Luton Rising

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London Luton Airport Expansion

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5.02 Appendix 17.4 Detailed Quantitative Risk Assessment - Controlled Waters

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5.02 ENVIRONMENTAL STATEMENT APPENDIX 17.4 DETAILED QUANTITATIVE RISK ASSESSMENT - CONTROLLED WATERS

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1 INTRODUCTION

1.1.1 This Detailed Quantitative Risk Assessment (DQRA) has been undertaken by Luton Rising (a trading name for London Luton Airport Limited) (the applicant) to support the application for development consent for the expansion of Luton airport ('Proposed Development').

1.1.2 The aim of this DQRA report is to quantitatively assess the risks to groundwater in relation to land contamination identified within the Preliminary Risk Assessment (PRA) (**Appendix 17.1**) of the ES (Ref. 1) **[TR020001/APP/5.02]**. It presents a detailed quantitative risk assessment relating to controlled waters for Area A which is a historical landfill. It is intended that this report is read in conjunction with the PRA (**Appendix 17.1**) and GQRA (**Appendix 17.2**) (Ref. 2) of the ES **[TR020001/APP/5.02]**.

1.1.3 The Proposed Development is described in detail in **Chapter 4** of the ES **[TR020001/APP/5.01]**.

1.1.4 This report meets the requirements of a quantitative risk assessment as defined by the Environment Agency's Land Contamination Risk Management Framework (LCRM)[1] (Ref. 3).

1.2 Information sources

1.2.1 Several ground investigations and other reports are available for the site and surrounding area. These were reviewed in detail in the PRA (**Appendix 17.1**) of the ES **[TR020001/APP/5.02]** (Ref. 1). Results of the most recent ground investigation completed in 2018 are presented in the GQRA (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** (Ref. 5). Data from these reports has been used in preparing this assessment.

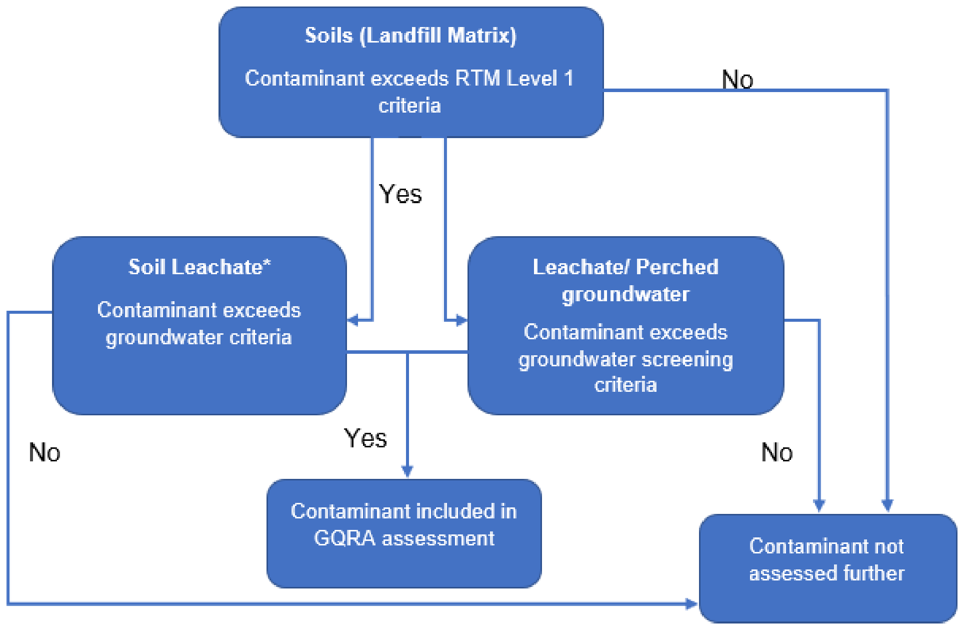
[1] LCRM was published in 2020, updated in April 2021 and replaced "CLR11 Model Procedures for the Management of Contaminated Land" (2004).

2 BASELINE CONTROLLED WATERS DETAILED QUANTITATIVE RISK ASSESSMENT

2.1 Contaminants of concern

2.1.1 A GQRA (Ref. 2) (**Appendix 17.2**) within the ES **[TR020001/APP/5.02]**, was undertaken which assessed the soil (landfill) matrix, soil leachate and leachate concentrations. The key contaminants of concern in the soils (landfill matrix) were selected using the process shown in **Image 2.1**: Process for selecting key contaminants of concern in the soils (landfill matrix) below. This is based on the methodology set out in the Environment Agency's Remedial Targets (RTM) User Manual[2].

Image 2.1: Process for selecting key contaminants of concern in the soils (landfill matrix)[2]



*Due to the nature of the analysis, soil leachate testing is only valid for metals and inorganic contaminants

2.1.2 Groundwater data was screened against appropriate groundwater screening criteria.

2.1.3 The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** undertaken indicated that there were relatively few exceedances of potential contaminants of concern recorded in groundwater beneath the site. Those which did exceed tended to be in boreholes beneath or close to the landfill and were typically in limited in extent. There is limited evidence of any significant contaminant plume migrating down-hydraulic gradient of the landfill.

2.1.4 The assessment of the material in the landfill, its leachability and the landfill leachate indicated there were more exceedances than recorded in the groundwater. The contaminants of concern identified from the GQRA (Ref. 2)

[2] Remedial Targets Methodology Level 1.From the Environment Agency's "Remedial Targets Worksheet v3.1; User Manual" (2006)

(**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** which required further detailed assessment are summarised in **Table 2.1** below.

Table 2.1: Key contaminants of concern in the groundwater and landfill requiring further detailed controlled waters assessment.

Landfill (Soils, Soil leachate and leachate)	Groundwater
Metals and Inorganics	
Antimony	Manganese
Arsenic	Ammoniacal nitrogen
Barium	Nitrate
Boron	Boron
Thiocyanate	Nickel
Iron	Iron
Manganese	
Ammoniacal nitrogen	
Nickel	
Petroleum hydrocarbons, PAHs, Phenols, VOCs and SVOCs, and PFAS	
Benzene	Trichloroethene (TCE)
Aromatic TPH C12-C16	Vinyl chloride
Aliphatic C12-C16	1,2-dichloroethane
Aliphatic C16-C21	Fluoranthene
Aliphatic C21-C35	
Aromatic C16-C21	
Aromatic C21-C35	
Xylene	
Benzo(a)pyrene	
Naphthalene	
Fluoranthene	
Anthracene	
1,2,4-trimethylbenzene	
Pesticides	
Mecoprop	Diuron
	Mecoprop

2.1.5 Concentrations of perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) have been recorded above the laboratory limit of detection in a number of groundwater samples at the site. Both PFOS and PFOA are two of the most abundant substances of a group of contaminants known collectively as poly and perfluoroalkyl substances (PFAS).

2.1.6 The highest concentrations of PFAS recorded are in groundwater wells which are located close to the airport's fire training facility. It is understood that the airport does not now use fire-fighting foams which contain PFAS and therefore the presence of PFAS in groundwater is a result of historic use of fire-fighting foams at the airport, the landfill and from other industrial sites across the wider Luton area.

2.1.7 Whilst PFAS has been observed to exceed guidance values, the use of the DWI guidance values is conservative when applied to an aquifer body. Therefore, at this stage, PFAS have not been assessed as part of this DQRA.

