening criteria employed and the screening assessments, are presented in Tables 1 - 14

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

Appendix A	Detailed Field Methodologies and Site Investigation Design.
Appendix B	Borehole/Trial Pit Logs.
Appendix C	Hydrogeological Test Data.
Appendix D	Controlled Waters Detailed Quantitative Risk Assessment.
Appendix E	Proposal for Site investigation Works: Plot C

2. OBJECTIVES

The project objectives listed below are in line with the *Assessment Actions* detailed in Section 3.1 of the Remediation Statement (Northern Surface Water Drainage Pond and "TPH Hotspot" Remediation Statement, 44319877/R2233.BO2, dated 6th June 2006). These Assessment Actions are also presented in the Site Remediation Statement, where the area is referred to as "Plot C".

2.1. North Pond Area (Phase II Drainage Pond)

- assess current soil and groundwater quality within the shallow strata in the vicinity of the pond area;
- understand the geology of the shallow strata, in order to better understand the flow of groundwater in the vicinity of the pond area;
- provide sampling coverage adequate to develop a remediation strategy
- understand the long term groundwater quality in the vicinity of the pond area;
- determine the requirement for a clay liner to the north lagoon designed to prevent the inflow of contaminated groundwater
- assess the potential influence that the drains may have on channelling potentially contaminated groundwater, held within the shallow strata, into the drainage ponds; and
- meet the Environment Agency's requirements for remedial action under Part 2A (in so far as there is requirement for additional assessment)

2.1.1. TPH "hotspot" Area

- gain access to soils beneath concrete slabs that were not accessed during the previous investigation
- provide sampling coverage adequate to develop a remediation strategy
- understand geology in the shallow strata to enable assessment of potential for migration of contamination to the proposed drainage lagoons
- get a better understanding of groundwater flow patterns in the shallow strata in this area
- meet the Environment Agency's requirements for remedial action under Part 2A (in so far as there is requirement for additional assessment)

2.2. Site Investigation Design

The site investigation design was submitted to the Environment Agency for comment prior to commencement of works. It was approved by Roger Green of the Penrith office. Details of the investigation design and rationale are presented in Appendix A.

3. SITE DESCRIPTION AND ENVIRONMENTAL SITE SETTING

3.1. Introduction

The Former Albright and Wilson Works (the site) is located in a coastal setting, on 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 C occupies an area of approximately 38000m^2 and is located to the south east of the Hutbank landfill in the southern part of the site.

Plot C slopes gently from north to south and lies down gradient of slopes to the east and west.

3.2. Plot C Current and Historical Operations

Plot C lies in an area which was previously used for storage and distribution warehouses, laboratories, cement works, UFEX Raffinate Operations (phosphate processing), and oil storage. All the buildings have now been demolished to ground level, and some stockpiles of demolition rubble remain. There are extensive concrete slabs remaining in place.

3.3. Environmental Setting

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

3.3.1. Geology and Hydrogeology

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

- Made Ground: the made ground (the man made or disturbed ground formed when the chemical works was built), overlying
- Glacial Boulder Clay (the "drift"): present across the area to the North Pond and TPH hotspot, although absent in some other parts of the site, overlying either
- St Bees Shales: siltstone and fine grained sandstones which form the bedrock beneath most of the relevant area, or
- St Bees Evaporites: anhydrites, gypsum, siltstones and sandstones forming the bedrock beneath the easternmost part of the relevant area (separated from the St Bees Shales by the Byerstead Fault which runs through the area)

URS considers there are two main groundwater systems:

The shallow groundwater system is found within the Made Ground and the Boulder Clay, at a varying depth, up to approximately 8m below ground level. Shallow groundwater generally flows towards the centre line of the site from both sides, paralleling the topography. There is a shallow groundwater divide, resulting in groundwater in the southern part of the site turning to the south along the centre line, and flowing towards Sandwith Beck, and groundwater in the northern part of the site turning north and flowing towards the Irish Sea. Perched groundwater (unconnected underground ponds of water) also exists within some of the made ground. All of Plot C is to the south of the groundwater divide.

Deep groundwater flow is complicated and poorly understood, however broadly flow is towards the Irish Sea (i.e. north and west). There are known to be rapid pathways through the Byerstead fault and old mine workings via which water from the site reaches the sea. The St Bees Evaporites have been affected by dissolution and flow within them is dominated by rapid flow through voids. This system is connected to the mine workings and fault; dye tracing has shown that water entering the St Bees Evaporites system appears rapidly at the Byerstead fault spring on the beach south of site. A full interpretation and cross sections are available in the Phase II report.

3.3.2. Surface Waters

A watershed is present on site with approximately two thirds of the site (including Plot C) draining south towards the Sandwith Beck and the northern third draining towards the coast to the north. This situation is complicated slightly by the existence of the site drainage system, which routes most of the surface water to the north.

The current proposal for the future of the site is to allow the extensive network of drainage pipes to gradually silt up and collapse over time, because in the absence of operations they are not necessary.

Sandwith Beck rises at the southern site boundary (NGR NX967154) approximately 180 meters south of the Plot C area. It flows in a south to south east direction through the villages of Sandwith and Rottingham, where it meets with Thorney Beck, and from there it flows towards the sea at St Bees as Rottingham Beck. The current water quality of Sandwith Beck is summarised in Table 3.3a below.

Table 3.3a Sandwith Beck water quality

Determinand	Average Concentrations (ug/l)*
Anionic Surfactant (MBAS)	103
Total Dissolved Phosphorus	113
pH value	8.2
Copper	5
Iron	143
Total Cyanide	nd
Chloride	25,250
Phosphate (Ortho as PO4)	273
Bicarbonate	96,250
Sulphate (soluble)	354,500
Fluoride	633
EPH (Mineral Oil)	nd
Naphthalene	0.25
Acenaphthene	0.08
Fluorene	0.02
Phenanthrene	0.04
PAH (16 Total)	0.20

* Average concentration of the most recent four monitoring rounds (Nov 05, January 06, April 06, July 06). nd- Analyte not detected above the method detection limit.

It is currently proposed that once demolition on site is complete to construct a drainage pond (North Pond) which will comprise a shallow depression designed to retain runoff water during rainfall and release it into South Pond (already constructed). South Pond releases stored to Sandwith Beck at a controlled rate, smoothing peak flow and preventing heavy flooding. The North Pond will therefore effectively be a seasonal extension to the Sandwith Beck, and will be designed to be empty most of the time. It will be lined with grass and planted with reeds in a damp base.

In addition to Sandwith Beck, approximately 500m to the south east of Plot C a tributary of Pow Beck drains eastwards towards a reservoir, which lies to the south of Mirehouse West. Approximately 500m further lies Bell House Gill, where a secondary tributary flows north easterly to meet Pow Beck and from there to Stanley Pond, and subsequently westwards along the Whitehaven- St Bees Valley towards St Bees and the Irish Sea. The current water quality of Bellhouse Gill (which is thought to be connected to the site through a deep groundwater pathway, which passes through flooded mine adits before emerging as a spring near Bellhouse farm) is summarised in Table 3.3b below.

Table 3.3b Water quality in Bellhouse Gill

Determinand	Average Concentrations (ug/l)
Anionic Surfactant (MBAS)	83
Total Dissolved Phosphorus	182
pH value	7.9
Copper	18
Iron	436
Total Cyanide	nd
Chloride	72500
Phosphate (Ortho as PO4)	705
Bicarbonate	95000
Sulphate (soluble)	32500
Fluoride	nd
EPH (Mineral Oil)	nd
GRO C4-10	nd
GRO C10-C12	nd
Naphthalene	0.18
Acenaphthylene	0.016
Acenaphthene	0.03
Fluorene	0.023
Phenanthrene	0.057
Anthracene	0.0245
Fluoranthene	0.132
Pyrene	0.1035
Benz(a)anthracene	0.0735
Chrysene	0.0695
Benzo(b)fluoranthene	0.057

Benzo(k)fluoranthene	0.063
Benzo(a)pyrene	0.0565
Indeno(1,2,3-cd)pyrene	0.0315
Dibenzo(a,h)anthracene	0.017
Benzo(g,h,i)perylene	0.0455
PAH 16 Total	0.71

* Average concentration of the most recent four monitoring rounds (Nov 05, January 06, April 06, July 06). nd- Analyte not detected above the method detection limit.

