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## G.1 INTRODUCTION

In March 2007 URS was commissioned to undertake an investigation of Plot F on the Whitehaven Site. Part of this investigation required a detailed risk assessment with regard to controlled waters using relevant data gathered from previous investigations and data from the 2007 investigation. This appendix presents the methodology and results of the Controlled Waters Quantitative Risk Assessment (CWQRA) for Plot F.

The risk assessment set out in this appendix is considered to be more rigorous and representative of site conditions than the previous risk assessment for the whole of the Whitehaven site (detailed in the original Phase II report REF: 44319623, Phase II Investigations and Environmental Assessments at the Former Albright & Wilson Works, Whitehaven, 23 June 2005), as it incorporates additional geological and geochemical data obtained during the Plot F investigation and uses a more sophisticated modelling approach.

The CWQRA is based upon the UK Department of the Environment, Food and Rural Affairs (DEFRA) and Environment Agency (EA) guidance including:

- Environment Agency Remedial Targets Methodology (2006) (referred to as EA-RTM), formerly R&D Publication 20 (1999) Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources (referred to as R&D P-20); and
- Environment Agency R&D Publication CLR11 (2004) Model Procedures for the Management of Land Contamination (referred to as CLR11).

Using CLR 11 methodology, risk assessment is carried out in three stages:

Stage 1 – Preliminary Risk Assessment

Stage 2 - Generic Quantitative Risk Assessment; and

Stage 3 – Detailed Quantitative Risk Assessment.

Stage 1 involves the development of a conceptual understanding of the site and the surrounding environment's geology, hydrogeology, observed contamination (and its distribution), and potential receptors. From this conceptual understanding, potential pollutant linkages (*source-pathway-receptor* relationships) are identified. This stage of the risk assessment is set out in Section 5 of the main body of the report.

Risk assessment at Stages 2 and 3 for Plot F is presented in full in this appendix.



## G.2 STAGE 2 - GENERIC QUANTITATIVE ASSESSMENT

## G.2.1 Methodology

The generic screening was undertaken by making a comparison of measured chemical concentrations in soil, soil leachate, and groundwater against conservative screening criteria appropriate for a designated potential receptor. This initial screening is designed to identify Potential Contaminants of Concern (PCoC), which could pose a potential risk to controlled waters. At the generic screening stage, no consideration is given to pathways or potential attenuation factors such as dilution, dispersion or biodegradation.

For this assessment, the receptor is considered to be groundwater in the Whitehaven Sandstone Formation classified as a minor aquifer by the Environment Agency and the screening values that have been used are the UK Drinking Water Quality Standards (UK DWS) for soil leachate and shallow groundwater samples. Where published UK DWS values for certain contaminants were not readily available, reference was made to World Health Authority (WHO) guidelines. In the absence of WHO guidelines, United States Environmental Protection Agency (US EPA) Region 9 Pathway Specific values were used for screening purposes.

VOC analysis was not carried out on soil leachates as the leaching methodology is unsuitable for VOCs, i.e. it allows VOCs to escape during the leaching process and thus any results obtained would be unrealistically low. Thus, for soils samples, concentrations of VOCs have been compared to theoretical soil concentrations that are protective of drinking water. The theoretical concentrations have been derived using partitioning equations, as outlined in EA-RTM (EA, 2006).

The Stage 2 soils VOC screening values are derived using the following site-specific parameters:

- Fraction of Organic Carbon 0.52%, from site data
- Soil Type (Silt, Gravel, Clay etc) Silty Clay
- Total Porosity 38%
- Water Filled Porosity 27%
- Air-filled Porosity 11%
- Dry bulk density 1.64 g/cm<sup>3</sup>

Details of the sources of all Stage 2 screening criteria are given in Tables G1 (soil VOCs) and G2 (soil leachate and groundwater).

Where concentrations of contaminants exceeded the generic screening criteria, they have been evaluated further as part of the Stage 3 assessment.



## G.2.2 Stage 2 Screening Method

The concentrations measured in samples taken from Plot F were used to define both source areas and source term concentrations for the Stage 2 assessment for soils and soil leachates. The spatial distribution of samples, where exceedances were measured, allowed Plot F to be further sub-divided into a potentially contaminated (source area) and an uncontaminated area. The delineation of the source area was also based on where historical usage of the chemicals had occurred. No small hot spot areas were identified.

The screening criteria for the various analytes are listed in Tables G1 and G2. Analytical results for the Plot F investigation are presented in Appendix D of the main report.

## G.2.3 Soil Contamination Generic Screening

With the exception of VOCs, generic screening of soils totals results, was not performed because screening was undertaken using leach test data, which is considered more representative of the potential risks to controlled waters. The screening criteria for soil VOCs are listed in Table G1.

The analytical results for soil VOCs are reported in Appendix D, Table 4. A summary of the determinands whose concentrations exceeded the Stage 2 generic screening values is given in Table G3. The measured exceedances are limited to two compounds 1,2,4-trimethylbenzene (1 exceedance from 11 samples) and benzene (all 11 samples generated an exceedance).

## G.2.4 Soil Leachate Generic Screening

The screening criteria for the analytes measured soil leachates are listed in Table G2.

### G.2.4.1 Metals and other Inorganic lons

The analytical results for metals in soil leachate are reported in Appendix D, Table 10. No measured concentrations of metals or inorganic ions exceeded the Stage 2 generic screening values.

## G.2.4.2 Total Petroleum Hydrocarbons (TPHs)

The analytical results for TPH in soil leachate are reported in Appendix D, Table 12. A summary of the determinands whose concentrations exceeded the Stage 2 generic screening values is given in Table G4. Exceedances of screening criteria were only measured in one out of the five samples collected. The review of the data indicates that for both aliphatic and aromatic species, the C10-C12 carbon band represented the only fraction determined.



# G.2.4.3 Semi Volatile Organic Compounds (SVOC) and Polycyclic Aromatic Hydrocarbons (PAHs)

The analytical results for SVOCs and PAHs in soil leachate are reported in Appendix D, Table 11. No measured concentrations of SVOCs or PAHs exceeded the Stage 2 generic screening values.

## G.2.5 Shallow Perched Groundwater Results Generic Screening

Shallow groundwater was generally not encountered across Plot F, however, samples of perched groundwater were collected from two shallow boreholes: ERM1 and ERM2. Prior to the March 2007 site investigation, samples had also been collected from WS108, WS109 and TP756F (a grab sample from the base of the trial pit). These results have been included in the current assessment. The perched groundwater sample from TP756F was analysed only for metals and TPH. Samples from the remaining boreholes were analysed for heavy metals, anions, phenols, SVOCs, TPH and VOCs. The screening criteria for the analytes measured water samples are listed in Table G2. The results are summarised below:

- The analytical results for VOCs in the sampled groundwater are reported in Appendix D, Table 15. Four shallow perched groundwater samples were submitted for VOC analysis. There were no measured exceedances of Stage 2 generic screening values.
- The analytical results for SVOCs in the sampled groundwater are reported in Appendix D, Table 16. In the perched groundwater samples submitted for analysis of SVOCs and metals, no measured exceedances of Stage 2 generic screening values were detected.
- The results of the screening assessment for TPH in perched groundwater samples are reported in Appendix D, Table 17 and summarised in Table G5. The results indicate that exceedances of screening criteria were only measured in one out of the five samples collected. The review of the data indicates that for both aliphatic and aromatic species, the measured concentrations were limited to the C12-C16 and C16-C21 carbon bands.