2.1.8 There is work ongoing by the Environment Agency to understand the risks and develop pragmatic approaches to PFAS assessment. Whilst the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** concludes that the risk with respect to PFAS is low at the development site, PFAS should be considered contaminants of concern until the guidance is available and further assessment may be required at detailed design stage.

2.2 Identified potential contaminant linkages (PCLs) requiring further assessment

2.2.1 The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** identified that the controlled waters PCLs shown in **Table 2.2** and **Figure 1** of this document required further DQRA. **Table 2.3** below includes the PCLs which were assessed in the GQRA (Ref. 2) as not requiring further detailed assessment, but measures were required to be included in the Outline Remediation Strategy (ORS) (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

2.2.2 It has been indicated within **Table 2.2** below whether the PCLs apply either:

- during excavation, remediation and construction phase; or
- future use of Proposed Development

2.2.3 In addition, the PCLs have been classified as follows:

	Confirmed relevant contaminant linkage (RCL) and requires inclusion in the ORD
	PCL requires further consideration through Detailed Quantitative Risk Assessment (DQRA)
	Impact is possible but can be mitigated by design and/or managed under an alternative regime such as permitted operation or occupational safety. Measure should be included in the ORS.
	Impact ruled out no further assessment required

Table 2.2: Controlled waters PCLs requiring DQRA.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative assessment of risk	Justification of Qualitative Assessment of Risk
23	DEV	Leachate in former landfill[3]	Downward migration of leachate	Principal aquifer in Chalk	Moderate/ Low	Further detailed risk assessment is required to inform the risks from this PCL.
40	DEV	Contaminants in groundwater (dissolved phase)	Lateral migration of contaminants in groundwater	Controlled waters (including potable water groundwater abstraction and nearby private water supply abstractions)	Moderate	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated that there were relatively few exceedances of potential contaminants of concern recorded in groundwater beneath the site. Those which did exceed tended to be in boreholes beneath or close to the landfill and were typically localised. There is limited evidence of any significant contaminant plume migrating down-hydraulic gradient of the landfill. Cautiously assessed as a moderate risk. Further DQRA is required to confirm risks.
KEY: CON- PCL during excavation, remediation and construction phase DEV- PCL associated with future use of Proposed Development						

[3] The source of the leachate in assumed to be the landfill waste material

Table 2.3: PCLs which do not require further assessment but required further consideration in the ORS.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative assessment of risk	Justification of Qualitative Assessment of Risk
17	CON	Waste in former landfill	Driving of contaminants downward during any future piling	Principal aquifer in Chalk	Moderate	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** has indicated that there are isolated instances of contaminants present and a localised area of free product which was encountered at location WS224. Care will be required during construction not to create a pathway. This may involve removal of localised hotspots in locations where works may create a pathway. Incorporation of removal at select locations was included in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]** for the site to reduce potential for pathway creation. Risk from piling and construction can be mitigated by completion of a foundation works risk assessment report to determine appropriate assessment for pile design and construction.
26	CON	Contaminants in perched water in former landfill	Driving of contaminants downward during any future piling	Principal aquifer in Chalk	Low	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated that perched water was present in some locations within the landfill. The GQRA indicated that there are isolated hotspots of contaminants present and a localised area of free product. Care will be required during construction to not to create a pathway. This may involve localised removal of hotspots at key locations. The risks from piling and construction can be mitigated by completion

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative assessment of risk	Justification of Qualitative Assessment of Risk
						of a foundation works risk assessment report to determine appropriate assessment for pile design and construction.
27	CON	Contaminants in perched water in landfill	Migration of contaminants via preferential pathways e.g. drainage	Principal aquifer in Chalk	Moderate	A survey and assessment of the purpose of drainage passing through the landfill is to be undertaken and incorporated into the design proposals. Measures are to be incorporated into the design to prevent the creation of preferential pathways.
39	CON	Contaminants in Made Ground (car park, capping material)	Balancing pond	Principal aquifer in Chalk	Very Low	The Thames Water balancing pond present in the north of the former landfill area will remain in place during the proposed development. Appropriate site management and construction techniques will be required during the development construction process in the vicinity of the current pond to reduce the risk.
KEY: CON- PCL during excavation, remediation and construction phase DEV- PCL associated with future use of Proposed Development						

3 BACKGROUND TO ASSESSMENT

3.1 Summary of the hydrogeological regime

3.1.1 The hydrogeological regime is discussed in detail in the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** and a detailed review of the hydrogeological conditions beneath the site has been undertaken and is provided in the following report:

a. Luton Rising (2022) Hydrogeological Characterisation Report (**Appendix 20.3**) of the ES **[TR020001/APP/5.02]**. LLADCO-3B-ARP-00-00-RP-CG-0001 (Ref. 5).

3.1.2 Key points of relevance to the transport of potential contaminants and chemical quality of groundwater in the Chalk are:

a. The groundwater levels beneath the landfill are typically 112m AOD (40m bgl) and range between 17.5m to 36m below the base of the landfill. Therefore, under normal groundwater level conditions there is usually a significant unsaturated zone;
b. The hydrogeological report concluded that the maximum groundwater levels are expected to range from 134m AOD in the centre of the groundwater divide, west of the landfill, to 116m AOD in the east of the proposed development area. This was predicted to be a 1 in 100-year event and under these extreme conditions the groundwater could be within 5-10m of the base of the landfill;
c. The Proposed Development will also include new drainage systems to manage surface water and discharge to groundwater (after treatment) via a combination of two infiltration basins. The effect of the new infiltration basins on groundwater levels is considered within the hydrogeological report (Ref. 5). The new drainage and treatment system provide a significant improvement on the current system at the airport. The quality of the discharge to groundwater from the infiltration basins is being addressed in a separate document to support the Environmental Permit application;
d. The permeability of the Chalk is principally controlled by fractures, which are both horizontal and vertical. The frequency of fractures is generally thought to peak at about 20m bgl; productive fractures decrease with depth. It is generally accepted that productive fractures are restricted to the upper few tens of meters of the aquifer (circa 50m). Packer tests undertaken on the chalk underneath the landfill supported this. Flow of groundwater in the factures is difficult to predict;
e. Solution features are common in the top of the chalk and are infilled with material with higher permeability. They may increase the vertical transport of infiltration into the body of the chalk;
f. The hydraulic regime is further complicated by the weathered top of the chalk, which is often referred to as ‘putty chalk’, where the chalk is structureless and forms a clayey silt. This material can have significantly lower hydraulic conductivity reducing the transmissivity of the aquifer.

The travel time within the putty chalk horizon is estimated to be between 2-15 times slower than in the main Chalk;

g. In addition, there are localised layers of Clay-with-Flints and other lower permeability layers of such as Head deposits which will impede the leaching of contaminants from the landfill through the unsaturated zone; and
h. Published information indicates that there is contamination of the Chalk aquifer in the vicinity of Luton by chlorinated solvents (Ref. 6) This report also indicates that a wide variety of contaminants including nitrate, ammonia, pesticides, bromate, hydrocarbons and solvents have been detected in the Chalk between the River Colne and the River Lea.