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 C area:

- *Human beings*: Given that the proposed end-state for the Plot C 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.
- *North Pond and South Pond*: Surface runoff is to run from the southern part of the site through North Pond and South Pond and onward to Sandwith Beck. If this surface water is contaminated (through interaction with contaminated soils as it migrates across Plot C), it may pose a risk to the beck. Contamination in the ponds themselves is undesirable since it could adversely affect reed growth and wildlife.
- *Sandwith Beck*: Water that does not flow across the area as surface runoff, but infiltrates into the drift geology beneath the site may reach the Beck without entering the ponds.
- *Bell House Gill and Byerstead Spring*: These are freshwater streams which appear to be connected to deep groundwater beneath the site by complex and rapid pathways. The Byerstead Spring drains immediately into The Irish Sea.
- *Deep groundwater*: The groundwater within the St Bees Evaporites. The St. Bees Evaporites are classified as a non-aquifer, however they contain a void and fracture system capable of transmitting water rapidly to the coast (the Byerstead Spring). The Whitehaven Sandstone also underlies the site at depth, and is classified as a minor aquifer.
- *Coastal Waters*: The site lies close to the Irish Sea, which is situated approximately 1.3km to the west of Plot C. This is a distant receptor, but it is likely that shallow groundwater within Plot C will ultimately drain into Sandwith Beck, then feed other streams before discharging to the coast. It is likely that deep groundwater within Plot C will also move through deep strata westwards towards the coast.

3.5. Potential Current and Historical Sources of Contamination

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

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

- The Ufex Raffinate operations treated a mix of phosphoric and sulphuric acid containing metal impurities to produce a stabilised waste for disposal in the Ufex landfill.
- The historical Cement Works which may have caused the contamination of soils or shallow groundwater through leaks and spills of chemicals;
- Historical laboratories, from where there may have been leaks, spills or releases to ground;
- Former Oil Storage areas containing above ground storage tanks;
- Former Warehouse operations (surfactant storage); and
- Concentrations of contaminants within imported materials used for ground raising and reclamation (*e.g.* ash and clinker fill which may contain TPH, PAH and heavy metals).

The following land uses with the potential to cause soil and/or groundwater contamination were identified in the vicinity of the Plot C Area:

- The Hutbank Landfill;
- The Ufex Landfill

4. FIELD OBSERVATIONS AND GROUND CONDITIONS ENCOUNTERED

4.1. Introduction

This section reviews the soil and groundwater conditions observed during the fieldworks. This section also summarises the field evidence of impact identified as a result of visual/olfactory observations and/or the results of field screening. Eleven boreholes were advanced across the investigation, of which ten were installed for groundwater monitoring. Ten trial pits were advanced in the area.

4.2. Soil Conditions

The site-specific ground conditions underlying the site are derived from the logging of soil borings advanced during the investigation. A summary of the ground conditions encountered is provided in Table 4.2a below.

Table 4.2a Summary of typical Geological Profile Encountered

Unit	Description	Depth Encountered (m)	Maximum Thickness (m)
Made Ground	Concrete	0-0.5	0.25
	White friable substance (thought to be phosphate) within medium to coarse limestone gravel matrix	0.5-1.5	0.5
	Loose red brown angular medium to coarse gravel within silty clay/ silty sand matrix	1.0-3.5	2.5
	Concrete (often with steel reinforcement bars)	1.4-2.7	1.8
Natural Ground	Soft to firm brown yellow mottled CLAY with occasional angular fine to coarse rounded gravel. Often containing interbedded silt horizons.	1.3-8.0	5.6

The logs for each of the boreholes and trial pits are presented in Appendix B. A selection of photographs accompanying the work performed in Plot C is presented at the end of this report.

Made Ground

The site investigation area contained a thickness of made ground which ranged from 1.0m (BH706 C) to 8.0m (BH712 C). As is often the case on industrial sites, the made ground displayed significant heterogeneity.

Common to each of the locations proximal to North Pond and the TPH hotspot, was the presence of one or more layers of concrete. Within this concrete were steel reinforcement bars thought to be associated with foundations for the structures that used to exist in the area.

Much of the made ground included a white friable substance, which was thought to be remnant phosphate associated with the UFEX Raffinate plant, located immediately to the east of the investigation area.

Also present were layers of ash and clinker. Historically, these materials were commonly used for levelling purposes on industrial sites.

The deepest extent of made ground was encountered at BH712 C, where the made ground extended to a depth of at least 8m. At this location, foundations were also observed in the trial pit to a depth of 4mbgl. These are thought to be associated with the cement works that formerly operated in this area. The foundations were set in a granular fill material ranging from fine gravel to cobble sized fragments. When examined, this material was considered to be derived from an evaporite sequence, with translucent white crystals present at the surface. When exposed to acid, it effervesced, suggesting it may have been of a calcareous nature. This material may have existed in situ at this location, before being removed to allow foundations to be installed, before being replaced around the foundations. This material has weathered a deep red/purple colour, potentially suggesting the presence of iron.

Other material included bricks, steel wire, redundant cables, angular medium to coarse limestone gravel, and reworked clays.

Drift Geology (Glacial Boulder Clays)

The drift geology in the investigation area comprises grey brown silts and brown (occasionally sandy) clays. These were encountered at depths of between 2.5m and 8.0m during the intrusive works. It is considered likely that some of the uppermost layers of the natural drift geology have been removed across parts of the site during historic ground works.

BH706 C encountered a sand lens between 3.0 and 3.2m below ground level, and in BH707 C sand lenses were detected at 4.8 and 5.5.m.

Solid Geology

No consolidated geological horizons were encountered during the site investigation.

4.3. Groundwater Conditions

Groundwater elevations obtained during the groundwater monitoring round conducted on 19th July 2006 are presented in Table 1 and Figure 2. Based on data from boreholes BH701 C, 702 C, 703 C, 706 C and 707 C (which were screened within the drift (silts and clays)) it is considered by URS that groundwater flow within the drift is to the south towards Sandwith Beck.

In addition the depth to water within BH712 C does not appear to conform to the range of groundwater depths across the other boreholes and BH710 C, BH711 C, and BH713 C did not contain ground water when dipped. It is considered likely that BH712 C is in hydraulic connectivity with the deep groundwater (St Bees Evaporites). A detailed interpretation of the groundwater observations and geological structure is presented in Appendix D.

Rising head tests were undertaken as part of this investigation, which monitored the rate at which groundwater was able to flow into the installed wells. The results of these tests were entered onto time-elevation graphs (presented in Appendix C). Analysis of the data revealed permeability values of between 1.08×10^{-7}m/s (metres per second) and 1.74×10^{-6}m/s.

4.4. Field Observations of Contamination

The field observations made during the soil bore advancement are summarised below.

4.4.1. Visual Evidence of Impact

Inspection of the soil samples and soil cores retrieved during drilling works identified visual and olfactory evidence of impact. Field observations are presented below and are also detailed on the borehole logs in Appendix B.

Table 4.4a PID (Photo Ionisation Detector) Results and Field Observations

Location	0.5m	1.0m	1.5m	2.0m	2.5m	3.0m	3.5m	4.0m	4.5m	5.0m	Observations
A108C	<1*	5.4	1.5	1.0	-	2.1	-	-	x	x	No visual / olfactory evidence of impact
A109C	<1	12	-	-	1.8	<1	0.8	x	x	x	Slight rubber odour at 1.0m
A110C	<1	<1	<1	-	<1	-	-	<1	x	x	No visual / olfactory evidence of impact
A111C	<1	<1	<1	-	-	70	x	x	x	x	Slight hydrocarbon odour at 3.2m
A112 C	<1	-	<1	<1	<1	<1	<1	<1	<1	x	No visual / olfactory evidence of impact
A113 C	<1	-	1.2	<1	<1	<1	<1	x	x	x	No visual / olfactory evidence of impact
A114 C	<1	-	<1	-	<1	-	<1	x	x	x	Rubber like odour at 1.0m
A115 C	<1	-	x	x	x	x	x	x	x	x	No visual / olfactory evidence of impact
A116 C	<1	-	<1	-	-	1.2	3.0	-	x	x	No visual / olfactory evidence of