## G.2.6 Summary of Identified Exceedances of Generic Screening Criteria

From the Stage 2 generic screening process the determinands in soils, soil leachate and shallow groundwater that exceeded the Stage 2 screening criteria are summarised in Table G8 below. With the exception of 1,2,4-trimethylbenzene, there was only one detection of each determinand on Plot F: benzene in TP752F; leachable TPH aromatic and aliphatic C10-12 in TP752F; and TPH aromatic and aliphatic C12-16 and C16-21 in TP756F.

#### Table G8 – Stage 2 Assessment – Summary of Screening Criteria Exceedances

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

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

## G.3 STAGE 3 DETAILED QUANTITATIVE RISK ASSESSMENT

## G.3.1 Methodology

Natural attenuation processes such as dilution, dispersion and other physical/geochemical processes are considered at this stage of assessment. The Stage 3 assessment has been undertaken using the CONSIM (v2.02) software package.

Borehole logs and estimations of deep groundwater elevations suggest that a 4m unsaturated zone may exist between the source zones within Plot F and the underlying groundwater within the Whitehaven Sandstone. No continuous groundwater table has been identified in Plot F. The only shallow groundwater encountered is considered to represent a pocket of perched groundwater.

However, due to the potential presence of fractures in the Whitehaven sandstone, all of the modelling was carried out under the assumption that an unsaturated zone did not exist between the source (thought to be immediately above the Whitehaven Sandstone) and the water table.

CONSIM Level 3 modelling was carried out for all determinands that were measured in either soil or soil leachate assuming that the contamination rested directly on top of the Whitehaven Sandstone.

CONSIM Level 3a modelling was carried out for the determinands measured in the groundwater as it is assumed that these have already entered the underlying aquifer.

Both levels of modelling were carried out with the defined area within Plot F specified as the source area.

## G.3.2 Model Selection and Key Model Assumptions

CONSIM (version 2.02) was run in probabilistic mode to allow for uncertainty in key input parameters. Simulated concentrations at a defined receptor are reported at both the  $50^{th}$ 



percentile and the 95th percentile. Simulated concentrations at the 50th percentile confidence limit represent 'on the balance of probabilities' the most likely simulated concentrations given the range of parameters applied. Simulated concentrations at the 95th percentile confidence limit represent a worse case or extreme condition, resulting from a worse case combination of parameters (e.g. high permeability, high source concentrations and low degradation rate). This approach is consistent with EA requirements and the original R&D-P20 (EA, 1999) methodology.

The CONSIM model allows for the input of site-derived parameters such as aquifer permeability, hydraulic gradient, organic carbon content, bulk density and effective porosity. These parameters are assumed to be continuous (and homogeneous) between the site and designated receptor or compliance point. The physical parameter ranges and distributions used to define the model in this assessment along with the justifications for their use are set out as follows:

- source zone model parameters: Table G6;
- unsaturated zone model parameters: Table G7; and
- saturated zone model parameters: Table G8.

The parameters are based on previous modelling works and are described in full in URS Report 44319623: Phase II Investigations and Environmental Assessments at the Former Albright & Wilson Works, Whitehaven, 23 June 2005.

Other key model assumptions include the following:

- In order to maintain conservativeness, declining source terms have been not been assigned to designated soil sources.
- Conservative estimates of biodegradation have been applied. Conservative halflives applied and relevant literature sources for the physical/chemical parameters used in the model are presented in Table G9. The applied degradation rates were obtained, where available, from EA (2002) R&D Technical Report P2-228/TR.
- No attenuation or biodegradation processes have been simulated in the unsaturated zone. It has been assumed the soil source extends to the water table, *i.e.* no unsaturated zone is present.
- Longitudinal dispersion set at 1/10<sup>th</sup> the travel distance to the receptors 100m and 250m away from the source.
- Lateral dispersion is simulated as being 1/10<sup>th</sup> to 1/3<sup>rd</sup> of longitudinal dispersion.
- Vertical dispersion, where considered, is simulated as being 1/10<sup>th</sup> of the travel distance.



## G.3.3 Sources

A single source area has been modelled based on the screening of measured concentrations. The source area encompasses an area of 1200m<sup>2</sup> in the vicinity of the historical location of the TPH storage tanks. The area of the source was defined from the spread of sample locations where exceedances of screening criteria were identified. Source term concentrations have been defined as follows:

- 1,2,4-trimethylbenzene: A triangular distribution using the minimum and maximum measured values and the most likely value derived from the calculated US95 concentration value. For calculating the US95 samples whose measured concentrations were below the method detection limit (MDL) were treated as having concentrations equal to the MDL.
- **Benzene and TPH:** Uniform concentration based on the single exceedance measured for these determinands.

The source concentrations and dimensions used for Model Levels 3 and 3a are given in Tables G10 to G15.

### G.3.4 Pathways

The pathways that are considered applicable to this assessment include the partitioning of contaminants from the soil into the soil pore water, migration of contaminants as soil leachate, and shallow perched groundwater (where present) vertically into the Whitehaven Sandstone.

Due to the potential that vertical migration through the unsaturated zone may occur via fracture flow, the following model scenario has been developed:

The model assumes that an unsaturated zone does not exist. This considers that the determinands rapidly migrate vertically through (potential) fractures in the Whitehaven Sandstone, directly into the underlying groundwater. In effect, it can be considered that this model assumes the source zone directly overlies the deeper groundwater table.

This scenario is highly conservative, but is useful, as it provides an understanding of a reasonable worst-case scenario for the impact of contamination within Plot F on the underlying groundwater body.

From the point of entry of determinands into the groundwater within the Whitehaven Sandstone, contamination moves laterally towards the compliance point (see Section 3.5).

By defining the thickness of the unsaturated zone as zero (Table G7), the model assumes that the unsaturated zone does not act to attenuate the contaminants. This is thought to be the case because the flow through the sandstone may be rapid through a network of fractures. This is a conservative assumption as although fracture flow may be the predominant flow mechanism, it is unlikely to be the sole transport mechanism for



groundwater that may be migrating from the source area to deep groundwater; as transport through pore spaces is likely to be occurring also. Furthermore, a degree of attenuation can actually take place when water migrates through fracture flow. This model assumes that this is not occurring.

## G.3.5 Receptors

The receptor for Plot F derived contaminants has been determined as the Whitehaven Sandstone Formation. For the purpose of this assessment theoretical compliance points have been located 100m down hydraulic gradient from Plot F to assess the potential risks beneath the site, and 250m at the down gradient site boundary. These have been considered as the receptors. Theoretical compliance points have been adopted given the absence of identifiable groundwater abstractions or discharge points to surface close to the site. The compliance points are designed to be protective of water resources present within the Whitehaven Sandstone Formation and are positioned such that large portions of the aquifer are protected (rather than being used to attenuate any site derived contamination).

## G.3.6 Summary of Model Results

Simulated 50<sup>th</sup> and 95<sup>th</sup> percentile concentrations at the theoretical compliance point within the Whitehaven Sandstone Formation at distances of 100 and 250m down hydraulic gradient from the source area are presented in Tables G16 to G18. Time-variant graphical outputs for each model run, presenting simulated concentrations of the determinands are presented in Figures G3.6.1 A-H and G3.6.2 A-H. The ConSim model files are included on the CD in Appendix H to the main report.

For simulated concentrations of chemicals at a given compliance point to pose a potential risk to controlled waters, they must be in excess of defined generic screening criteria, in this case UKDWS and should occur within a reasonable time frame.

Calculated travel times provide a measure of the relative mobility of individual contaminants and the time scale over which breakthrough of concentrations at the receptor is likely to occur. URS considers travel times of more than 250 years to be theoretical in terms of assessing potential risk.

In addition, current UK guidance suggests that simulated 95<sup>th</sup> percentile concentrations are used to assess potential risks. However, in assessing the potential significance of an identified risk, predicted travel times and 50<sup>th</sup> percentile concentrations are taken into consideration given that these are reflective of the most likely conditions, rather than a combination of extreme variables. The results are presented in Tables G16 to G18 and are summarised below.