3.2 Adequacy of data

3.2.1 As discussed in **Section 9.3** of the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**, preliminary and detailed ground investigations (GIs) have been undertaken within the landfill area. The sampling locations have a good spatial, lateral and vertical distribution, encompassing all the main eras of waste deposition. An appropriate number of soil (1,219 samples), groundwater and leachate (328 tests) and gas/VOC samples (96 tests) have been undertaken and analysed to industry standards. Therefore, there is a comprehensive and robust data set which provides adequate characterisation of the landfill to inform the risk assessment.

3.2.2 The groundwater data collected from both the preliminary and detailed GIs included:

a. Samples obtained using low flow micro-purging and sampling techniques to obtain samples which are, as far as possible, representative of the chalk aquifer and minimise disturbance to the water column. The samples were tested for a range of contaminants including metals, volatile organic compounds (VOCs), total petroleum hydrocarbons (TPHs), polyaromatic hydrocarbons (PAHs), pesticides, phenols, polychlorinated biphenyls (PCBs) and volatile fatty acids (VFAs);
b. Data loggers were installed in three groundwater boreholes (GW201, GW204 and GW207A) which measured the groundwater level at five-minute intervals. The data was collected between October 2018 to March 2019;
c. In parallel to the detailed GI a 12-month period of monthly groundwater and gas monitoring was undertaken across the network of boreholes established during the preliminary ground investigations;
d. Monthly monitoring for groundwater levels and samples taken at 17 groundwater quality monitoring points (GQMP); and
e. Monitoring of leachate thicknesses and sampling every 2 months at 4 leachate monitoring wells.

3.3 Methodology

Level of complexity

3.3.1 The assessment has been undertaken consistent with the principles described in **Section 9.2** of the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**. The following assumptions have been considered for the initial DQRA assessment:

a. The GQRA identified no significant variation in the chemistry and that there are no obvious accumulations of contamination within the landfill which need to be considered as a separate source. This is based on the comprehensive dataset collected as part of the preliminary and detailed GIs as described in **Section 3.2.1** above;

b. As detailed above, no obvious accumulations of contamination were noted in the analysis of the chemistry. However, the landfill was operated during a period where there were no controls on disposal and is heterogenous in nature. Given the high variability in the material, a reasonable worst-case has been assumed for the groundwater concentrations. Good characterisation of the groundwater has been undertaken but as groundwater concentrations vary temporally and spatially a conservative approach has been taken in the modelling (see **Table 2.3** above);

c. The Chalk beneath the landfill has assumed to have fracture flow occurring and no superficial or weathered Chalk of lower permeability present; and

d. The most direct flow path to the receptors has been assumed.

3.3.2 Further specific assumptions relating to the hydrogeological modelling are described in **Table 3.1** below. If the initial assessment indicates a significant risk the modelling will be further refined to represent a greater degree of complexity.

3.4 Modelling approach

3.4.1 ConSim (Ref. 7) has been used for undertaking a Detailed Quantitative Risk Assessment (DQRA) of the risks from soils and groundwater, as outlined in the following sections.

3.4.2 ConSim version 2.5 has been used to model the site conditions for the contaminants of concern. ConSim is a software package that was designed to provide a means of assessing the risk posed to groundwater by leaching of contaminants from contaminated land. ConSim was developed in conjunction with and is endorsed by the Environment Agency.

3.4.3 ConSim is considered the most suitable modelling software to use as it allows multiple contaminants and multiple receptors to be assessed simultaneously and enables an assessment of the risk posed by existing contamination levels at each receptor to be defined. It models contaminant mobilisation and transport and allows the incorporation of available site investigation data.

3.4.4 ConSim deals with uncertainty by using a probabilistic method of modelling known as the Monte Carlo method. In this method, the calculations are carried out many times, with a different parameter value randomly selected from the input range of values each time. The input range of values for each parameter can be entered as a probability density function. The choice of probability density function depends on how much data is available and the quality of the data.

3.4.5 ConSim then calculates the probability of contaminants reaching a designated receptor. Level 1, 2 and 3 ConSim models quantify the risk posed by elevated concentrations within the soil to a controlled water receptor; the Level 3a ConSim model quantifies the risk posed by elevated groundwater concentrations to a controlled water receptor.

3.4.6 A Level 3 assessment has been undertaken on the key contaminants of concern in the soils (landfill matrix) identified from the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**. The Level 3 assessment allows concentrations of each contaminant of concern in soil to be modelled at compliance points downgradient in the aquifer. There is the option in the Level 3 assessment to enter 'measured leachate concentrations' and therefore either the soil leachate or measured leachate concentration have been used in the modelling.

3.4.7 The Level 3 assessment considers both the current state of the landfill and the proposed development where infiltration through the landfill waste will be minimal due being covered by buildings and hardstanding.

3.4.8 Following the Level 3 assessment contaminants which have been identified as potentially posing a risk to controlled waters have been assessed further in a Level 3a assessment. In addition, any contaminants identified from the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** as contaminants of concern (see **Table 2.1**) in the groundwater have also been modelled.

3.4.9 The following receptor points have been modelled in Consim (locations shown on **Figure 2** of this document):

a. The Affinity water potable groundwater abstraction 2.8km northeast of the landfill (1.5km northeast of the Main Application Site);
b. BH55 located 150m from the boundary of the landfill. This borehole is located downgradient of the groundwater flow path towards the potable abstraction; and
c. Compliance point 50m from the boundary of the landfill. This is consistent with compliance point for resource protection detailed in the Environment Agency guidance on compliance points.

3.4.10 The second potable abstraction at Whitwell has not been identified as a receptor due to its greater distance from the landfill (approximately 5.3km), any impacts would be likely observed at King's Walden first given the shorter travel time.

3.4.11 Private water supply abstractions have been identified over 2km to the southeast of the landfill. As this is opposite to the predominant groundwater flow direction, it is considered that use of the above receptors will be protective of the private water supplies.

Input parameters

3.4.12 The main hydrogeological model input parameters are provided in **Table 3.1** below. The following assumptions have been made as part of the ConSim (Ref. 7) model:

a. Groundwater flow is assumed to occur towards the groundwater abstraction (northeast) in the Chalk aquifer and that the thickness of the aquifer is constant throughout the flow path;
b. Retardation in both the unsaturated and saturated zone have only been modelled in the dissolved phase;
c. The whole landfill site is assumed to be a source of contamination. The boundaries have been set at the area which has been known to be infilled, which is smaller than the boundary indicated by Environment Agency records;
d. No dual porosity is assumed in the unsaturated zone;
e. No biodegradation is assumed;
f. Background groundwater concentrations have been assumed to be zero;
g. 1,001 iterations of the simulation have been applied;
h. Time slices varying from 10-7000 years have been modelled;
i. Mixing zone thickness is calculated in ConSim. ConSim estimates this from the source length, the aquifer properties and infiltration rate.

Table 3.1: Hydrogeological model input parameters

Parameter	Value	Units	Data Source
Source properties - Landfill			
Dry bulk density	1.2	g/cm^3	Value for sandy clay loam, listed in **Table 4.4** of the CLEA Report (Ref. 8).
Air filled soil porosity	0.16	fraction	Value for sandy clay loam, listed in **Table 4.4** of the CLEA Report (Ref. 8).
Water filled soil porosity	0.37	fraction	Value for sandy clay loam, listed in **Table 4.4** of the CLEA Report (Ref. 8).
Source thickness	20.5	m	Maximum thickness of Made Ground in the landfill.
Fraction of organic carbon (foc)	5.2	%	Average site data (0.07 to 60.4).