Location	0.5m	1.0m	1.5m	2.0m	2.5m	3.0m	3.5m	4.0m	4.5m	5.0m	Observations
											impact
A117 C	<1	5.2	9.6	90	-	154	8.0	-	<1	<1	Black staining at 0.8m and hydrocarbon odour 3.2m
BH701 C	-	-	-	-	<1	<1	<1	<1	<1	<1	Black staining at 2.0m
BH702 C	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	No visual / olfactory evidence of impact
BH703 C	-	<1	<1	<1	-	<1	<1	<1	-	<1	Moderate unknown odour at 0.5 to 2.0m
BH704 C	<1	<1	<1	<1	<1	<1	-	<1	<1	<1	No visual / olfactory evidence of impact
BH706 C	0.5	-	0.9	0.8	0.8	-	0.5	-	-	-	No visual / olfactory evidence of impact
BH707 C	<1	-	<1	<1	-	<1	-	<0	-	-	No visual / olfactory evidence of impact
BH710 C	1.2	8.5	-	-	13.8	-	2.5	-	2.6	3.5	Moderate hydrocarbon odour at 1.5 and 3.5m
BH711 C	0.3	-	0.4	-	0.6	-	<1	-	<1	-	No visual / olfactory evidence of impact
BH712 C	31	3	-	11	-	10	-	3	-	0.7	Slight hydrocarbon odour at 0.5m
BH713 C	<1	<1	<1	<1	<1	-	-	5.5	-	-	Moderate hydrocarbon odour at 4.0 to 4.5m
BH714 C	0.7	-	0.2	-	0.5	-	x	x	x	X	No visual / olfactory evidence of impact

Key: * PID results in parts per million (ppm); **-** no sample taken; **<1** result less than 1ppm; x borehole/trial pit not advanced to this depth.

4.5. Geochemical Results

The analytical results are provided in detail in Tables 3 to 15. 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 an analyte concentration compared to its average 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)

Thirty soil samples were scheduled for VOC analysis. Of these only seven samples returned VOC concentrations above the laboratory method detection limits (MDL). Trial pit A117 C (at 3.2m depth), located towards the centre of Plot C contained elevated concentrations of VOCs (including toluene, ethylbenzene, xylene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, naphthalene). Seven groundwaters were scheduled for analysis with no samples returning a concentration above the method-detection limit.

The sample from A117 at 3.2m depth was from made ground strata. The sample was taken containing loose grey blue silty sand within a fine to medium gravel matrix. It was also noted that the strata emitted a hydrocarbon odour. Headspace analysis generated a PID reading of 154ppm. Natural clay strata began at 5.0mbgl, the headspace reading from a sample within this strata was 0ppm, suggesting the contamination may be restricted to the made ground at this location. The remaining six samples that detected VOC were also taken from the made ground.

Metals

Twenty nine soil samples were scheduled for metals analysis. Pockets of elevated metals concentrations were found, and are summarised below:

- The most elevated results for chromium, lead, nickel, phosphorus, and vanadium were detected in A109 C at 2.8m (within the footprint of North Pond).
- A single elevated concentration of arsenic was detected in A111 C at 0.5m.
- The most elevated barium concentration was detected at BH713 C at 1.9m.
- A111 C at 0.5m returned the most elevated concentration of zinc.
- The most elevated copper concentrations were in A108 C at 1.0m and A109 C at 2.8m.

The majority of elevated concentrations of metals were reported in soil samples collected from within the made ground. As is typical with any historic industrial facility, ash and clinker were used as fill during levelling ground works on the Whitehaven site and these are typically considered to be a likely source for the increase of concentrations of metals in shallow horizons.

The leachate analysis reported elevated concentrations of copper and vanadium predominantly in samples taken from the made ground. However, some samples (e.g. BH702@2.7m) metals were detected in the natural drift geology which underlies the made ground. Groundwater analysis did not reveal elevated metals concentrations, nor trends in the distribution of metals across the site.

Anionic Surfactants

Seventeen of the eighteen soil samples scheduled for surfactant analysis from across Plot C detected the presence of surfactants at concentrations above the laboratory method detection limit (MDL) in both Made Ground deposits and the shallow drift. In addition, eleven of the twenty leachate samples also detected the presence of surfactant at concentrations above the Laboratory MDL. All six of the water samples detected surfactant above the method detection limit. The distribution of anionic surfactant appears to be across Plot C, with no discernible trend.

Semi Volatile Organic Compounds (SVOCs)

Twenty-eight soil samples were scheduled for SVOC analysis. Of these eight returned concentrations above the laboratory MDL. The majority of these detections were in the Polycyclic Aromatic Hydrocarbon (PAHs) group of analytes in samples collected from trial pits A108 C at 1.0m, A109 C at 2.8m, and A110 C at 1.5m (each from made ground). These locations are within or close to the footprint of north pond.

Two of the twenty-two leachate samples (A117 C at 3.2m and A113 C at 1.0m, both located to the south east of north pond) detected SVOCs above the method detection limit. At these locations, a limited concentration was detected for naphthalene, fluoranthene, fluorene, and pyrene. None of the seven water samples submitted for laboratory analysis reported SVOCs above the laboratory MDL.

Total Petroleum Hydrocarbons (TPH)

TPH was detected in each of the twenty four soil samples submitted for analysis at concentrations above the laboratory MDL. The dominant fractions were in the C12-C16, C16-C21, C21-C35 ranges in both aliphatic and aromatic compounds. The majority of the samples were taken from the made ground.

Only one (A117 C at 3.2m to the south east of North Pond) of the twenty two leachate samples detected TPH above the method detection limit. Furthermore, only one of the seven water samples (BH712 C, located close to the former diesel above ground storage tank) detected TPH above the method detection limit.

Based on the TPH fractions detected and their relative concentrations it is considered the source of the hydrocarbons was a diesel or heavy oil.

PCBs

Two soil samples were scheduled for Polychlorinated Biphenols (PCB) analysis and neither sample returned concentrations above the laboratory MDL.

Phosphates

Total phosphorus results ranged from 144 – 22,510mg/kg. This is well above the normal range for soils. Only two of the 24 samples analysed for orthophosphate gave results above the MDL, which is much lower than normal soil range. The samples were also leach tested, giving Total P range 11 – 400ug/l and orthophosphate from not detected to 1400ug/l. The results are correlated, so samples with higher leachable orthophosphate also showed higher leachate total phosphorus, because the tests are detecting the same phosphate.

The implication of the above results is that the phosphate present in the Made Ground is in a fairly insoluble form. None of the seven water samples scheduled for phosphate (as orthophosphate) analysis returned concentrations above the laboratory MDL.

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.*
Mercury *in soil, migrating from soil to groundwater and through drains impacting undefined*

Copeland Borough Council Pollutant Linkages
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, include the following

Table 5.1a – Summary of potential Sources

Potential Sources	**Contaminants of Concern**
Former Raffinate Operations (Ufex plant)(H1)	Ufex raffinate was the waste stream from the phosphoric acid purification process (purification of raw material "green acid" – a phosphate ore slurry). The raffinate was primarily a mix of sulphuric and phosphoric acids containing the metal impurities. The raffinate treatment process involved neutralisation with quicklime to form calcium sulphate and calcium hydroxyapatite, followed by hydration of the calcium sulphate to its dihydrate form. The resulting material is alkaline at about pH12 (5% slurry). The purpose of treating the waste was to immobilise the metals. This material is largely contained in the Ufex landfill, adjacent to Plot C.
Former Cement Operations (H2)	Metals, fuel oils
Former Laboratories (H3)	Small volumes of solvents.
Former Oil Storage (H4)	Petroleum hydrocarbons
Former Warehouse operations	The nature of the materials stored is not known but considered likely to include phosphates, surfactants,

	and small quantities of petroleum hydrocarbons and possibly very small quantities of bottled solvents. It is known that there was an outdoor storage and loading area used for detergent product drums.
Fill Materials (H6)	PAHs, petroleum hydrocarbons and heavy metals associated with ash and clinker fill. Potentially other contaminants associated with other materials.
Decommissioning Operations (S1)	TPH derived from leaks and spills. Asbestos, lead or other materials associated with buried demolition rubble
Ufex and Hutbank Landfills	Phosphates, sulphates, metals, surfactants, disposed of within the landfills
TPH hotspot (As defined by the Phase II Investigation in 1995)	Petroleum hydrocarbons and PAHs (napthalene in particular) as identified by the Phase II investigation.