The simulated concentrations in exceedance of their respective screening criteria at the  $50^{th}$  and  $95^{th}$  percentile limits at the 100 and 250m compliance points are summarised in Table G3.1.



### G.3.6.1 Simulated Risks from Soil to Deep Groundwater at the Site Boundary

The two determinands (1,2,4-trimethylbenzene and benzene) that were identified to be in exceedance of the Stage 2 generic screening criteria for soils and were subsequently included in Stage 3 modelling. The simulated results and breakthrough curves for soil VOCs are presented in Table G16 and Figures G3.6.1 A,B,E and F.

The simulated concentrations for both determinands at the 50<sup>th</sup> and 95<sup>th</sup> percentile confidence level did not exceed the screening criteria at the 100m or 250m compliance points.

### G.3.6.2 Risks from Soil Leachate to Deep Groundwater at the Site Boundary

Simulated results and breakthrough curves for leachable TPH from soils is presented in Table G.17 and Figures G3.6.1 C, D, G and H. Potential exceedances of generic screening criteria simulated at the 100 and 250 compliance points within the Whitehaven Sandstone beneath the site are summarised as follows:

- Leachable TPH (C10-C12) aromatic: Simulated breakthrough curves are presented as Figures G3.6.1 C and G for the 100 and 250m compliance points respectively. At the 100m compliance point, the curves indicate exceedances of the UK DWS at both the 50<sup>th</sup> and 95<sup>th</sup> percentile confidence limits. At the 95<sup>th</sup> percentile, a maximum concentration of 35µg/l is simulated, while a maximum of 13µg/l is simulated at the 50<sup>th</sup> percentile confidence limit. The simulated times to exceed the UK DWS at the 100m compliance point are predicted at approximately 60 years for the 95<sup>th</sup> percentile and approximately 540 years for the 50<sup>th</sup> percentile level. At the 250m compliance point, the curves indicate exceedances of the UK DWS are only simulated at the 95<sup>th</sup> percentile confidence limit. At the 95<sup>th</sup> percentile, a maximum concentration of 11µg/l is simulated, while a maximum of 5µg/l is simulated at the 50<sup>th</sup> percentile confidence limit. The simulated time to exceed the UK DWS at the 250m compliance point is predicted at approximately 3,200 years for the 95<sup>th</sup> percentile.
- Leachable TPH (C10-C12) aliphatic: Simulated breakthrough curves are presented as Figures G3.6.1 D and H for the 100 and 250m compliance points respectively. At the 100m compliance point, exceedances of the UK DWS are only simulated at the 95<sup>th</sup> confidence limit, where a maximum concentration of 12µg/l is simulated, while only a maximum of only 6µg/l is simulated at the 50<sup>th</sup> percentile confidence limit. The simulated times to exceed the UK DWS at the 100m compliance point are predicted at approximately 36,000 years for the 95<sup>th</sup> percentile level. At the 250m compliance point, the curves indicate that no exceedances of the UK DWS are simulated. At the 95<sup>th</sup> percentile, a maximum concentration of 3µg/l is simulated, while a maximum of 1µg/l is simulated at the 50<sup>th</sup> percentile confidence limit.



• Where potential risks to controlled waters are simulated to occur over an extended timescale in excess of 250 years, these are considered to be theoretical in nature.

## G.3.6.3 Risks from Shallow Perched Groundwater To Deep Groundwater

All determinands identified to be in exceedance of the Stage 2 generic screening criteria were included in the modelling. Simulated results and breakthrough curves for TPH from perched groundwater are presented in Table G.18 and Figures G3.6.2 A-H. Potential exceedances of generic screening criteria simulated at the 100 and 250 compliance points within the Whitehaven Sandstone beneath the site are summarised as follows:

- TPH (C12-C16) Aliphatic: Simulated breakthrough curves are presented as Figures G3.6.2 A and E for the 100 and 250m compliance points respectively. No exceedances of the UK DWS at the 50<sup>th</sup> or 95<sup>th</sup> percentile confidence limits are simulated at both the 100m and 250m compliance points. Simulated breakthrough curves indicate that at the 100m compliance point a maximum concentration of 3.7µg/l is simulated at the 95<sup>th</sup> percentile confidence limit. At the 250m compliance point, the simulated concentrations are less than 1x10<sup>-8</sup>µg/l.
- TPH (C16-C21) Aliphatic: Simulated breakthrough curves are presented as Figures G3.6.1 C and G for the 100 and 250m compliance points respectively. At the 100m and 250m compliance points, the curves indicate that there are no exceedances the UK DWS, with all the simulated concentrations less than 1x10<sup>-8</sup> µg/l.
- TPH (C12-C16) Aromatic: Simulated breakthrough curves are presented as Figures G3.6.2 B and F for the 100 and 250m compliance points respectively. At the 100m compliance point, the curves indicate exceedances of the UK DWS at both the 50<sup>th</sup> and 95<sup>th</sup> percentile confidence limits. At the 95<sup>th</sup> percentile confidence limit, a maximum concentration of 63µg/l is simulated, while a maximum of 49µg/l is simulated at the 50<sup>th</sup> percentile confidence limit. The simulated times to exceed the UK DWS at the 100m compliance point are predicted at approximately 30 years for the 95<sup>th</sup> percentile and approximately 210 years for the 50<sup>th</sup> percentile level. At the 250m compliance point, the curves indicate exceedances of the UK DWS at both 50<sup>th</sup> and 95<sup>th</sup> percentile confidence limits. At the 95<sup>th</sup> percentile, a maximum concentration of 27µg/l is simulated, while a maximum of 19µg/l is simulated at the 50<sup>th</sup> percentile confidence limit. The simulated time to exceed the UK DWS at the 250m compliance point are predicted at approximately 140 years for the 95<sup>th</sup> percentile and 830 years for the 50<sup>th</sup> percentile
- **TPH (C16-C21) Aromatic:** Simulated breakthrough curves are presented as Figures G3.6.2 D and H for the 100 and 250m compliance points respectively. At



the 100m compliance point, the curves indicate exceedances of the UK DWS at both the 50<sup>th</sup> and 95<sup>th</sup> percentile confidence limits. A maximum concentration of 46µg/l is simulated at the 95<sup>th</sup> percentile limit, while a maximum of 35µg/l is simulated at the 50<sup>th</sup> percentile confidence limit. The simulated times to exceed the UK DWS at the 100m compliance point are predicted at approximately 130 years for the 95<sup>th</sup> percentile level and 725 years at the 50<sup>th</sup> percentile level. At the 250m compliance point, the curves indicate exceedances of the UK DWS at both 50<sup>th</sup> and 95<sup>th</sup> percentile confidence limits. At the 95<sup>th</sup> percentile, a maximum concentration of 20µg/l is simulated, while a maximum of 14µg/l is simulated at the 50<sup>th</sup> percentile confidence limit. The simulated time to exceed the UK DWS at the 250m compliance point is predicted at approximately 500 years for the 95<sup>th</sup> percentile and 3,200 years for the 50<sup>th</sup> percentile.

• Where potential risks to controlled waters are simulated to occur over an extended timescale in excess of 250 years, these are considered theoretical in nature.

## G.3.6.4 Model Sensitivity Testing

#### Distance to Compliance Point

The model was also run using a 400m compliance point. This compliance point was used to assess potential contaminant concentrations in groundwater entering the Irish Sea. The modelled concentrations results are shown in Table G18. The modelling results suggest that the two TPH fractions determined as risks at the 250m compliance point (the site boundary) have been reduced by approximately 50%. Consequently, these concentrations are now 14 $\mu$ g/l and 11  $\mu$ g/l, only marginally above the screening criteria of 10  $\mu$ g/l. Furthermore, the travel time to the receptor has been modelled as being over 400 years, and therefore, the risk is considered theoretical in nature.