Parameter	Value	Units	Data Source
Source term- concentrations			
Soils (landfill matrix)	Log-triangular distribution		Soil leachate or leachate/perched leachate concentration. Source input concentrations provided in **Appendix A** of this document.
Groundwater	Single point		Reasonable worst case of maximum concentration in groundwater assumed to account for temporal and spatial variability. Source input concentrations provided in **Appendix A** of this document.
Aquifer properties			
Saturated aquifer thickness	5.0	m	Assumed saturated thickness for the Chalk. This is considered to be conservative value.
Unsaturated aquifer thickness	17.5	m	Groundwater monitoring indicates range of thickness of unsaturated zone beneath base of landfill of 17.5-36 m. Seasonal groundwater variation between 5-10 m was recorded during the monitoring. Therefore, as a conservative assumption the unsaturated aquifer thickness is assumed to be 17.5 m1.
Mixing zone thickness	-	m	Calculated in model.
Dry bulk density of aquifer materials	1.55	g/cm^3	Average site data for Chalk (range of 1.23 mg/m^3 to 2.26 mg/m^3)
Effective matrix porosity of aquifer	0.30	fraction	**Table 4.7** of CIRIA C574 (Ref. 9), Engineering Properties of Chalk.
Effective porosity of fissures	0.10	fraction	Assumed to be lower than matrix, due to fracture permeability in the Chalk.
Fraction of organic carbon in aquifer (foc)	0.00027-0.00036	%	Only one sample available for the Chalk, therefore range of literature values from ConSim manual used instead of 0.00027-0.00036.
Hydraulic conductivity of aquifer in which dilution occurs	2.4x10-5	m/s	Average site data from packer tests in the upper Chalk where predominant groundwater flow path is anticipated. Mean hydraulic conductivity for top 20 m of Chalk used which allows for fracture flow (Ref. 5).
Groundwater flow			
Infiltration – current state	611	mm/yr	Long term average rainfall (1961-1990) for Lee-Chalk (Ref. 10)

Parameter	Value	Units	Data Source
Infiltration – Proposed Development	61.1	mm/yr	The Proposed Development will cover the landfill in buildings and hardstanding areas. Current proposals include public realm areas of roughly 3ha on the area of the landfill. The total size of landfill is approx. 40ha. Conservative assumption for modelling is that all public realm is soft landscaping will allow infiltration. A rate of 10% of infiltration has been assumed.
Hydraulic gradient of water table	0.004	fraction	Calculated from contour plan of maximum measured groundwater concentration1. Full contours for area between landfill and abstraction point area unknown. Therefore, a line through the flow path from the landfill has been taken in the direction of abstraction. This indicated 5 m fall over 1083 m.
Receptor: Potable abstraction (Affinity Water)			
Assumed path length	2800	m	Distance from landfill boundary to Affinity Water potable abstraction receptor (used in dispersivity calculations below).
Vertical dispersivity	2.8	m	0.001 of path length.
Longitudinal dispersivity	280	m	0.1 of path length.
Lateral dispersivity	28	m	0.01 of path length.
Groundwater flow direction	65	degrees	Directly to the nearest potable groundwater abstraction (located to northeast).
Receptor: BH55 – 150m from boundary			
Assumed path length	150	m	Distance from landfill boundary to BH55.
Vertical dispersivity	0.15	m	0.001 of path length.
Longitudinal dispersivity	15	m	0.1 of path length.
Lateral dispersivity	1.5	m	0.01 of path length.
Groundwater flow direction	65	degrees	Flowpath towards nearest potable abstraction.
Receptor: Compliance Point – 50m			
Assumed path length	50	m	Distance from landfill boundary to 50 m compliance point.

Parameter	Value	Units	Data Source
Vertical dispersivity	0.05	m	0.001 of path length.
Longitudinal dispersivity	5	m	0.1 of path length.
Lateral dispersivity	0.5	m	0.01 of path length.
Groundwater flow direction	65	degrees	Flowpath towards nearest potable abstraction.
Notes: 1 Parameter taken from Hydrogeological Characterisation report (Ref. 5) (**Appendix 20.3**) of the ES **[TR020001/APP/5.02]**.			

3.5 Criteria for determining significance

3.5.1 A line of evidence approach has been used when determining the significance of the results. The following criteria have been used:

a. contaminants reaching a receptor within a 1,000-year retarded travel time at concentrations exceeding the assessment criteria has been considered as the threshold for determining whether the contaminant is of concern. This is considered a very conservative assumption as most contaminants will have degraded or been attenuated before 1,000 years;

b. presence of the contaminant in landfill material/soils, leachate and groundwater suggesting a source within the landfill;

c. contaminant is considered of concern if there is evidence of measured concentrations occurring above assessment criteria at modelled compliance points based on the predicted ConSim travel times; and

d. the magnitude, consistency, and frequency of exceedances in the groundwater has been considered when defining their significance. This is consistent with Environment Agency guidance on defining trivial exceedances (Ref. 11). Infrequent, random spikes in groundwater concentrations which are within an order of magnitude of the assessment criteria and are not consistently detected are not considered significant.

4 RESULTS

4.1.1 The ConSim model has been developed for the identified contaminants of concern to calculate predicted contaminant concentrations following advective and dispersive transport, attenuation, and degradation at each receptor/compliance point for both the site in its current condition and for the Proposed Development.

4.2 Current condition

Level 3 assessment – soils (landfill matrix)

4.2.1 The Level 3 assessment determines the concentration of contaminants entering the water table (at the base of the unsaturated zone) from the landfill (either as soil leachate or landfill leachate) and predicts the concentrations of contaminants at the receptors through migration in the groundwater. The outputs of the Level 3 ConSim assessment based on the current condition of the landfill are presented in **Table 4.1** to **Table 4.3** below.

4.2.2 The results predict the following contaminants to break through the base of the unsaturated zone within 1,000 years and reach at least one of the receptors:

a. boron;
b. ammoniacal nitrogen;
c. benzene;
d. xylene;
e. anthracene;
f. benzo(a)pyrene;
g. aromatic TPHs;
h. 1,2,4-trimethylbenzene; and
i. mecoprop.

4.2.3 The modelling results suggest that these contaminants should be present within the groundwater beneath the landfill. However, the following is noted:

Benzene, xylene and trimethylbenzene

a. The predicted travel times for benzene, xylene and trimethylbenzene are rapid (approximately 10-11 years to reach BH55) and therefore would be expected to be observed in groundwater. However, benzene, xylene and trimethylbenzene have not been observed above the limit of detection (LOD) in groundwater beneath, or downgradient, of the. Exceedances of these contaminants are isolated within the landfill leachate. **Figure 2** shows the exceedances of these contaminants within the landfill leachate and perched water overlaid on the groundwater concentration contours.

b. The highest concentrations of these contaminants were detected within the perched water at WS224. Other locations marginally exceed the assessment criteria and were within an order of magnitude. Borehole descriptions for WS224 noted a heavy black staining between 4-5m bgl, suggesting the presence of localised product (see **Section 10.2.8** of the GQRA (Ref.2) (**Appendix 17.2**) in the ES **[TR020001/APP/5.02]**). WS224 is located close to the area where landfill is to be excavated to enable the construction of the aviation platform. It was therefore recommended in the GQRA that the free product at this location should be removed as part of the works. Any perched water in the material will also be removed during these works (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**.

c. The presence of these contaminants in the landfill leachate and perched water suggests that whilst present in the landfill, they are not impacting groundwater either because they are being attenuated in the unsaturated zone, or adsorbed to organic material within the landfill. Due to this the landfill is not considered a significant source for these contaminants and further consideration of benzene, xylene and trimethylbenzene is not required.