In their determination of the site as "contaminated land", Copeland Borough Council listed a number of other contaminants which they considered likely to be present on the site as a result of its' previous history. These contaminants were included in Assessment Action to ensure that the possibility of 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 and are presented as cross sections in Figure 3. A two dimensional plan of these section lines has also been included, this is from a previous report and is entitled "Figure 3, 44319877".

Table 5.2a Pathway details

Pathway	Pathway characteristics
Controlled Water 1	Infiltration of rainwater through contaminated soil and subsequent leaching and vertical movement to shallow groundwater.
Controlled Water 2	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 or surface water.

Controlled Water 3a	Lateral flow of dissolved or liquid contaminants in shallow groundwater to discharge into North Pond and subsequently to Sandwith Beck via south pond.
Controlled Water 3b	Lateral flow of dissolved or liquid contaminants in shallow groundwater underneath the ponds and directly into Sandwith Beck.
Controlled Water 4	Overland flow of rainwater carrying particulate contaminants into the North and South ponds, to discharge into Sandwith Beck.
Controlled Water 5	Movement of dissolved or liquid contaminants from shallow groundwater to deep groundwater. This includes the movement of contaminants from streams running in anthropogenic (man-made) voids underneath the site within the shallow strata (predominantly the evaporate sequence), into deep groundwater. Movement from shallow groundwater to deep groundwater may be enhanced by faulting in certain areas.
Controlled Water 6	Transport of deep groundwater to surface water receptors – The Byerstead Spring (which immediately enters The Irish Sea) and Bell House Gill by complex pathways.
Controlled Water 7	Lateral western/northwestern flow of dissolved or liquid contaminants in shallow groundwater to the coast, and the Irish Sea.
Human Health 1	Dermal contact/ingestion of contaminated soil.
Human Health 2	Inhalation of vapours from soil and/or groundwater.
Human Health 3	Inhalation of dust from contaminated soil.

5.3. Potential Receptors

Table 5.3a Receptor characteristics

Receptor	**Receptor characteristics**
Controlled Waters: Sandwith Beck	Small stream that runs from the southern edge of the site south through Sandwith village, reaching the sea a few km to the south. The topography of the site is such that around two thirds of the site will drain to Sandwith Beck once the former site drainage system ceases to function.

	Surrounding fields also drain to Sandwith Beck. In Plot C, contamination to the west of the fault is most likely to flow to this receptor.
Controlled waters: Deep groundwater	Water in the St. Bees Shales, Whitehaven Sandstone and St. Bees Evaporites. The area to the eastern side of the fault in Plot C will be modelled to a 50m compliance point within the St. Bees Evaporites. This is a conservative approach, as it is likely that any groundwater abstractions in the area are substantially further away than this.
Controlled waters: Shallow groundwater	Groundwater in drift beneath the site. These are not themselves considered as specific receptors*, but they may receive groundwater that is ultimately destined for Sandwith Beck (in ground to the west of the fault) or the Groundwater within the Evaporite Sequence (in ground to the east of the fault)
Controlled Waters: The Byerstead Spring and the coast	These are distant receptors to the site, over 1.3km away. The Byerstead Spring drains immediately into The Irish Sea. The pollutant linkage to these receptors appears to be complex (and is discussed in detail the previous Phase II Investigation, REF: 44319623/R2037, dated 23rd June 2005). Contamination may enter this deep groundwater system to the eastern side of the fault within Plot C. However, the risk assessment assumes a compliance point of 50m from the point of source, and assesses the risks at this point (as a conservative worst case). All points further away from this are likely to produce lower concentrations (due to greater dispersion, dilution etc), and hence are not considered further. This receptor is only likely to be at risk from contamination to the eastern side of the fault within the Plot C area.

* The drift horizons within which the discontinuous shallow groundwater is encountered, is considered to be generally of low permeability (with the exception of some more permeable sand/silt horizons) and does not form part of a scheduled aquifer. The land use in the area is dominated by this former industrial site, which covers an area of approximately 50 hectares. It is considered highly unlikely that shallow groundwater, where present, would be used for potable supply, or could sustain high enough yields to be used if the water quality was deemed good enough.

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.

Based on the current data set, significant Human Health pollutant linkages are not thought to exist in the area of the site to which the remediation statement applies. This is because the analytes tested for in the previous Phase II investigation either do not exist in sufficient quantity to constitute a significant *source*, or the *pathway* does not exist to pose a risk to Human Health. Full details of the risk assessment previously carried out are given in the Phase II report.

In the remediation statement, the analytes that were considered to present a potentially significant risk to controlled waters were naphthalene and TPH. Various pollutant linkages are thought to exist from these contaminant sources. Table 5.4a below shows the significant pollutant linkages considered to exist on the land as detailed in the Remediation Statement. (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**	**Source location**	**Pathway**	**Main Receptor**	**Subsequent Receptors**	**Description of Harm/Pollution of Controlled Waters**
C1	TPH	PLOT C	CW1 and CW3a.	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.
C2	TPH	PLOT C	CW2 and CW3a.	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.
C3	TPH	PLOT C	CW1 and CW3b	Sandwith Beck	Irish Sea	Potential for entry of contaminant into Sandwith Beck after it has passed in the groundwater under the ponds and directly into Sandwith Beck.
C4	TPH	PLOT C	CW2 and CW3b	Sandwith Beck	IrishSea	Potential for entry of contaminant into Sandwith Beck after it has passed in the groundwater under the

Pollutant Linkage Identifier	Pollutant	Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
						ponds and directly into Sandwith Beck.
C5	TPH	PLOT C	CW4 and CW3a.	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.
C6	TPH	PLOT C	CW1, CW5 and CW6.	Bellhouse Gill	Irish Sea	Potential for entry of contaminant into Bellhouse Gill after it has passed through the complex geological system in the area.
C7	TPH	PLOT C	CW2, CW5 and CW6.	Bellhouse Gill	Irish Sea	Potential for entry of contaminant into Bellhouse Gill after it has passed through the complex geological system in the area.
C8	TPH	PLOT C	CW1, CW5 and CW6.	Byerstead Spring	Irish Sea	Potential for entry of contaminant into the Byerstead Spring (which immediately enters the Irish Sea) after it has passed through the complex geological system in the area.
C9	TPH	PLOT C	CW2, CW5 and CW6.	Byerstead Spring	Irish Sea	Potential for entry of contaminant into the Byerstead Spring (which immediately enters the Irish Sea) after it has passed through the complex geological system in the area.
C10	naphthalene	PLOT C	CW1 and CW3a.	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it

Pollutant Linkage Identifier	Pollutant	Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
						has passed through North and South Pond.
C11	naphthalene	PLOT C	CW2 and CW3a.	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.
C12	naphthalene	PLOT C	CW1 and CW3b	Sandwith Beck	Irish Sea	Potential for entry of contaminant into Sandwith Beck after it has passed in the groundwater under the ponds and directly into Sandwith Beck.
C13	naphthalene	PLOT C	CW2 and CW3b	Sandwith Beck	IrishSea	Potential for entry of contaminant into Sandwith Beck after it has passed in the groundwater under the ponds and directly into Sandwith Beck.
C14	naphthalene	PLOT C	CW4 and CW3a.	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.
C15	naphthalene	PLOT C	CW1, CW5 and CW6.	Bellhouse Gill	Irish Sea	Potential for entry of contaminant into Bellhouse Gill after it has passed through the complex geological system in the area.
C16	naphthalene	PLOT C	CW2, CW5 and CW6.	Bellhouse Gill	Irish Sea	Potential for entry of contaminant into Bellhouse Gill after it has passed through the complex geological system in the area.
C17	naphthalene	PLOT	CW1,	Byerstead	Irish Sea	Potential for entry of

Pollutant Linkage Identifier	Pollutant	Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
		C	CW5 and CW6.	Spring		contaminant into the Byerstead Spring (which immediately enters the Irish Sea) after it has passed through the complex geological system in the area.
C18	naphthalene	PLOT C	CW2, CW5 and CW6.	Byerstead Spring	Irish Sea	Potential for entry of contaminant into the Byerstead Spring (which immediately enters the Irish Sea) after it has passed through the complex geological system in the area.