#### Inclusion of an Unsaturated Zone

One of the additional assumptions of the model is treating transport from the source zone to the aquifer only as fracture flow and thereby disregarding any effect that the unsaturated zone may have on contaminant concentrations. In order to determine whether the unsaturated zone does have any effect, the model has been run with a simulated 4m unsaturated zone between source zone and the groundwater table within the sandstone aquifer. This thickness is representative of bedrock levels measured on Plot F and inferred groundwater contours (based on groundwater levels within wells screened in the Whitehaven Sandstone elsewhere on site). The results are summarised in Table G19. The modelling results suggest that inclusion of the unsaturated zone does not reduce contaminant concentrations at the receptor, but the travel times to the 250m compliance point of the most mobile of the measured contaminants (Aromatic TPH range C10-C12) are increased significantly from approximately 3000 years (without an unsaturated zone) to 9000 years with an unsaturated zone present.



#### Table G3.1 – Stage 3 Assessment – Summary

100m Compliance point				250m compliance point – Site Boundary							
So	oil	Soil Le	achate	Shallow Gr	Shallow Groundwater Soil Soil Leachate Shallow Gr		w Groundwater Soil Soil Leachate Shallow Groundwate		Soil Soil Leachate		roundwater
50%ile	95%ile	50%ile	95%ile	50%ile	95%ile	50%ile	95%ile	50%ile	95%ile	50%ile	95%ile
-	-	Leachable TPH (>EC10-12) aromatic (0.013mg/L)	Leachable TPH (>EC10-12) aromatic (0.034mg/L)	-	-	-	-	IR	Leachable TPH (>EC10-12) aromatic (0.011mg/L)	-	-
-	-	IR	Leachable TPH (>EC10-12) aliphatic (0.012mg/L)	-	-	-	-	IR	IR	-	-
-	-	-	-	TPH (>EC12-16) aromatic (0.049mg/L)	TPH (>EC12-16) aromatic (0.063mg/L)	-	-	-	-	TPH (>EC12-16) aromatic (0.019mg/L)	TPH (>EC12-16) aromatic (0.027mg/L)
-	-	-	-	TPH (>EC16-21) aromatic (0.035mg/L)	TPH (>EC16-21) aromatic (0.046mg/L)	-	-	-	-	TPH (>EC16-21) aromatic (0.014mg/L)	TPH (>EC16-21) aromatic (0.020mg/L)

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



## G.4 UNCERTAINTIES

It is acknowledged that there are uncertainties inherent in all risk assessment methodologies, particularly in relation to the assignment of assumed values for difficult to measure site-specific variables, such as infiltration rate. However, a reasonable body of research exists such that these variables can be estimated with reasonable accuracy, and in a manner that is known to be conservative. It is therefore likely that risks are, if anything, overestimated, due to these assumptions (constant source terms, use of 95<sup>th</sup> percentile concentrations), and so the results of the controlled waters risk assessment should be viewed in this context.

The assessment can only be undertaken on the data set available from site investigations, thus it is possible that higher concentrations of ground contaminants than observed during the site assessment works conducted by URS to date. This uncertainty has been reduced as far as is reasonably practical with use of a relatively high sampling density and several phases of site investigation. It is also balanced by the inherent conservatism of the modelling process.

## G.5 SUMMARY OF RISKS TO CONTROLLED WATERS

The conservatism in the models is generally included in their parameterisation, and must be taken into account when considering the potential risk to controlled waters posed by residual contamination within Plot F.

In the model that considers the transport of contaminant directly through fractures from the source zone to the groundwater table through the four meters of bedrock (i.e effectively no unsaturated zone) the connectivity of the fractures has not been considered. It is more likely that water migrates through a complex system of fractures in the unsaturated zone. This will increase the residence time of the water in this system, increasing the potential for attenuation.

The possible pollutant linkages identified relate to the risk of soil leachate or shallow contaminated perched groundwater entering the Whitehaven Sandstone minor aquifer by migration from the Made Ground source and directly into the underlying aquifer.

Taking into account both the physical site evidence and the results of the risk assessment and modelling it is considered that potential risks to off site-controlled waters may be posed by soil leachable aromatic TPH C10-C12 fraction and aromatic TPH fractions C12-C16 and C16-C21 within shallow perched groundwater. However, where potential risks to controlled waters are simulated to occur over an extended timescale in excess of 250 years these are considered theoretical in nature, therefore, the greatest risk to the receptor at 250m is posed by the aromatic TPH fraction C12-C16 within shallow perched groundwater.

Although the modelled concentrations at the site boundary (250m) and offsite (400m) receptors suggest that there is limited risks to ground water outside the Rhodia



Whitehaven site from Plot F, the observed black staining on the top of the bedrock at TP752F may need to be assessed. Furthermore, additional characterization of the nature of the contamination at TP756F is also required.

Therefore, it is proposed that one groundwater well is advanced in the vicinity of TP752F and one in the vicinity of TP756F. Soil samples shall be taken at approximately 0.5m intervals for subsequent on site headspace analysis. Up to two soil samples shall be scheduled for analysis; one shallow sample within the made ground and one deeper sample within the underlying strata (where possible). Following development of these wells, an assessment will be made as to whether the black contamination on the groundwater forms a discernible product layer. If so, then Rhodia may wish to remove this product through dewatering the shallow horizons.

The recommended zones for additional investigation based on current information are shown in Figure 9.

## G.6 REFERENCES

- CLR-7 (2002) Assessment of Risks to Human Health from Land Contamination: An overview of the Development of Soil Guideline Values and Related Research. Department for the Environment, Food and Rural Affairs (DEFRA) and Environment Agency (EA), Appendix A.
- 2) CLR-11 (2004) Model Procedures for the Management of Land Contamination" (Environment Agency, 2004).
- Environment Agency (1999) Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources. Authors Marsland, P.A. and Carey, M.A. Environment Agency R&D Publication 20, 89pp.



## FIGURES



## TABLES



#### TABLE G1 - STAGE 2 SOIL SCREENING CRITERIA - VOCS IN SOILS

Target Compound	Controlled Waters Soil Screening Values (mg/kg)	Source		
1 1 1 2-Tetrachloroethane	0.0004	B		
1 1 1-Trichloroethane	ny	ny		
1 1 2 2-Tetrachloroethane	0.00007	B		
1 1 2-Trichloroethane	0.0001	B		
1 1-Dichloroethane	0 294	B		
1 1-Dichloroethene	0.017	C C		
1 1-Dichloropropene	ny	ny ny		
1.2.3-Trichlorobenzene	ny	ny		
1.2.3-Trichloropropane	0.00004	B		
1.2.4-Trichlorobenzene	0.075	B		
1.2.4-Trimethylbenzene	0.099	B		
1,2-Dibromo-3-Chloropropane	0.0001	A		
1,2-Dibromoethane	0.00004	A		
1,2-Dichlorobenzene	3.743	С		
1,2-Dichloroethane	0.002	A		
1,2-Dichloropropane	0.00004	А		
1,3,5-Trimethylbenzene	0.099	В		
1,3-Dichlorobenzene	2.127	В		
1,3-Dichloropropane	nv	nv		
1,4-Dichlorobenzene	1.125	С		
2,2-Dichloropropane	nv	nv		
2-Chlorotoluene	0.265	В		
4-Chlorotoluene	nv	nv		
4-Isopropyltoluene	nv	nv		
Benzene	0.001	A		
Bromobenzene	0.020	В		
Bromochloromethane	nv	nv		
Bromodichloromethane	nv	nv		
Bromoform	nv	nv		
Bromomethane	0.002	В		
Carbon Disulfide	0.497	В		
Carbon Tetrachloride	0.006	A		
Chlorobenzene	nv	nv		
Chloroethane	0.001	В		
Chloroform	nv	nv		
Chloromethane	0.032	В		
Cis-1,2-Dichloroethene	0.023	В		
Cis-1,3-Dichloropropene	nv	nv		
Dibromochloromethane	nv	nv		
Dibromomethane	0.024	В		
Dichlorodifluoromethane	1.741	В		
Dichloromethane	0.006	С		