Anthracene and benzo(a)pyrene

a. Concentrations of anthracene and benzo(a)pyrene in groundwater beneath the landfill have remained consistently below the limit of detection and have only been marginally above the detection limit on two occasions. Neither of these contaminants have been detected in the groundwater downgradient of the landfill above the limit of detection. The detections beneath the landfill were noted in different locations on individual monitoring rounds and were below groundwater assessment criteria.

b. The modelling predicted that anthracene and benzo(a)pyrene would take 138 and 590 years respectively to reach BH55 (150m downgradient of the landfill). These contaminants were not predicted to reach the groundwater abstraction within 1,000 years. This suggests that these contaminants are not particularly mobile in groundwater. This is supported by CL:AIRE guidance (Ref. 12) which indicates overall mobility of anthracene and benzo(a)pyrene in groundwater is low and very low respectively. In addition, organic contaminants such as anthracene and benzo(a)pyrene tend to sorb to organic material, as such are probably strongly bound to organic material within the landfill matrix.

c. Significant monitoring has been undertaken and these contaminants have not been detected consistently beneath the landfill and have not been detected downgradient. The detections have been observed as intermittent which suggests there is not a significant source of these contaminants which poses a risk to controlled waters. This is consistent with Environment Agency guidance on defining trivial exceedances (Ref. 11). Due to no significant source and low mobility in groundwater, further consideration of these contaminants is not required.

Aromatic TPHs

a. Aromatic TPHs were detected at elevated concentrations within the landfill leachate at several locations (see Figure 2 of this document). The fractions detected were TPH aromatic C12-16, C16-21 and C21-35. The travel times predicted that TPH aromatic C12-16, C16-21 and C21-35 would reach borehole BH55 (150m from landfill boundary) within 40, 82 and 576 years respectively. Based on the predicted travels times it would be expected that TPH aromatic C12-16 and C16-21 would be detected within the groundwater. However, no exceedances for TPH fractions have been observed below the landfill or downgradient (see **Figure 2** of this document). **Figure 2** shows the exceedances of these contaminants within the landfill leachate and perched water overlaid on the groundwater concentration contours.

b. These compounds are known to have a relatively low mobility in groundwater (Ref. 12). Whilst these contaminants are present in the landfill, they are not reaching the groundwater either because they are being attenuated in the unsaturated zone or absorbed to organic material within the landfill and as such does not pose a risk to controlled waters. Therefore, further consideration of these contaminants is not required.

Table 4.1: Output from Level 3 soils assessment for current landfill for potable abstraction (Affinity Water) receptor.

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
Antimony	0.005	0.11	0	7,256	-	-
Arsenic	0.01	0.01	0	14,444	-	-
Barium	0.7	1.2	0	3,242	-	-
Boron	1	6.5	6.5	251	2.15	819
Iron	0.2	11.6	0	6,360	-	-
Manganese	0.05	2.02	0	1,452	-	-
Nickel	0.02	0.06	0	14,444	-	-
Ammoniacal nitrogen	0.39	19.4	19.4	8.9	11.8	21.9
Thiocyanate	0.05	0.4	0	36,357	-	-
Benzene	0.001	0.0021	0.0021	8.9	0.0014	26.6
Xylene	0.03	0.031	0.031	8.9	0.02	54.2
Anthracene	0.0001	0.13	0.131	11.1	-	-
Fluoranthene	0.0000063	0.52	0	525,369	-	-
Benzo(a)pyrene	0.00001	0.12	0.12	18.94	-	-

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
TPH Ali C12-C16	0.3	0.82	0.78	399.6	-	-
TPH Ali C16-C21	0.3	3.52	0	31,042	-	-
TPH Ali C21-C35	0.3	19.6	0	31,042	-	-
TPH Aro C12-C16	0.09	0.45	0.45	9.4	0.26	480.3
TPH Aro C16-C21	0.09	1.28	1.28	10.1	-	-
TPH Aro C21-C35	0.09	4.14	4.14	18.7	-	-
1,2,4-trimethylbenzene	0.001	0.77	0.77	9.23	0.47	331.8
Mecoprop	0.0001	0.0028	0.0028	9.01	0.0017	119.7

Note:

Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value

Table 4.2: Output from Level 3 soils assessment for current landfill for BH55 – 150 m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
Antimony	0.005	0.11	0	8,613	-	-
Arsenic	0.01	0.021	0	17,146	-	-
Barium	0.7	1.3	0	3,849	-	-
Boron	1	7.8	7.8	298	7.28	333
Iron	0.2	9.60	0	7,550	-	-
Manganese	0.05	1.70	0	1,724	-	-
Nickel	0.02	0.07	0	17,146	-	-
Ammoniacal nitrogen	0.39	79.6	79.6	10.6	75.2	11.4
Thiocyanate	0.05	0.36	0	43,159	-	-
Benzene	0.001	0.0021	0.0021	10.6	0.0020	12
Xylene	0.03	0.034	0.034	10.6	0.031	13
Anthracene	0.0001	0.30	0.30	13.2	0.28	138
Fluoranthene	0.0000063	0.39	0	623,733	-	-
Benzo(a)pyrene	0.00001	0.08	0.08	22	0.0038	590
TPH Ali C12-C16	0.3	0.76	0.76	474	-	-

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
TPH Ali C16-C21	0.3	3.05	0	36,849	-	-
TPH Ali C21-C35	0.3	17.44	0	36,849	-	-
TPH Aro C12-C16	0.09	0.44	0.44	11.2	0.423	40
TPH Aro C16-C21	0.09	1.39	1.39	12.0	1.24	82
TPH Aro C21-C35	0.09	3.79	3.79	22.2	0.43	576
1,2,4-trimethylbenzene	0.001	0.66	0.66	11.0	0.63	30
Mecoprop	0.0001	0.00	0.0028	10.7	0.0026	17

Note:
Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value.

Table 4.3: Output from Level 3 soils assessment for current landfill for compliance point – 50 m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
Antimony	0.005	0.11	0	8,613	-	-
Arsenic	0.01	0.02	0	17,146	-	-
Barium	0.7	1.25	0	3,849	-	-
Boron	1	7.29	7.29	298	6.9	316
Iron	0.2	10.4	0	7,550	-	-
Manganese	0.05	2.09	0	1,724	-	-
Nickel	0.02	0.06	0	17,146	-	-
Ammoniacal nitrogen	0.39	91.01	91.01	11	85.3	11
Thiocyanate	0.05	0.36	0	43,159	-	-
Benzene	0.001	0.0021	0.0021	11	0.002	11
Xylene	0.03	0.031	0.031	10.6	0.030	12
Anthracene	0.0001	0.43	0.43	13	0.41	77
Fluoranthene	0.0000063	0.42	0	623,652	-	-

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
Benzo(a)pyrene	0.00001	0.098	0.098	23	0.024	312
TPH Ali C12-C16	0.3	0.58	0.58	474	-	-
TPH Ali C16-C21	0.3	3.52	0	36,848	-	-
TPH Ali C21-C35	0.3	18.6	0	36,848	-	-
TPH Aro C12-C16	0.09	0.45	0.45	11	0.427	25.7
TPH Aro C16-C21	0.09	1.28	1.28	12	1.21	48
TPH Aro C21-C35	0.09	4.06	4.06	22	1.35	305
1,2,4-trimethylbenzene	0.001	0.77	0.77	11	0.72	21
Mecoprop	0.0001	0.0028	0.0028	11	0.003	14

Note:
Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value.