6. HUMAN HEALTH QUANTITATIVE RISK ASSESSMENT

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 the site as detected by investigations undertaken at the site. The methodology used was fully compliant with current UK guidance on human health risk assessment, as set out in the CLR series of guidance notes. The model used was URS in-house model Human7, which operates on the same basis as the CLEA UK model.

Tier 1 screening criteria were compared to the laboratory data for Plot C. In the event of any exceedences of Tier 1 values, available site specific Tier 2 values from the Phase II investigation report were utilised. The Tier 2 values were derived for the proposed public open space use. 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. The full explanation of the derivation of the Tier 2 values is given in the Phase II report[4]. Note that no risks to human health in Plot C were identified by the Phase II investigation.

The soil screening is presented in Tables 3 to 7. Screening was also performed for water samples, in Tables 11 to 14. The Tier 1 values and their derivation are presented in the Tables adjacent to the results.

The following table summarises the exceedences found.

6.1. Soil Exceedences

Target Compound	Tier 1/2 Human Health (mg/kg)	Maximum concentration (mg/kg)	Location/Depth of maximum concentration	Number of Samples Taken	Number of Samples Exceeding Tier 1
Arsenic	104*	431	A111@0.5m	28	1
Phosphate / total Phosphorus as P		22510	A109@2.8m	28	28

*Tier 2 value used.

URS is unable to source a screening value for phosphate – see below.

Remaining VOC, SVOC, metals, and TPH results were not above their respective Tier 1-2 screening value.

[4] Pahse II Investigation and Environmental Assessment (REF 44319623/R20370, June 2005. URS Corporation Ltd. – Appendix C.

Arsenic

Only one exceedence has been detected for arsenic at a depth of 0.5m. There is potential for this area to contain elevated concentrations of arsenic from this depth to the surface (i.e. from ground level to 0.5m). The Phase II investigation did not detect arsenic concentrations in any part of the site above 100mg/kg, and therefore it appears likely that this area is not likely to be representative of the general arsenic distribution within the Made Ground. The result is a statistical outlier using the CLR 7 "Maximum Value Test".

It is considered possible that there is an arsenic hotspot at this location, which may pose a risk to Human Health for the proposed future use. It is proposed that surface samples are taken at this location to confirm the presence and lateral distribution of arsenic.

Phosphate and Phosphorus

Phosphate in soils was measured as orthophosphate (the form most common in soil) and as total phosphorus (which measures all phosphorus in whatever chemical form it occurs). Orthophosphate was detected in only two of the 28 samples, however total phosphorus levels were quite high across the area. We know that the "total phosphorus" does not include elemental phosphorus because this substance has never been used on the site. Therefore, the measured phosphorus will be present as a variety of phosphate forms, most likely the calcium hydroxyapatite which is a component of the Ufex waste.

No screening criteria could be sourced for phosphate compounds. The UK Food Standards Agency conclude in the Expert Group on Vitamins and Minerals (2003) report on Phosphate that it is widely found in common food groups with concentrations up to 4,000 mg/kg (fish).

Since phosphate background intakes are likely to be substantially higher than a modelled exposure, it is not considered necessary to attempt to generate a screening criterion (which would be very difficult, since phosphate is not generally considered an important human toxin). It is considered very unlikely that the phosphate in Plot C will pose a risk to human health for the future site use.

6.2. Water Exceedences

Tables 11 and 12 show that drinking water standards are exceeded for major ions sulphate, potassium, sodium and calcium in several of the 6 samples of shallow groundwater. There are also a few instances of exceedances for arsenic, magnesium, selenium and surfactants. Since the water in question is inaccessible to people, and is not present in an aquifer likely to be used for drinking water supply, it is considered that there is no pathway, and therefore no significant risk to human health.

The sample from BH712 C, representing deeper groundwater, also exceeded drinking water standards for several TPH fractions. As above, there is not considered to be a pathway, and therefore no significant risk to human health.

6.3. Summary of human health risks

One potentially significant risk to human health has been identified in Plot C. There may be an arsenic hotspot in the region of trial pit A111 at shallow depth (0.5m). Additional sampling is recommended to confirm the presence and extent of arsenic contamination.

7. CONTROLLED WATERS QUANTITATIVE RISK ASSESSMENT

7.1. Rationale

The UK Environment Agency R&D 20 methodology[5] is based on a tiered approach to determine risk-based remedial targets for soil and groundwater. The tiers have been developed by the Environment Agency (EA) to provide a structured decision making tool, requiring progressive data collection at each stage. A Tier I assessment considers the partitioning of contaminants from soils into the pore waters / perched groundwater. With each stage, further processes of contaminant dilution and attenuation into the underlying aquifer and at off-site receptors (surface water bodies, abstractions, etc.) are considered and additional data is collected to derive a remedial target. At progressive stages the remedial target becomes less stringent, given the lessening of the model's conservatism through the use of site specific data, and the confidence in the target concentration increased. A fuller description of the rationale for the Controlled Waters Detailed Quantitative Risk assessment and the results of the modelling undertaken are presented in Appendix D.

URS undertook a generic quantitative screening risk assessment using a conservative, worst case, scenario (TIER 1 Stage). Contaminants identified though this were then modelled (TIER 2/3 Stage) using the Environment Agency sponsored CONSIM program to develop a *probabilistic* approach to assist in understanding the levels of risk that may exist from the range of contaminant levels within source zones defined for each contaminant that exceeded the initial screening risk assessment.

By using this CONSIM approach it has been possible to more accurately define the following parameters:

- The three dimensional extent of the source area, which includes an accurate zone being superimposed onto a baseplan (see Appendix D). The modelling input values are based on the data obtained during the most recent site investigation and the pre-existing data set obtained during the 2005 investigation.

- The most likely concentrations existing within the source area. This is more realistic than previous modelling, which simply utilised the maximum concentration detected in the source area.

- The properties of the system (such as porosity, aquifer bulk density, infiltration rate, etc) are now considerate of a range of likely values and not simply single values as utilised in previous modelling.

(5) 'Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources' Environment Agency R&D 20. 1999.

7.2. Summary of Identified Exceedences of Tier 1 Screening Criteria

Our interpretation of the geological and hydrogeological data is that Plot C is divided by a north-northwest to south-southeast trending fault. It downthrows the solid strata to the west, where there is thick St Bees Shale beneath the drift. To the east however, the St Bees Evaporites appear beneath the made ground and drift. The St Bees Shale is highly stratified, and is not considered an aquifer. Further, it appears to be reliably overlain by low permeability drift in Plot C (refer to Figure 4). The risk to deep groundwater is therefore considered reduced in the area west of the fault, because the pathway is not plausible.

To the east of the fault, BH712 C has encountered what appears to be the St Bees Evaporites directly beneath granular made ground (which may itself be reworked St.Bees Evaporite). A direct pathway to the evaporate sequence in this location has therefore been proven. In areas where drift does exist over the St Bees Evaporite east of the fault, no groundwater is found within the drift. This indicates that rainfall incident on this area is likely to percolate straight down to the aquifer. A full explanation is given in Appendix D.

The result of the geological interpretation is that the critical receptor for sources to the west of the fault is Sandwith Beck, and the critical receptor for sources to the east of the fault is the St Bees Evaporites. The results of the Tier 1 screening are presented separately for the east and west sides. Note that North Pond is to the west of the fault.

West Side of fault: (Sandwith Beck) exceedence of Tier 1 screening criteria

- arsenic (soil leachate)
- barium (soil leachate)
- chromium (soil leachate)
- copper, two separate source areas (soil leachate)
- lead (soil leachate)
- selenium (soil leachate)
- vanadium (soil leachate)
- zinc (soil leachate)
- anionic surfactant (soil leachate)
- toluene (soils)
- ethylbenzene (soils)
- m & p Xylene (soil leachate)
- o-xylene (soil leachate)
- naphthalene (soil leachate)
- fluoranthene (soil leachate)
- 1,2,4 trimethylbenzene (soils)
- 1,3,5 trimethylbenzene (soils)
- total petroleum hydrocarbons (soil leachate)
- anionic surfactant (groundwater)
- selenium (groundwater)

The above determinands were identified as individual source areas (Source Areas 1 to 21) located within Plot C, these are presented in Figure D2 and Table D1 (in Appendix D). These substances were then assessed at Tier2/3.