## Plot F Soil and Groundwater Investigation Former Albright and Wilson Works, Whitehaven, Cumbria Appendix G– Controlled Waters Quantitative Risk Assessment,

	Controlled Waters Soil Screening	
Target Compound	(mg/kg)	Source
Ethylbenzene	0.806	С
Hexachlorobutadiene	0.187	С
Isopropylbenzene	2.072	В
M,P-Xylene	See Note 1	See Note 1
МТВЕ	0.002	В
Naphthalene	0.047	В
N-Butylbenzene	1.615	В
O-Xylene	See Note 1	See Note 1
P-Isopropyltoluene	nv	nv
Propylbenzene	1.069	В
Sec-Butylbenzene	4.038	В
Styrene	0.093	С
Tert-Butylbenzene	4.861	В
Tetrachloroethene	nv	nv
Toluene	0.696	С
Total Xylene	1.3	С
Trans-1,2-Dichloroethene	0.060	В
Trans-1,3-Dichloropropene	nv	nv
Trichloroethane	nv	nv
Trichloroethene	nv	nv
Trichlorofluoromethane	1.846	В
Vinyl Chloride	0.0003	А

Note 1: Total Xylenes = Sum of M,P-Xylene and O-Xylene

#### TABLE G2 – STAGE 2 SCREENING CRITERIA – SOIL LEACHATE AND SHALLOW GROUNDWATER

	Controlled Waters DWS & EQS	
Target Compound/Element	(µg/L)	Source
1,2,4-Trichlorobenzene	7	В
1,2-Dichlorobenzene	1,000	С
1,3-Dichlorobenzene	183	В
1,4-Dichlorobenzene	300	С
1-Methylnaphthalene	nv	nv
2,4,5-Trichlorophenol	9	С
2,4,6-Trichlorophenol	200	С
2,4-Dichlorophenol	nv	nv
2,4-Dimethylphenol	730	В
2,4-Dinitrotoluene	73	В
2,6-Dinitrotoluene	36	В
2-Chloronaphthalene	487	В
2-Chlorophenol	nv	nv
2-Methylnaphthalene	nv	nv



## Plot F Soil and Groundwater Investigation Former Albright and Wilson Works, Whitehaven, Cumbria Appendix G– Controlled Waters Quantitative Risk Assessment,

	Controlled Waters DWS & EQS	_
Target Compound/Element	(μg/L)	Source
2-Methylphenol	1,825	В
2-Nitroaniline	109	В
2-Nitrophenol	nv	nv
3-Nitroaniline	3	В
4-Bromophenyl Phenyl Ether	nv	nv
4-Chloro-3-Methylphenol	40	S
4-Chloroaniline	146	В
4-Chlorophenyl Phenyl Ether	nv	nv
4-Methylphenol	182	В
4-Nitroaniline	3	В
4-Nitrophenol	nv	nv
Acenaphthene	365	В
Acenaphthylene	10	Α
Anthracene	1,825	В
Arsenic	10	Α
Azobenzene	1	В
Benzo(a)anthracene	0.1	В
Benzo(a)pyrene	0.01	Α
Benzo(b)fluoranthene	See Note 2	See Note 2
Benzo(g,h,i)perylene	See Note 2	See Note 2
Benzo(k)fluoranthene	See Note 2	See Note 2
Biphenyl	nv	nv
Bis(2-Chloroethoxy)Methane	nv	nv
Bis(2-Chloroethyl)Ether	0.01	В
Bis(2-Ethylhexyl)Phthalate	8	С
Boron	1,000	Α
Butylbenzylphthalate	7,300	В
Cadmium	5.0	Α
Carbazole	3	В
Chromium	50	Α
Chrysene	9	В
Copper	2,000	Α
Dibenz(a,h)anthracene	0.01	В
Dibenzofuran	12	В
Diethylphthalate	29,199	В
Dimethylphthalate	364,867	В
Di-N-Butylphthalate	nv	nv
Di-N-Octylphthalate	1,460	В
Fluoranthene	0	Α
Fluorene	243	В
Hexachlorobenzene	1	С
Hexachlorobutadiene	1	С
Hexachlorocyclopentadiene	219	В
Hexachloroethane	5	В



## Plot F Soil and Groundwater Investigation Former Albright and Wilson Works, Whitehaven, Cumbria Appendix G– Controlled Waters Quantitative Risk Assessment,

	Controlled Waters DWS & EQS	
Target Compound/Element	(μg/L)	Source
Indeno(1,2,3-cd)pyrene	See Note 2	See Note 2
Isophorone	71	В
Lead	25	Α
Mercury	10.95	В
Naphthalene	6	В
Nickel	20	А
Nitrobenzene	3	В
N-Nitroso-Di-N-Propylamine	0.01	В
Pentachlorophenol	9	С
Phenanthrene	10	А
Phenol	1	А
Pyrene	183	В
Selenium	10	А
Total PAH (Sum of 4)	0.1	А
Zinc	3,000	С

Note 2: Total PAH (Sum of 4) = Sum of benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene

nv = no value

A = UK Drinking Water Standards (DWS) 2000

B = USEPA Region 9 (pathway specific)

C = World Health Organisation Drinking Water Guidelines (WHO DWG)

D = UK Marine / Estuarine EQS Surface Waters (Dangerous Substances)(Classification) Regulations 1997

E = UK Marine / Estuarine EQS Surface Waters (Dangerous Substances)(Classification) Regulations 1989

F = URS Generic Assessment Criteria (GAC)

G = UK Marine / Estuarine EQS Surface Waters (Dangerous Substances)(Classification) Regulations 1998

H = UK Marine / Estuarine EQS Surface Waters (Dangerous Substances)(Classification) Regulations 1992

J = UK Marine / Estuarine Environmental Quality Standards (EQS) UK EQS

K = UK Soil Guideline Values (SGV)

L = Dutch SRC

M = US EPA Region 9 PRG

N = Corrected DIV

P = US EPA Region 3

Q = Dutch SRC: NB based on Res with Gardens

R = Dutch Indicative Intervention Value

S = Freshwater EQS



#### Table G3 – Stage 2 Assessment – VOCs in Soils

		Statistical Analysis					Number of
Target Compound	Generic Controlled Waters Screening Criteria (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	US95 (mg/kg)	Number Analysed	Samples Exceeding Generic Screen
1,2,4-Trimethylbenzene	0.099	0.009	0.390	0.045	0.108	11	1
Benzene	0.001	0.009	0.022	0.010	0.012	11	11**

\*\* - in exceedance because the method detection limit is higher than the generic controlled waters screening criteria.