Level 3a assessment – groundwater

4.2.4 Frequent detections of boron, ammoniacal nitrogen and mecoprop above the detection limit have been observed in groundwater directly beneath the landfill. Therefore, these contaminants require further consideration. The presence of these contaminants in the groundwater is assessed further in the Level 3a assessment detailed in this Section. The significance of these exceedances is discussed further in **Section 6** below**.**

4.2.5 The Level 3a ConSim model quantifies the risk posed by elevated groundwater concentrations to a controlled water receptor. The contaminants identified as exceeding assessment criteria in the groundwater sampled from beneath the landfill in the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** (see **Section 2** of this document) were included in the Level 3a assessment and the contaminants identified as requiring further assessment from the Level 3 assessment (boron, ammoniacal nitrogen and mecoprop).

4.2.6 The outputs of the Level 3a ConSim assessment are presented in **Table 4.4**: Output from Level 3a groundwater assessment. below. The source concentrations and physiochemical parameters used in the modelling are presented in **Appendix A** of this document.

4.2.7 The following contaminants are predicted to reach the 50m compliance point above the assessment criteria within 1,000 years:

a. ammoniacal nitrogen;
b. trichloroethene;
c. nitrate;
d. vinyl chloride; and
e. boron.

4.2.8 Ammoniacal nitrogen, nitrate, boron and vinyl chloride are predicted to reach BH55 (150m) compliance point within 1,000 years. The significance of these exceedances is discussed further in **Section 6** below**.**

4.2.9 Only nitrate was predicted to reach the potable abstraction receptor within 1,000 years above the groundwater guideline value.

Table 4.4: Output from Level 3a groundwater assessment.

Contaminant	Guideline value (mg/l)	Retarded travel time to receptor (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)
Potable abstraction (Affinity Water)			
Manganese	0.05	69531	5.96x10-16
Ammoniacal nitrogen	0.39	961	1.77x10-6

Contaminant	Guideline value (mg/l)	Retarded travel time to receptor (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)
Nitrate	50	325	65.4
Trichloroethene	0.01	269	1.65x10-11
1,2-dichloroethane	0.003	268	2.69x10-21
Vinyl chloride	0.0005	268	2.52x10-8
Mecoprop	0.0001	274	3.04x10-22
Diuron	0.0001	270	1.05x10-22
Boron	1	14121	1.90x10-11
Iron	0.2	305024	0
Nickel	0.02	692896	0
Fluoranthene	0.0000063	25000000	0
BH55 – 150 m from landfill boundary			
Manganese	0.05	4067	3.59x10-6
Ammoniacal nitrogen	0.39	56	0.844
Nitrate	50	16	88.3
Trichloroethene	0.01	16	0.0038
1,2-dichloroethane	0.003	16	1.96x10-6
Vinyl chloride	0.0005	16	0.00157
Mecoprop	0.0001	16	2.22x10-7
Diuron	0.0001	16	7.65x10-8
Boron	1	826	2.25
Iron	0.2	17841	2.18x10-12
Nickel	0.02	40528	7.15x10-16
Fluoranthene	0.0000063	1470000	0
Compliance Point – 50 m from landfill boundary			
Manganese	0.05	1536	0.05
Ammoniacal nitrogen	0.39	21	2.67
Nitrate	50	6	88.3

Contaminant	Guideline value (mg/l)	Retarded travel time to receptor (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)
Trichloroethene	0.01	6	0.028
1,2-dichloroethane	0.003	6	0.00014
Vinyl chloride	0.0005	6	0.0039
Mecoprop	0.0001	6	0.000015
Diuron	0.0001	6	5.48x10-6
Boron	1	312	4.05
Iron	0.2	6738	1.14x10-11
Nickel	0.02	15306	1.15x10-13
Fluoranthene	0.0000063	556853	0
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value			

4.3 Influence of the Proposed Development

Earthworks

4.3.1 As detailed in the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**, there will be significant earthworks required to create the development platform. These earthworks will involve the excavation of approximately 350,000m^3 of landfill material. The excavation work to the landfill will be undertaken in a manner as such that the potential impacts are controlled and minimised. These control measures are detailed in the Remediation Strategy (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. This will include consideration of relevant criteria for reuse of materials based on the findings of this DQRA.

Development

4.3.2 The Proposed Development will result in the construction of buildings and hardstanding areas across the entire footprint of the landfill site. Minimal areas of soft landscaping are planned to be present in the area overlying the landfill. To reflect this a further Level 3 assessment has been undertaken. This has a reduced assumed infiltration rate of 10% of total precipitation to allow for infiltration in the public realm areas. The results of this Level 3 ConSim assessment based on the proposed development of the landfill are presented in **Table 4.6 - Table 4.8** below**.**

4.3.3 Without the development the following contaminants are predicted to reach the 50m compliance point (see **Table 4.8** below) above the groundwater guideline value within 1,000 years:

a. ammoniacal nitrogen;
b. benzene;
c. xylene;
d. anthracene;
e. aromatic TPHs;
f. 1,2,4-trimethylbenzene; and
g. mecoprop.

4.3.4 Most of these contaminants were also predicted to reach the BH55 (150m from the landfill) (see **Table 4.7** below) with the exception of anthracene.

4.3.5 The following contaminants were predicted to reach Green Horizons Park (formerly New Century Park), the groundwater abstraction point above the groundwater guideline value within 1,000 years (see **Table 4.5** below):

a. ammoniacal nitrogen;
b. benzene;
c. xylene; and
d. mecoprop.

4.3.6 The results indicate that the reduced infiltration resulting from the development of the site will cause fewer contaminants to break through the base of the unsaturated zone when compared to current conditions (see **Table 4.5** below). Only ammoniacal nitrogen, benzene, xylene and mecoprop were predicted to reach the potable abstraction at levels exceeding the assessment criteria within 1,000 years. In addition, the predicted travel times were much slower when compared to current conditions as shown in **Table 4.5** below.

Table 4.5: Comparison of predicted travel times for contaminants which exceed groundwater assessment criteria within 1,000 years at each receptor, for the current conditions and the Proposed Development.

Contaminant	Predicted travel time to receptor (years)	
	Current condition	Proposed Development
Potable abstraction (Affinity Water)		
Boron	819	-
Ammoniacal nitrogen	21.9	197
Benzene	26.6	229
Xylene	54.2	422
TPH aromatic C12-C16	480.3	-
1,2,4-trimethylbenzene	331.8	-
Mecroprop	119.7	880
BH55- 150m from landfill boundary		
Boron	333	-
Ammoniacal nitrogen	11.4	129
Benzene	12	138
Xylene	13	190
Anthracene	138	-
Benzo(a)pyrene	590	-
TPH Aro C12-C16	40	990
TPH Aro C16-C21	85	-
TPH Aro C21-C35	576	-
1,2,4-trimethylbenzene	30	711
Mecoprop	17	313
Compliance point- 50m from landfill boundary		
Boron	316	-
Ammoniacal nitrogen	11	108
Benzene	11	110

Contaminant	Predicted travel time to receptor (years)	
	Current condition	Proposed Development
Xylene	12	116
Anthracene	77	576
Benzo(a)pyrene	312	-
TPH Aro C12-C16	25.7	231
TPH Aro C16-C21	48	371
TPH Aro C21-C35	305	-
1,2,4-trimethylbenzene	21	179
Mecoprop	14	131

4.3.7 The influence of the rate of infiltration on the overall assessment is considered further in the sensitivity analysis presented in **Section 5** of this document.