East side of fault: St Bees Evaporites exceedance of screening criteria

- Chromium (soil leachate) at TP511 at 0.3m
- Total Petroleum Hydrocarbons (groundwater) at BH712 C
- Arsenic (soil) at TP A111C 0.5m

Chromium and TPH were identified as individual source areas (Source Areas 22 and 23) located within Plot C, these are presented in Figure D2 and Table D1 (in Appendix D). Tier 2/3 risk assessment was then carried out.

Despite arsenic being present in exceedence of the Tier 1 criterion at 0.5m in TP A111C, it was not considered necessary to incorporate this into the model. This is because arsenic did not exceed the screening criterion in the deeper sample taken from 3.2m. Based on this sample, arsenic appears not to be migrating to 3.2m within the dry clay strata, and it is therefore reasonable to suggest that arsenic is unlikely to migrate to the groundwater within the Evaporite sequence, which is at approximately 8mbgl in this area.

The limited exceedences of Tier 1 screening criteria measured in groundwater provides an indirect measure of the leachable content of the overlying soils. Shallow groundwater would be expected to be in equilibrium with the overlying soils and the fact that relatively low concentrations and infrequent detections in excess of screening criteria are measured indicates that any residual determinands in the soil are dominantly of low mobility.

7.3. Tier 2/3 Modelling Results

The sources defined by the Tier 1 exceedances listed above were taken through to Tier 2/3. A full summary of the designated source areas and input concentrations used in the Tier 2/3 QRA are presented in Tables D.1 to D.3. (in Appendix D). The individual source areas have been digitised for the modelling process and they are presented in Figure D2 entitled “Graphical Definition of Individual Source Areas using CONSIM” at the back of Appendix D.

A full explanation of the Controlled Waters Risk Assessment process, and how the conceptual model has been formulated is provided in Appendix D. The Tier 2/3 modelling results are provided below.

7.3.1. West of the Fault: Potential Risks to Sandwith Beck

Copper

The predicted maximum concentration at the 95th percentile confidence limit was 10.1µg/l (for Large source) and 15.6µg/l (for Copper cumulative risk). These are only slightly above the EQS value of 10µg/l. However at the 50th percentile confidence limit, both source's simulated maximum concentrations are significantly less than the EQS value (less than 1µg/l). The timescale for simulated concentrations to exceed the EQS value is predicted to occur is 5,000years.

The risk to Sandwith Beck from copper is therefore not considered to be significant.

Anionic Surfactant

The predicted maximum concentration at the 95th percentile confidence limit was 300µg/l, which is above the EQS value of 200µg/l. However at the 50th percentile confidence limit, simulated maximum concentrations are significantly less than the EQS value at less than 40µg/l. The timescale for simulated concentrations to exceed the EQS value is predicted to occur is 15,000 years.

The simulated results suggest that the theoretical risk posed by surfactant contamination within Plot C will not exist for over 15000 years. Surfactant is already detected in Sandwith Beck (e.g. 80µg/L in January 2006, REF: Groundwater Monitoring, Whitehaven Cumbria, Former Albright and Wilson Facility, Rounds 1 to 8, 44319646/R2216.BO2, dated 24th April 2006). It is therefore thought that the theoretical risks posed by Plot C contamination may not be the most pertinent for the protection of Sandwith Beck.

Anionic Surfactant is likely to degrade over time. In the absence of a published half life values, a conservative estimate has been provided based on TPH (>EC21-35) aliphatic half-life fraction. This half life may be too conservative, allowing degradation to occur quicker than has been modelled. Consequently, simulated concentrations may reduce to below the EQS value.

It is concluded that the soil contamination in Plot C does not pose a significant risk to Sandwith Beck. A source elsewhere on site may be present.

7.3.2. East Of Fault: Potential Risks to St Bees Evaporite Groundwater

No potential risks were simulated for chromium or TPH based on the data utilised for the modelling process.

7.3.3. Comparison to results of previous investigation "TPH and naphthalene" source

One of the objectives of this study was to provide further assessment of an apparent risk to controlled waters from TPH and naphthalene in Plot C. Gathering of additional data and the use of a more realistic and more site specific risk assessment has shown that there is no significant risk to controlled waters from either TPH or naphthalene.

Both determinants were assessed at Tier 2/3, using the data from this investigation and the data from the 2005 Phase II investigation, which originally identified the possible source.

7.4. Risk to water quality in North Pond

The possible pollutant linkage identified relates to the risk of contaminated groundwater entering the pond by flowing through the Made Ground. It is not certain that this pollutant linkage exists because the water table appears to be below the pond base; trial pit A109 was dry to 3.4m where it encountered a concrete base (this is 80.07m AOD, approximately 1m beneath the proposed base of the pond at around 81m AOD). Trial pit A108 encountered water perched on top of the Boulder Clay at 3.1m below ground level (80.32m AOD). The Boulder Clay appears to have been removed to install the concrete floors, and flow of perched water appears to be along the surface of the clay. Therefore it is not certain whether the water table will ever rise under wetter conditions to intersect the base of the pond.

Leach test results from the Made Ground in trial pit A109 at 2.8m (approximately the base of North Pond) showed exceedances of Tier 1 criteria for Cu, Se, V and surfactant. The results were very similar to other Made Ground samples in Plot C, indicating that the Made Ground in the pond area is typical of site Made Ground. Since the pond is directly in contact with this material, a Tier 1 exceedance indicates a potential risk to water quality. There is also the unquantified possibility of groundwater from further away bringing contaminants from elsewhere on site (e.g. the VOCs in trial pit A117).

Actual groundwater monitoring results indicate that the shallow groundwater is slightly impacted by surfactant (at around double drinking water standard), but does not show evidence of contamination by metals, TPH, VOC or SVOC compounds.

It is concluded that this pollutant linkage may be present. The most cost effective means to establish whether it is would appear to be to construct the pond and observe water levels over the winter, taking samples at regular intervals when the pond contains water. If the monitoring shows evidence of unacceptable water quality, then additional action (for example lining the pond) should be considered.

7.5. Risks to Controlled Waters from the site drainage system: 2007 update

In 2006 this report concluded that potential pollutant linkages from the site drainage system could not be discounted and that monitoring of the Byerstead Spring, Bellhouse Gill and Sandwith Beck should be continued with the addition of a full suite of contaminants consistent with the Part 2A determination. This was started in October 2006 (monitoring for all the contaminants except the metals has been undertaken quarterly since February 2004). A report (“the Groundwater Monitoring Report”) providing the full set of results and interpretation was issued to Rhodia and the Environment Agency in October 2007[6].

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[6] Former Albright & Wilson Works, Whitehaven, Cumbria: Groundwater Monitoring Rounds 1-14 Feb 2004 – July 2007 Issue 2 31st October 2007, ref 44319904/MARP0002

The drainage system as a source was originally included in the determination because it was well known that leakage from the system was able to reach the Irish Sea via the Byerstead Spring. Contaminants of concern previously identified with respect to Plot C were TPH and naphthalene because these had been identified in the soils and groundwaters. In terms of the site as a whole, the primary contaminants of concern from the drainage system were surfactants and phosphates, because these substances were those detected in highest concentrations at Byerstead Spring.

The site drainage system originally carried effluent from the works to a discharge pipe at the northern boundary, where effluent was discharged to the Irish Sea via a long sea outfall. Rhodia ceased production in 2001, and Huntsman who subsequently leased the site, ceased during 2007. Effluent currently travelling through the drainage system is now limited to leachate from the Ufex and Hutbank landfills, and there will also be surface water drainage from around the site. A dedicated sealed pipe is under construction to take the Ufex and Hutbank leachates direct to the outfall, and once this is in use there will be no more discharge of effluent to ground from leaks in the drainage system. As a source, the drainage system is likely to be almost finished.

It is worth considering the possibility of remnant contamination within the drainage system, and the extent to which this could constitute a source. The main contaminants, surfactants and phosphates are highly soluble and are not likely to remain in the system for very long. A by-product advantage of surfactant effluent is that it is an effective degreaser and prevents the build up of oily and greasy residues which can trap contaminants (this is also probably why the drainage system leaks so badly).