#### Table G4 – Stage 2 Assessment – Leachable TPH from Soil

			Stat	Number			
Target Compound	Generic Controlled Waters Screen (µg/l)	Minimum (MDL: 10µg/l)	Maximum (µg/l)	Mean (µg/l)	US95 (µg/l)	Number Analysed	samples exceeding MDL
TPH (>EC10-C12) Aromatic	10	10	990	336.7	1,290.5	5	1
Total Aromatics (C6-C35)	10	10	990	336.7	1,290.5	5	1
(>EC10-12) Aliphatic	10	10	660	226.7	859.3	5	1
Total Aliphatics (C5-C35)	10	10	660	226.7	859.3	5	1
TPH (C5-C35)	10	10	1,600	540.0	2,087.6	5	1

#### Table G5 – Stage 2 Assessment – Groundwater TPH

			Statis	stical Ana	lysis		Number
Target Compound	Generic Controlled Waters Screening Criteria (µg/l)	Minimum (MDL: 10µg/l)	Maximum (µg/l)	Mean (µg/l)	US95 (µg/l)	Number Analysed	samples exceeding MDL
TPH (>EC12-16) Aromatic	10	10	140	36.0	91.4	5	1
TPH (>EC16-21) Aromatic	10	10	100	28.0	66.4	5	1
Total Aromatics (C6-C35)	10	10	250	58.0	160.3	5	1
TPH (>EC12-16) Aliphatic	10	10	14	10.8	12.5	5	1
TPH (>EC16-21) Aliphatic	10	10	37	15.4	26.9	5	1
Total Aliphatics (C5-C35)	10	10	51	18.2	35.7	5	1
TPH (C5-C35)	10	10	300	68.0	191.7	5	1

#### Table G6 – Stage 3 Assessment – Source Zone Model Parameters

	P	arameter Valu	he	Distribution				
Parameter (units)	Min	Most Likely	Max	Used	Comment			
Total Organic Carbon (%)	0.07	0.58	1.0	Triangular	Most likely value taken from a sample from the Made Ground in Plot F. Min value taken from minimum value detected in the silt underlying the Made Ground and the maximum value from the maximum value detected in the unsaturated zone.			
Infiltration rate (mm/year)	80	161	275	Triangular	Based on impervious hardstanding and building structures, as well as the low permeability drift cover. Assumed to vary between 7.5, 15 and 25% of long-term (1970-2000) average rainfall of approximately 1070mm (estimated from Meteorological Office UK Rainfall Maps, retrieved via the internet).			
Air filled porosity (fraction)	0.045	0.11	0.31	Triangular	Adopted range of likely air filled porosities for sandy gravel dominated Made Ground. Min value for clay; most likely value for sandy gravel; and maximum value for gravel).Todd, D.K., 1980. Ground Water Hydrology, 2d ed., New York: Wiley, P. 535.			
Water filled porosity (fraction)	0.02	0.27	0.28	Triangular	Adopted range of likely water filled porosities for silty clay dominated Made Ground. Min value for gravel; most likely value for sandy gravel; and maximum value for clay). Brady, N.C., 1984. The nature and properties of soils. Macmillan Publishing Company, New York, pp. 750.			
Dry bulk density (g/cm <sup>3</sup> )	1.86	-	2.52	Uniform	Calculated from the range in porosities for sandstone provided in the ConSim manual and assuming a solid particle density of 2.65 g/cm3 (Freeze & Cherry, 1979).			

	Para	ameter Va	lue	Distribution	
Parameter (units)	Min L		Max	Used	Comment
Thickness (m) for risks to Deep Groundwater	0	0(4)	0	-(single)	Owing to the limited information regarding the hydraulic conductivity of the Whitehaven Sandstone and the likelihood of vertical contaminant migration being dominated by fracture flow, the unsaturated aquifer was omitted as a potential pathway in some simulations. Where the unsaturated zone was simulated, the thickness is based on measurements of water levels on other areas of the site and levels of bedrock on Plot F.
Dry bulk density (g/cm3)	1.86	-	2.52	Uniform	Calculated from the range in porosities for sandstone provided in the ConSim manual and assuming a solid particle density of 2.65 g/cm3 (Freeze & Cherry, 1979).
Hydraulic conductivity (m/s)	3 x 10 <sup>-9</sup>	6 x 10 <sup>-6</sup>	4.3 x 10 <sup>-5</sup>	Triangular	Minimum and most likely values represent the range of hydraulic conductivities provided for sandstone in ConSim manual. Maximum conductivity taken from the EA aquifer properties database (The Physical Properties of major aquifers in England and Wales, Hydrogeology Group Technical Report WD/97/34, Environment Agency R&D Publication 8) for the St. Bee's Triassic sandstone - assumed surrogate for Carboniferous Whitehaven Sandstones. The high value is low for a major aquifer and demonstrates the high degree of cementation in the strata.
Water filled porosity (fraction)	0.03	0.06	0.09	Triangular	Adopted range of likely water filled porosities for sandy gravel dominated Made Ground. (Min and max values taken as 0.5x and 1.5x the most likely value) Brady, N.C., 1984. The nature and properties of soils. Macmillan Publishing Company, New York, pp. 750.
Vertical dispersivity (m)	-	1e-29 (0.4)	-	Single	The unsaturated aquifer has been omitted as a potential pathway. (where modelled, the vertical dispersivity of the unsaturated zone was modelled as being 1/10 <sup>th</sup> of the unsaturated zone thickness)
Fraction of organic carbon (Percentage)	0.028	0.15	2.2	Triangular	The Whitehaven Sandstone unit forms part of the Carboniferous Coal Measures however it is unlikely to have a FOC content as high as those encountered in the siltstones and mudstones where coal bands are present. Therefore, the following ConSim manual FOC values have been conservatively estimated to represent this unit: (Min taken to be the mean value for permo-triassic sandstone; most likely value taken as the maximum value for permo-triassic sandstone; and the maximum value taken to be the mean value for Carboniferous Coal Measures).

#### Table G7 – Stage 3 Assessment – Unsaturated Zone Model Parameters

	Para	ameter Va	lue				
Parameter (units)	Parameter (units) Most Min Likely Max		Distribution Used	Comment			
Hydraulic conductivity (m/s)	3 x 10 <sup>.9</sup>	6 x 10 <sup>-6</sup>	4.3 x 10 <sup>-5</sup>	Triangular	Minimum and most likely values represent the range of hydraulic conductivities provided for sandstone in ConSim manual. Maximum conductivity taken from the EA aquifer properties database (The Physical Properties of major aquifers in England and Wales, Hydrogeology Group Technical Report WD/97/34, Environment Agency R&D Publication 8) for the St. Bee's Triassic sandstone - assumed surrogate for Carboniferous Whitehaven Sandstones. The high value is low for a major aquifer and demonstrates the high degree of cementation in the strata.		
Hydraulic gradient	0.056	-	-	Single	Interpreted from on-site groundwater contour plot.		
Effective porosity (fraction)	0.05	0.15	0.3	Triangular	In the absence of effective porosity data, range of porosities for sandstone taken from Domenico & Schwartz pg.15 (2nd edition).		
Aquifer Bulk Density (g/cm <sup>3</sup> )	1.86	-	2.52	Uniform	Calculated using sandstone porosity ranging from 5% to 30% (Domenico& Schwartz) and assuming a bulk density of 2.65g/cm3		
Fraction of organic carbon (Percentage)	0.028	0.15	2.2	Triangular	The Whitehaven sandstone unit forms part of the Carboniferous Coal Measures however it is unlikely to have a FOC content as high as those encountered in the siltstones and mudstones were coal bands are present. Therefore the following ConSim manual FOC values have been conservatively estimated to represent this unit: (Min taken to be the mean value for permo-triassic sandstone; most likely value taken as the maximum value for permo-triassic sandstone; and the maximum value taken to be the mean value for Carboniferous Coal Measures).		
Groundwater flow direction (degrees)	250	-	-	Single	Inferred groundwater flow direction based on measured groundwater elevations. (ConSim requirement). A West South-Westerly flow to compliance points 100 and 250m away		
Longitudinal Dispersivity (m)	10 or 25	-	-	Single	Longitudinal Dispersivity (m): Assumed 1/10th travel distance to 100m or 250m receptors (this is the minimum distance between closest part of contaminant source and identified receptor) as defined in ConSim manual.		
Lateral Dispersivity (m)	1 or 2.5	-	3.3 or 8.3	Uniform	Lateral Dispersivity (m):Assumed to range between 1/10 <sup>th</sup> and 1/3 <sup>rd</sup> of travel longitudinal dispersivity (defined in ConSim manual		