Table 4.6: Output from Level 3 soils assessment for proposed development on the landfill at potable abstraction (Affinity Water) receptor.

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
Antimony	0.005	0.13	0	86,128	-	-
Arsenic	0.01	0.02	0	171,464	-	-
Barium	0.7	1.21	0	38,490	-	-
Boron	1	7.15	0	2,984	-	-
Iron	0.2	10.37	0	75,503	-	-
Manganese	0.05	1.88	0	17,242	-	-
Nickel	0.02	0.06	0	171,464	-	-
Ammoniacal nitrogen	0.39	96.35	96.4	105.7	43.0	197
Thiocyanate	0.05	0.36	0	431,586	-	-
Benzene	0.001	0.00	0.002	106	0.001	229
Xylene	0.03	0.03	0.032	106	0.014	422
Anthracene	0.0001	0.36	0.36	132	0	14,516
Fluoranthene	0.0000063	0.27	0	6,236,520	-	-
Benzo(a)pyrene	0.00001	0.08	0.08	225	0	65,653

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
TPH Ali C12-C16	0.3	0.76	0	4,743	-	-
TPH Ali C16-C21	0.3	3.08	0	368,488	-	-
TPH Ali C21-C35	0.3	15.79	0	368,488	-	-
TPH Aro C12-C16	0.09	0.43	0.43	112	0	3,401
TPH Aro C16-C21	0.09	1.39	1.39	120	0	8,248
TPH Aro C21-C35	0.09	3.62	3.62	222	0	64,163
1,2,4-trimethylbenzene	0.001	0.70	0.70	110	0	2,363
Mecoprop	0.0001	0.0028	0.0028	107	0.0007	880
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

Table 4.7: Output from Level 3 soils assessment for proposed landfill development for BH55 – 150m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
Antimony	0.10	0	0	85,634	-	-
Arsenic	0.02	0	0	170,481	-	-
Barium	1.18	0	0	38,269	-	-
Boron	6.55	0	0	2,967	-	-
Iron	9.30	0	0	75,070	-	-
Manganese	1.87	0	0	17,143	-	-
Nickel	0.057	0	0	170,481	-	-
Ammoniacal nitrogen	94	94	19.4	105.1	12.83	129
Thiocyanate	0.37	0	0	429,113	-	-
Benzene	0.00	0.0021	0.0021	105.1	0.0014	138
Xylene	0.03	0.033	0.031	105.5	0.021	190
Anthracene	0.40	0.404	0.13	131.0	-	-
Fluoranthene	0.26	0	0	6,200,000	-	-
Benzo(a)pyrene	0.08	0.080	0.12	223.6	-	-
TPH Ali C12-C16	0.66	0	0	4,716	-	-

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than) (years)
TPH Ali C16-C21	2.95	0	0	366,377	-	-
TPH Ali C21-C35	16.18	0	0	366,377	-	-
TPH Aro C12-C16	0.49	0.49	0.45	110.9	0.27	990
TPH Aro C16-C21	1.32	1.32	1.28	119.6	0.122	2292
TPH Aro C21-C35	3.66	3.66	4.14	220.9	-	-
1,2,4-trimethylbenzene	0.64	0.64	0.77	109.0	0.51	711
Mecoprop	0.0028	0.0028	0.0028	106.3	0.0018	313
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

Table 4.8: Output from Level 3 soils assessment for proposed landfill development for compliance point – 50m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) mg/l	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Antimony	0.005	0.12	0	86,128	-	-
Arsenic	0.01	0.02	0	171,464	-	-
Barium	0.7	1.17	0	38,490	-	-
Boron	1	7.48	0	2,984.5	-	-
Iron	0.2	10.13	0	75,503	-	-
Manganese	0.05	1.85	0	17,242	-	-
Nickel	0.02	0.06	0	171,464	-	-
Ammoniacal nitrogen	0.39	94.4	94.4	105.7	63.2	108
Thiocyanate	0.05	0.36	0	431,586	-	-
Benzene	0.001	0.0021	0.002	105.7	0.0014	110
Xylene	0.03	0.03	0.033	106	0.022	116
Anthracene	0.0001	0.39	0.393	131.8	0.0025	576
Fluoranthene	0.0000063	0.29	0	6,236,520	-	-
Benzo(a)pyrene	0.00001	0.06	0.064	224.9	0	-
TPH Ali C12-C16	0.3	0.76	0	4,743	-	-

Contaminant	Guideline value (mg/l)	Made Ground concentration (95% of values less than) mg/l	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
TPH Ali C16-C21	0.3	3.35	0	368,488	-	-
TPH Ali C21-C35	0.3	18.00	0	368,488	-	-
TPH Aro C12-C16	0.09	0.45	0.45	111.5	0.29	213
TPH Aro C16-C21	0.09	1.25	1.25	120.3	0.29	371
TPH Aro C21-C35	0.09	4.19	4.19	222.2	0	2195
1,2,4-trimethylbenzene	0.001	0.77	0.77	109.6	0.49	179
Mecoprop	0.0001	0.0028	0.0028	106.9	0.0018	131
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

5 SENSITIVITY ANALYSIS

5.1.1 Sensitivity analysis demonstrates how the predicted effect on groundwater and associated receptors may change when parameters in the model are adjusted. This analysis identifies the most sensitive parameters so a reasoned judgement can be made on whether further data is needed to better constrain the parameter that is being tested. This provides greater confidence in the model results.

5.1.1 A number of parameters in the hydrogeological CSM are considered sensitive with regards to contaminant transport (Ref. 13). **Table 5.1** below indicates the main sensitivity parameters from literature and a justification for their exclusion/inclusion in the sensitivity analysis.

Table 5.1: Influence of model parameters on contaminant transport.

Parameter	Influence on contaminant transport	Included in sensitivity analysis (✓/✗)	Justification
Source term	Mass of contaminant entering the system. Contaminant concentrations in groundwater	✗	The current conservative approach is considered to be protective and accounts for uncertainty in conditions given the heterogenous nature of landfills.
Hydraulic conductivity	Rate of contaminant transport (advection) and arrival time at receptor. Calculated groundwater dilution	✓	Predicting the hydraulic conductivity of Chalk is difficult due to most of the flow occurring through fractures. There was a large range in results from the packer testing undertaken at site (see **Table 6.1** of the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**)). Hydraulic conductivity can vary due to weathered chalk and solution features. The influence of solution features is discussed in **Section 5.2**.
Faction of organic carbon (foc)	Calculation of partition coefficient	✗	Organic carbon in the unsaturated and saturated zone provides sites for hydrophobic contaminants to sorb to and reduces contaminant transport. No further data is available to refine the value. Foc of Chalk is likely to be low.