Drains that have been unused for a long period could act as reservoirs for build up of contaminants, however these are not substantially different from the variety of concrete floors and sumps that are present on the site. Many such areas have been encountered and sampled in the site investigations, and none to date has been found to constitute a significant risk. It is considered likely that the site investigation data includes a representative selection of samples from parts of the drainage system, and these are included in the risk assessments for each plot.

The Groundwater Monitoring Report concludes that there is now sufficient data to be able to show that discharges from the site are demonstrably declining. In particular, the Byerstead Spring surfactant and phosphate data show declining trends, as expected. The other surface waters (Sandwith Beck and Bellhouse Gill) also provide evidence that there is no demonstrable impact from the site drainage system:

- No TPH has been detected in either Sandwith Beck or Bellhouse Gill since 2004
- PAHs have been detected at low concentrations, sporadically, in all three locations. The incidence seems to have been reducing since 2004, and has reduced very markedly since 2002. The continuing occasional presence of PAHs is interpreted as likely to be caused by the site, although the concentrations are considered to low to be a significant issue.

- The full metals suite analysed between October 2006 and July 2007 showed no exceedances of EQS in Byerstead Spring, Sandwith Beck or Bellhouse Gill
- Bellhouse Gill has surfactant levels close to the laboratory method detection limit, with no significant detection since April 2005
- Sandwith Beck downstream (in the village – the monitoring point at the site boundary has been inaccessible since April 2006) showed no detectable surfactant before 2006. During 2006 and 2007 there have been several detections, interpreted as resulting from disturbance of soils during construction of South Pond and North Pond. This is indirect evidence that Sandwith Beck has never been affected by the site drainage system, since the appearance of surfactant shows that the effects from the site are not masked by dilution at the downstream sampling point. Therefore if the drainage system did have an outlet to the Beck, since surfactant levels in the effluent were high, an effect would have been noted. The lack of connection is not surprising since the drainage system drains north.

It is concluded that the Groundwater Monitoring Report provides good evidence that the possible pollutant linkages from site drainage previously described are not significant.

7.6. Summary of risks to Controlled Waters

Risk to Sandwith Beck and groundwater in the St Bees Evaporites

There are considered to be no significant risks to either Sandwith Beck or groundwater in the St Bees Evaporites from Plot C. The previous TPH and naphthalene hotspot has been shown to be insignificant.

Risk to water quality in the North Pond

There may be no pollutant linkage for groundwater to enter North Pond because the water table appears to be about 1m below the base of the pond. When the pond contains water, there is potential for a risk to water quality because soils may contain leachable metals and surfactants. It is recommended that the pond should be sampled when water is present to assess whether a water quality problem exists. If it does, mitigation action should be undertaken (e.g. lining the pond).

Risk to controlled waters from the site drainage system

Monitoring of groundwater and surface water receptors, together with site investigation data, indicates that there are no significant pollutant linkages from the site drainage system in Plot C.

8. REFINED POLLUTANT LINKAGE ASSESSMENT

The risk assessment/modelling above details which analytes pose a potential risk to Sandwith Beck. It is now possible to review each individual potential pollutant linkage (Section 5.4) as detailed in the Remediation Statement. The tables below give a detailed assessment of which analytes and associated linkages still exist, and which can now be ruled out based on the data obtained in this investigation.

Pollutant Linkage Identifier	Pollutant	Source location	Pathway (see table 5.2a for descriptions)	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	TPH	PLOT C	CW1 and CW3a. (leaching– groundwater - ponds)	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.	MAYBE. Monitoring of pond water quality should be carried out.
C2	TPH	PLOT C	CW2 and CW3a. (drainage system – groundwater - ponds)	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.	NO – Groundwater does not intercept pond base, therefore no pathway
C3	TPH	PLOT C	CW1 and CW3b (Leaching – shallow groundwater – Beck)	Sandwith Beck	Irish Sea	Potential for entry of contaminant into Sandwith Beck after it has passed in the groundwater under the ponds and directly into Sandwith Beck.	NO- The Tier 2/3 risk assessment indicates that there is no risk to Sandwith Beck from TPH fractions.
C4	TPH	PLOT C	CW2 and CW3b Drainage - groundwater -	Sandwith Beck	Irish Sea	Potential for entry of contaminant into Sandwith Beck after it has passed in the groundwater under the	NO – the Groundwater Monitoring Report shows that there is no linkage between Sandwith Beck and the site drainage system

Pollutant Linkage Identifier	Pollutant	Source location	Pathway (see table 5.2a for descriptions)	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)
			beck			ponds and directly into Sandwith Beck.	
C5	TPH	PLOT C	CW4. Overland flow - ponds	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.	MAYBE- Despite no evidence of surface contamination during the site investigation, there is a potential risk (albeit low), that surface water runoff may entrain particulate contamination that may exist on the surface of Plot C and carry it into the north (and south) pond, before being released to Sandwith Beck. Precautionary monitoring of the ponds and Sandwith Beck is recommended.
C6	TPH	PLOT C	CW1, CW5 and CW6. Leaching – deep groundwater	Bellhouse Gill	Irish Sea	Potential for entry of contaminant into Bellhouse Gill after it has passed through the complex geological system in the area.	NO. Tier 2/3 risk assessment has shown that there is no significant risk to deep groundwater from TPH.
C7	TPH	PLOT C	CW2, CW5 and CW6. Drainage – deep groundwater	Bellhouse Gill	Irish Sea	Potential for entry of contaminant into Bellhouse Gill after it has passed through the complex geological system in the area.	NO – the Groundwater Monitoring Report shows that Bellhouse Gill is not contaminated with TPH.
C8	TPH	PLOT C	CW1, CW5 and CW6. Leaching – deep	Byerstead Spring	Irish Sea	Potential for entry of contaminant into the Byerstead Spring (which immediately enters the Irish	NO. Tier 2/3 risk assessment has shown that there is no significant risk to deep groundwater from TPH.

Pollutant Linkage Identifier	Pollutant	Source location	Pathway (see table 5.2a for descriptions)	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)
			groundwater			Sea) after it has passed through the complex geological system in the area.	
C9	TPH	PLOT C	CW2, CW5 and CW6. Drainage – deep groundwater	Byerstead Spring	Irish Sea	Potential for entry of contaminant into the Byerstead Spring (which immediately enters the Irish Sea) after it has passed through the complex geological system in the area.	NO – there is no significant source modelled in Plot C, and the Groundwater Monitoring Report shows that there is no significant detection of TPH in Byerstead Spring.

Pollutant Linkage Identifier	Pollutant	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)
C10	naphthalene	PLOT C	CW1 and CW3a. Leaching-groundwater - ponds	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.	MAYBE see C1
C11	naphthalene	PLOT C	CW2 and CW3a. Drainage-groundwater-ponds	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.	NO see C2

Pollutant Linkage Identifier	Pollutant	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)
C12	naphthalene	PLOT C	CW1 and CW3b Leaching-groundwater-beck	Sandwith Beck	Irish Sea	Potential for entry of contaminant into Sandwith Beck after it has passed in the groundwater under the ponds and directly into Sandwith Beck.	NO- The Tier 2/3 risk assessment indicates that there is no risk to Sandwith Beck from naphthalene.
C13	naphthalene	PLOT C	CW2 and CW3b Drainage-groundwater-beck	Sandwith Beck	Irish Sea	Potential for entry of contaminant into Sandwith Beck after it has passed in the groundwater under the ponds and directly into Sandwith Beck.	NO – see C4
C14	naphthalene	PLOT C	CW4 Overland flow - ponds	North Pond	Sandwith Beck.	Potential for entry of contaminant into Sandwith Beck after it has passed through North and South Pond.	MAYBE – see C5
C15	naphthalene	PLOT C	CW1, CW5 and CW6. Leaching – deep groundwater	Bellhouse Gill	Irish Sea	Potential for entry of contaminant into Bellhouse Gill after it has passed through the complex geological system in the area.	NO- the site investigation indicates no significant source of naphthalene east of the fault in Plot C.
C16	naphthalene	PLOT C	CW2, CW5 and CW6. Drainage-deep groundwater	Bellhouse Gill	Irish Sea	Potential for entry of contaminant into Bellhouse Gill after it has passed through the complex geological system in the	NO – the Groundwater Monitoring Report shows no naphthalene contamination in Bellhouse Gill, and no significant source of naphthalene to deep groundwater detected in Plot C.