#### Table G8 – Stage 3 Assessment – Saturated Zone Model Parameters



	Parameter Value									
Saturated Aquifer Thickness (m)	60	63	65	Triangular	Calculated from the variation in thickness of the Whitehaven Sandstone across the site taken from the geological map and using the dip of the unit (10°) minus the variation in distance between the top of the sandstone unit and the water table within the sandstone.					
Retarded Travel in UZ		NO								
Retarded Travel in Aquifer		YES		Helardalio	on processes are considered to occur in the aquiter but not in the unsaturated zone					
Biodegredation in UZ		NO		Biodegradation processes are considered to occur in the aquifer but not in the unsaturated zone.						
Blodegredation in Aquifer		YES								

Analytical	Contaminant	Partition Coefficient, K <sub>oc</sub> or K <sub>d</sub> (ml/g)		Maximum	ef.	Henry's Law	ef.	Half-life (years)			
Suite	Contaminant			(mg/l)	ä	(unitless)	Я	Minimum	Most Likely	Maximum	Ref.
VOCs	1,2,4-trimethylbenzene	1.35E+03	е	5.70E+01	а	2.52E-01	а	9.5	19	28.5	с
BTEX	Benzene	1.34E+02	а	1.78E+03	d	1.82E-01	d	0.14	1	1.4	d
	AROMATIC										
	TPH (>EC10-12) aromatic	2.51E+03	b	n/a	n/a	1.40E-01	b	4.8	9.5	14.3	с
	TPH (>EC12-16) aromatic	5.01E+03	b	n/a	n/a	5.30E-02	b	9.5	19.0	28.5	с
трц	TPH (>EC16-21) aromatic	1.58E+04	b	n/a	n/a	1.30E-02	b	19.0	38.1	57.1	с
IFN	ALIPHATIC										
	TPH (>EC10-12) aliphatic	2.51E+05	b	n/a	n/a	1.20E+02	b	1.0	1.9	2.8	с
	TPH (>EC12-16) aliphatic	5.01E+06	b	n/a	n/a	5.20E+02	b	1.0	1.9	2.8	С
	TPH (>EC16-21) aliphatic	6.31E+08	b	n/a	n/a	4.90E+03	b	1.9	3.8	5.7	с

#### Table G9 – Stage 3 Assessment – Physical/Chemical Parameters

#### Literature Sources:

- **a** USEPA. 1996. Technical Background Document for Soil Screening Guidance Review Draft.
- **b** Calculated as per TPH Criteria Working Group, Fate and Transport Technical Action Group. 1997. Selection of Representative TPH Fractions Based on Fate and Transport Considerations. Amherst Scientific Publishing.
- c URS-derived conservative degradation rates.
- d Environment Agency (2003). Review of the Fate and Transport of Selected Contaminants in the Soil Environment, Draft Technical Report P5-079/TR1.
- e Calculated from solubility after Kenaga, EE and Goring, CAI. 1980. Relationship between water solubility, soil sorption, octanol-water partitioning, and bioconcentration of chemicals in biota. Special Technical Publication 707. ASTM, Philadelphia, PA.

#### Table G10 – Stage 3 Justification of Soil Source Concentrations

MODELLED RECEPTOR	Compound	Source Concentration mg/kg (soil)			Distribution	Justifications		
		Most Likely	Minimum	Maximum	Used	Input contaminant value	Justification	
100m and	VOCs							
Compliance	1,2,4-Trimethylbenzene	0.009	0.108	0.390	Triangular	-	Based on the statistical analysis of analytical results	
Points within the Whitehaven Sandstone	Benzene	0.022	-	-	Single	0.022	The only detection in the source area.	

 Table G11 – Stage 3 Assessment – Justification of Soil Source Dimensions

MODELLED RECEPTOR	Compound		Most Likely	Min	Max	Distribution Used	Comment
100m and 250m Compliance Points within	Source Thickness (m)	2.75	-	-	Single	Source zone specific- Depth representing the uniform thickness of the Made Ground as measured on site.	
the Whitehaven Sandstone	, in containing ite	Source Area (m <sup>2</sup> )		1200		-	Defined on Plan

#### Table G12 – Stage 3 Assessment – Justification of Soil Leachate Source Concentrations

MODELLED RECEPTOR	Compound	Source Concentration mg/l (leachate)			Distribution	Justifications		
		Most Likely	Minimum	Maximum	Used	Input contaminant value	Justification	
100m and	ТРН							
250m Compliance Points	Leachable TPH (>EC10-12) aliphatic	0.660	-	-	Single	0.660	The only detection in the source area	
within the Whitehaven Sandstone	Leachable TPH (>EC10-12) aromatic	0.990	-	-	Single	0.990	The only detection in the source area	

#### Table G13 – Stage 3 Assessment – Justification of Soil Leachate Source Dimensions

MODELLED RECEPTOR	Compound		Most Likely	Min	Max	Distribution Used	Comment
100m and 250m Compliance	All contominante	Source Thickness (m)	2.75	-		Single	Source zone specific- Depth representing the uniform thickness of the Made Ground as measured on site.
within the Whitehaven Sandstone	Air containinairte	Source Area (m <sup>2</sup> )		1200		-	Defined on Plan

#### Table G14– Stage 3 Assessment –Justification of Shallow Groundwater Source Concentrations

MODELLED RECEPTOR	Compound	Sou m	Source Concentration mg/l (groundwater)			Justifications		
		Most Likely	Minimum	Maximum	Used	Input contaminant value	Justification	
	ТРН							
100m and 250m	Leachable TPH (>EC12-16) aromatic	0.140	-	-	Single	0.140	The only detection in the source area	
Compliance Points within	Leachable TPH (>EC16-21) aromatic	0.100	-	-	Single	0.100	The only detection in the source area	
the Whitehaven	Leachable TPH (>EC12-16) aliphatic	0.014	-	-	Single	0.014	The only detection in the source area	
Sandstone -	Leachable TPH (>EC16-21) aliphatic	0.037	-	-	Single	0.037	The only detection in the source area	

Table G15 – Stage 3 Assessment – Justification of Shallow Groundwater Source Dimensions

MODELLED RECEPTOR	Compound		Most Likely	Min	Max	Distribution Used	Comment
100m and 250m Compliance Points All contaminants within the Whitehaven Sandstone	Source Thickness (m)	2.75	-	2	Single	Source zone specific- Depth representing the uniform thickness of the Made Ground as measured on site.	
	, in containing the	Source Area (m²)		1200		-	Defined on Plan





### Table G16 – Stage 3 Assessment – Soil Source Simulated Receptor Concentrations

MODELLED	Individual Compounds	Stage 2 Controlled Waters Screening Criteria (mg/kg)	Source	SIMULATED TIME FOR 95 <sup>th</sup> PERCENTILE TO EXCEED DWS (years)	Maximum Simulated Concentrations at Receptor			
RECEPTOR	(Soil and Leachate Concentrations)				50th PERCENTILE (mg/l)	95th PERCENTILE (mg/l)		
100m Compliance Point within the Whitehaven Sandstone	1,2,4-Trimethylbenzene	0.099	UK DWS (2000)	N/A	8.6 × 10 <sup>-4</sup>	3.8 x 10 <sup>-3</sup>		
	Benzene	0.001	UK DWS (2000)	N/A	3.1 x 10 <sup>-4</sup>	6.2 x 10 <sup>-4</sup>		
250m Compliance Point within the Whitehaven Sandstone	1,2,4-Trimethylbenzene	0.099	UK DWS (2000)	N/A	3.3 x 10 <sup>-4</sup>	1.4 x 10 <sup>-3</sup>		
	Benzene	0.001	UK DWS (2000)	N/A	5.6 x 10⁻⁵	1.69 x 10 <sup>-4</sup>		
N/A =	Not Applicable, predicted cond	Not Applicable, predicted concentrations do not exceed DWS						