Pollutant Linkage Identifier	Pollutant	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)
						area.	
C17	naphthalene	PLOT C	CW1, CW5 and CW6. Leaching-deep groundwater	Byerstead Spring	Irish Sea	Potential for entry of contaminant into the Byerstead Spring (which immediately enters the Irish Sea) after it has passed through the complex geological system in the area.	NO- the site investigation indicates no significant source of naphthalene east of the fault in Plot C.
C18	naphthalene	PLOT C	CW2, CW5 and CW6. Drainage-deep groundwater	Byerstead Spring	Irish Sea	Potential for entry of contaminant into the Byerstead Spring (which immediately enters the Irish Sea) after it has passed through the complex geological system in the area.	NO – the Groundwater Monitoring Report shows no significant contamination by naphthalene in Byerstead Spring.
C19	arsenic	A111 hotspot	HH1, HH2, HH3	Public users		Potential exposure to arsenic of future users of the site	MAYBE – additional investigation recommended.
C20	Cu, V, Se and surfactant	North Pond	CW1, CW3a, CW4	North Pond	Sandwith Beck	Potential for contamination of surface water in North Pond via contact with contaminated soils	MAYBE – monitoring of water in North Pond recommended

Based on the above tables, a small number of significant and potentially significant pollutant linkages still exist within Plot C. The most practical approach to addressing these linkages is discussed in Section 9 below.

9. REMEDIATION ACTIONS

9.1. Summary of remediation actions required

As a result of the assessments carried out in Section 6-8 above, the remediation actions summarised below are required to address the potentially significant pollutant linkages in Plot C.

Table 9.1a Summary of remediation actions

Remediation Actions	Pollutant linkages addressed by action
Monitoring of North Pond and Sandwith Beck for TPH, naphthalene, surfactant, Cu, V, Se	C1, C5, C10, C11, C14 and C20 are addressed by checking to see whether any contamination is reaching the ponds.
Additional sampling around trial pit A111 for Arsenic	C19 is addressed by seeking further information to determine whether a significant source exists.

9.2. Remediation actions details

9.2.1. North Pond Excavation and Construction

The outline of the North Pond is shown on Figure 2. Analysis indicates that the Made Ground to be excavated contains some elevated levels of metals chromium, lead, nickel and vanadium in comparison to Made Ground elsewhere on the site. There are also high levels of phosphate, although it appears to be highly insoluble. Trial pit A117, likely to be up hydraulic gradient of North Pond contained some VOC contamination. The made ground in this area is deep, and there are concrete bases at between 3-4m below ground level. Apart from the phosphate, the Made Ground contamination levels are typical of industrial fills. No risks to human health or water resources have been identified.

It is therefore considered that the material excavated from the North Pond will be suitable for use elsewhere on the site for levelling and regarding, and should be stockpiled in a suitable location away from the pond. The material will not be hazardous waste.

Given that groundwater is below the base of the proposed pond, even allowing for fluctuation in the ground water levels after site closure, it is not considered that the influx of contaminated groundwater to the North Lagoon is potentially significant pathway. It is therefore considered by URS that there is no requirement for the installation of a pond liner.

9.2.2. Monitoring of North Pond and Sandwith Beck

Monitoring of the Sandwith Beck is currently required under the Waste Management Licence for the Ufex landfill. The required monitoring is:

- monthly for pH, electrical conductivity and dissolved oxygen
- quarterly for As, Ca, Cd, Cr, Cu, Hg, K, Mo, Na, Ni, Pb, Ti, V, Zn, phosphate, total phosphorus, fluoride, sulphate, chloride, COD, BOD, TON, TOC and ammoniacal nitrogen

It is recommended that Se, anionic surfactants, TPH (TPH CWG method) and naphthalene are added to the quarterly suite for a period of 1 year after the North Pond becomes operational. The monitoring location in Sandwith Beck is from the bridge in Sandwith village because there is inadequate flow at the accessible location just at head of stream. The neighbouring farmer has denied access to Rhodia for sampling Sandwith Beck just downstream of Rhodia's site boundary.

Water from North Pond should be sampled at least 6 times in its first year of operation, and analysed for pH, electrical conductivity, dissolved oxygen, Cu, V, Se, anionic surfactants, TPH (TPH CWG method) and naphthalene. Since the pond is designed to be dry most of the time, sampling will have to be carried out when water is available. There should be at least 1 week between samples.

9.2.3. Additional sampling around A111

It is proposed that up to 18 soils samples are collected from 6 locations in the area of A111 from 0.05m, 0.5m and 1.0m below ground level and submitted for laboratory chemical analysis of their arsenic concentrations. The concentrations reported should then be screened against the site specific assessment criteria derived for arsenic in order to determine whether there is arsenic contamination present and its extent or whether the report was anomalous.

9.3. Remediation actions related to Part 2A Pollutant Linkages

For regulatory purposes it is necessary to explain how each of the pollutant linkages listed by Copeland Borough Council in their determination of the site as statutory Contaminated Land are dealt with. Table 9.3a below summarises the findings of the investigation and the actions applicable to each pollutant linkage.

Copeland Borough Council Pollutant Linkage	**Findings and Remediation Actions for Plot C**
Petroleum Hydrocarbons *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	Soils in Plot C have been shown not to constitute a significant source to Sandwith Beck or groundwater in the St Bees Evaporites. No remediation actions are proposed. There is a possible pollutant linkage to North Pond, to be tested by monitoring
Poly Aromatic Hydrocarbons *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	Soils in Plot C have been shown not to constitute a significant source using Consim quantitative risk assessment. Shallow groundwater does not exceed Tier 1 criteria in any sample. It is concluded that this pollutant linkage is not significant in Plot C. There is a possible pollutant linkage to North Pond, to be tested by monitoring
Surfactants *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	Site investigation shows that there is no significant pollutant linkage to Sandwith Beck or groundwater in the St Bees Evaporites. There is a possible pollutant linkage to North Pond, to be tested by monitoring
Phosphates *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	Phosphate risks assessed on a site wide basis, and no pollutant linkage present. See Remediation Statement Appendix J.
Arsenic *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	This pollutant linkage is considered to be insignificant as no samples submitted from Plot C reported arsenic concentrations which exceeded the site specific assessment criteria
Boron *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	This pollutant linkage is considered to be insignificant as no samples submitted from Plot C reported boron concentrations which exceeded the site specific assessment criteria
Cadmium *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	This pollutant linkage is considered to be insignificant as no samples submitted from Plot C reported cadmium concentrations which exceeded the site specific assessment criteria
Chromium *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	This pollutant linkage is considered to be insignificant as no samples submitted from Plot C reported chromium concentrations which exceeded the site specific assessment criteria
Copper *in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	There is a possible pollutant linkage to North Pond, to be tested by monitoring
Lead *in soil, migrating from soil to groundwater and through drains impacting*	This pollutant linkage is considered to be insignificant as no samples submitted from Plot C reported lead concentrations

Copeland Borough Council Pollutant Linkage	**Findings and Remediation Actions for Plot C**
undefined controlled waters receptor.	which exceeded the site specific assessment criteria
***Mercury** in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	This pollutant linkage is considered to be insignificant as no samples submitted from Plot C reported mercury concentrations which exceeded the site specific assessment criteria
***Nickel** in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	This pollutant linkage is considered to be insignificant as no samples submitted from Plot C reported nickel concentrations which exceeded the site specific assessment criteria
***Selenium** in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	There is a possible pollutant linkage to North Pond, to be tested by monitoring
***Zinc** in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	This pollutant linkage is considered to be insignificant as no samples submitted from Plot C reported zinc concentrations which exceeded the site specific assessment criteria
***VOCs/SVOCs** in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.*	This pollutant linkage is considered to be insignificant as samples submitted from Plot C did not report concentrations which exceeded the site specific assessment criteria.

Figures

Photographs

Appendix A -

Description of Field Methodologies

Appendix B -

Borehole/ Trial Pit Logs

Appendix C -

Hydrogeological Test Data

Appendix D -

Controlled Waters Detailed Quantitative Risk Assessment

Appendix E -

Proposal for Site investigation Works: Plot C