#### Table G17 – Stage 3 Assessment –Soil Leachate Source Simulated Receptor Concentrations

MODELLED	Individual Compounds	Stage 2 Controlled Waters Screening Criteria (mg/l)SourceSIMULATED TIME FOR 95th PERCENTILE TO EXCEED DWS (years)Maxim Concentraliphatic0.01UK DWS (2000)364000.006romatic0.01UK DWS (2000)620.013liphatic0.01UK DWS (2000)620.013liphatic0.01UK DWS (2000)0.0010.001	Source	SIMULATED TIME FOR 95 <sup>th</sup> PERCENTILE TO	Maximum Simulated Concentrations at Receptor	
			50th PERCENTILE (mg/l)	95th PERCENTILE (mg/l)		
100m Compliance Point within the Whitehaven Sandstone	Leachable TPH (>EC10-12) aliphatic	0.01	UK DWS (2000)	36400	0.006	0.012
	Leachable TPH (>EC10-12) aromatic	0.01	UK DWS (2000)	62	0.013	0.034
250m Compliance Point within the Whitehaven Sandstone	Leachable TPH (>EC10-12) aliphatic	0.01	UK DWS (2000)	N/A	0.001	0.003
	Leachable TPH (>EC10-12) aromatic	0.01	UK DWS (2000)	3210	0.005	0.011

N/A = Not Applicable, predicted concentrations do not exceed DWS



## Table G18 – Stage 3 Assessment –Shallow Groundwater Source Simulated Receptor Concentrations

MODELLED	Individual Compounds	Stage 2 Controlled Waters Screening Criteria (mg/l)	Source	SIMULATED TIME FOR 95 <sup>th</sup> PERCENTILE TO EXCEED DWS (years)	Maximum Simulated Concentrations at Receptor	
NEGER ION					50th PERCENTILE (mg/l)	95th PERCENTILE (mg/l)
	Leachable TPH (>EC12-16) aliphatic	0.01	UK DWS (2000)	N/A	2.1 x 10⁻⁵	0.004
100m Compliance Point within	Leachable TPH (>EC16-21) aliphatic	0.01	UK DWS (2000)	N/A	<1 x 10 <sup>-10</sup>	<1 x 10 <sup>-10</sup>
the Whitehaven Sandstone	Leachable TPH (>EC12-16) aromatic	0.01	UK DWS (2000)	30	0.049	0.063
	Leachable TPH (>EC16-21) aromatic	0.01	UK DWS (2000)	133	0.035	0.046
250m Compliance Point within the Whitehaven Sandstone	Leachable TPH (>EC12-16) aliphatic	0.01	UK DWS (2000)	N/A	<1 x 10 <sup>-10</sup>	3.82 x 10 <sup>-4</sup>
	Leachable TPH (>EC16-21) aliphatic	0.01	UK DWS (2000)	N/A	<1 x 10 <sup>-10</sup>	<1 x 10 <sup>-10</sup>
	Leachable TPH (>EC12-16) aromatic	0.01	UK DWS (2000)	143	0.019	0.027
	Leachable TPH (>EC16-21) aromatic	0.01	UK DWS (2000)	512	0.014	0.020
400m Compliance Point within the Whitehaven Sandstone	Leachable TPH (>EC12-16) aliphatic	0.01	UK DWS (2000)	N/A	<1 x 10 <sup>-10</sup>	1.75 x 10 <sup>-4</sup>
	Leachable TPH (>EC16-21) aliphatic	0.01	UK DWS (2000)	N/A	<1 x 10 <sup>-10</sup>	<1 x 10 <sup>-10</sup>
	Leachable TPH (>EC12-16) aromatic	0.01	UK DWS (2000)	472	0.011	0.014
	Leachable TPH (>EC16-21) aromatic	0.01	UK DWS (2000)	7500	0.008	0.011

Not Applicable, predicted concentrations do not exceed DWS



## Table G19 – Stage 3 Assessment –Soil Source Simulated Receptor Concentrations- effect of the unsaturated zone

MODELLED	Individual Compounds (Soil and Leachate Concentrations)	Stage 2 Controlled Waters Screening Criteria (mg/kg)	Source	SIMULATED TIME FOR 95 <sup>th</sup> PERCENTILE TO EXCEED DWS (vears)	Maximum Concentration 50th PERCENTILE (mg/l)	Simulated is at Receptor 95th PERCENTILE (mg/l)
250m Compliance Point within the Whitehaven Sandstone, no unsaturated zone	1,2,4-Trimethylbenzene	0.099	UK DWS -2000	N/A	3.3 x 10 <sup>-4</sup>	1.4 x 10 <sup>-3</sup>
	Benzene	0.001	UK DWS -2000	N/A	5.6 x 10 <sup>-4</sup>	1.69 x 10 <sup>-4</sup>
	Leachable TPH (>EC10-12) aromatic	0.01	UK DWS -2000	3210	0.005	0.011
	Leachable TPH (>EC10-12) aliphatic	0.01	UK DWS -2000	N/A	0.001	0.003
250m Compliance Point within the Whitehaven Sandstone, with unsaturated zone	1,2,4-Trimethylbenzene	0.099	UK DWS -2000	N/A	3.16 x 10 <sup>-4</sup>	1.3 x 10 <sup>-3</sup>
	Benzene	0.001	UK DWS -2000	N/A	1.67 x 10⁻⁵	7.24 x 10 <sup>-5</sup>
	Leachable TPH (>EC10-12) aromatic	0.01	UK DWS -2000	8660	0.004	0.01
	Leachable TPH (>EC10-12) aliphatic	0.01	UK DWS -2000	N/A	<1 x 10 <sup>-5</sup>	0.001
	1,2,4-Trimethylbenzene	0.099	UK DWS -2000	N/A	1.84 x 10 <sup>-4</sup>	6.98 x 10 <sup>-4</sup>
400m Compliance Point within the Whitebayen	Benzene	0.001	UK DWS -2000	N/A	1.58 x 10 <sup>-5</sup>	6.39 x 10 <sup>-5</sup>
Whitenaven Sandstone, no unsaturated zone	Leachable TPH (>EC10-12) aromatic	0.01	UK DWS -2000	N/A	0.002	0.005
	Leachable TPH (>EC10-12) aliphatic	0.01	UK DWS -2000	N/A	4.39 x 10 <sup>-4</sup>	0.001
400m Compliance Point within the Whitehaven Sandstone, with unsaturated zone	1,2,4-Trimethylbenzene	0.099	UK DWS -2000	N/A	1.75 x 10 <sup>-4</sup>	5.97 x 10 <sup>-4</sup>
	Benzene	0.001	UK DWS -2000	N/A	<1 x 10 <sup>-5</sup>	2.42 x 10 <sup>-5</sup>
	Leachable TPH (>EC10-12) aromatic	0.01	UK DWS -2000	N/A	0.002	0.004
	Leachable TPH (>EC10-12) aliphatic	0.01	UK DWS -2000	N/A	<1 x 10 <sup>-5</sup>	5.11 x 10 <sup>-4</sup>