Parameter	Influence on contaminant transport	Included in sensitivity analysis (✓/✗)	Justification
Hydraulic gradient	Rate and direction of groundwater flow. Calculated groundwater dilution	✗	The hydraulic gradient is known to vary across the flow path, with localised steepening of the hydraulic gradient due to the influence of nearby soakaways and during periods of high groundwater (Ref. 5). The current hydraulic gradient in the modelling is based on maximum measured groundwater levels and therefore is considered to be representative of a reasonable worst-case hydraulic gradient.
Infiltration rate	Dilution. Contaminant loading (leaching)	✓	There is opportunity within the development design to reduce the infiltration rate further i.e. not allowing infiltration in public realm areas. Therefore, sensitivity analysis of this parameter is useful to inform the design of the development.
Unsaturated aquifer thickness	Rate of contaminant transport (advection) and arrival time at receptor. Calculated groundwater dilution	✓	The groundwater is known to vary seasonally. Worst case groundwater levels identified in the detailed hydrogeology report (**Appendix 20.3**) of the ES **[TR020001/APP/5.02]** (Ref. 5) predicted the unsaturated zone could be as little as 5 m based on a 1 in 100-year event.
Biodegradation	Reduction of contaminant mass and concentration	✗	No site-specific data is available. Literature values are not specific to site conditions but are extensively researched and observed under multiple scenarios and conditions.
Complications of the topography and geology	Increase in travel times and reduction in risk	✗	The pathway to the Affinity Water abstraction is likely to be complicated by the way in which the geology reflects the varied topography of the valleys that lie between the landfill and abstraction. This complication is unlikely to increase the rate of flow

Parameter	Influence on contaminant transport	Included in sensitivity analysis (✓/✗)	Justification
			and make the abstraction more vulnerable compared to the simple model assumed so this parameter is not considered further.

5.2 Solution features

5.2.1 Solution features provide a potential direct pathway to the aquifer from the landfill. As noted in **Section 5.5.3** of the GQRA (**Appendix 17.2**) in the ES **[TR020001/APP/5.02]** (Ref. 2), the GI identified solution pipes and infilled fissures present beneath the landfill. The particle size analysis undertaken on the infill of solution features (provided in **Appendix C** of this document) indicates that these are greater than 10% fines and therefore the fill material will behave like a clay. An estimate of the permeability of material with 10% fines using the Hazen equation indicates that the permeability would be in the order of $4x10^{-8}$ m/s. Therefore, these features are not providing a permeable pathway for contaminants and the ConSim modelling undertaken is considered conservative in respect to these features.

5.3 Input parameters

5.3.1 Sensitivity analysis has been conducted on the parameters identified above in **Table 5.1.** Model runs have been undertaken varying each of the parameters in turn to examine which parameters have the greatest influence on the modelling results. The results of the sensitivity analysis are presented in **Appendix B** of this document and summarised below in **Table 5.2.**

Table 5.2: Parameters varied for sensitivity analysis.

Parameter	Value		Units	Data Source
Aquifer properties				
Unsaturated aquifer thickness – worst case maximum groundwater level	5		m	An assessment of worst-case groundwater levels has identified that the thickness of the unsaturated zone could be a minimum of 5 m, based on a 1 in 100-year event[1]. Modelled to understand potential effect on receptors.

Parameter	Value	Units	Data Source
Hydraulic conductivity of aquifer in which dilution occurs	1.3 $x10^{-6}$	m/s	Predicting the hydraulic conductivity of Chalk is difficult due to most of the flow occurring through fractures. Hydraulic conductivity used in ConSim modelling was based on the mean value ($2.4x10^{-5}$ m/s) obtained from the top 20 m of the Chalk, which allowed for fracture flow. A geometric mean hydraulic conductivity for 0-20 m (Ref. 5) has been used in the sensitivity analysis to examine the importance of this parameter.
Groundwater flow			
Infiltration – 5%	30.5	mm/yr	The Proposed Development will cover the landfill in buildings and hardstanding areas. Reduction in amount of infiltration to 5% of current value (611 mm/yr).
Infiltration – 1%	6.1	mm/yr	The Proposed Development will cover the landfill in buildings and hardstanding areas. Reduction in amount of infiltration to 1% of current value (611 mm/yr).
Notes: [1] Parameter taken from **Appendix 20.3** of the ES **[TR020001/APP/5.02]** (Ref. 5)			

5.4 Results

Infiltration

5.4.1 The results of the sensitivity analysis identify infiltration of surface water runoff is a key parameter that influences both the concentration and travel time of contaminants to the receptors.

5.4.2 The results show that by reducing the infiltration to 5% and 10% several contaminants of concern break through the unsaturated zone and reach the receptors. Further reducing infiltration rates to 1% results in no contaminants of concern breaking through the base of the unsaturated zone or reaching the receptors within 1,000 years. Full results are provided in **Appendix B** of this document.

5.4.3 Minimising infiltration from surface water runoff into the landfill would significantly reduce the generation of leachate and leaching of contaminants from the waste material to the underlying groundwater.

Unsaturated zone aquifer thickness

5.4.4 The unsaturated zone aquifer thickness had a significant effect on contaminant travel time. A 5m unsaturated zone predicted that contaminants reach the receptor faster compared to the 17.5m unsaturated zone which was previously modelled. The model predicted Ammoniacal nitrogen to have a travel time of 16 years for a 5m unsaturated zone and 24 years for the 17.5m unsaturated zone. This was consistent for all contaminants modelled.

5.4.5 Therefore, during 1 in 100-year groundwater events there is the potential for transport of contaminants to occur at a faster rate through the unsaturated zone. Although, this should be noted that this is not likely to occur for a prolonged period, so the modelling is considered to be conservative. Full results are provided in **Appendix B** of this document.

Hydraulic conductivity

5.4.6 Hydraulic conductivity is a sensitive parameter in relation to rate of contaminant transport and arrival at the receptor (Ref. 13) The use of the geometric mean hydraulic conductivity of 1.3×10^{-6} m/s compared to mean of 2.4×10^{-5} m/s resulted in the same contaminants of concern breaking through the unsaturated zone, however, travel times were slower and predicted concentrations were slightly less. Overall, the sensitivity analysis concluded that the parameter selected for the model does not make a significant difference to the assessment.

6 DISCUSSION

6.1.1 Based on current conditions at the landfill the ConSim Level 3 assessment predicted the following contaminants to break through the base of the unsaturated zone and migrate to the identified receptor/compliance points. These contaminants were also detected frequently in groundwater directly beneath the landfill:

a. boron;
b. ammoniacal nitrogen; and
c. mecoprop.

6.1.2 These contaminants were further assessed in the ConSim Level 3a assessment and the potential risk to groundwater of these contaminants in the landfill is discussed further in **Section 6.2** below.

6.1.3 The results of the Level 3a assessment indicated that only nitrate was predicted to reach the potable abstraction at concentrations above the Drinking Water Standard (DWS) within 1,000 years. In addition, the following contaminants were predicted to reach BH55 at concentrations exceeding the groundwater assessment criteria within 1,000 years:

a. ammoniacal nitrogen;
b. boron;
c. nitrate; and
d. vinyl chloride.

6.1.4 The potential risk that the presence of these contaminants of concern in the groundwater pose is discussed further in **Section 6.2** below.

6.2 Contaminants of concern

Boron

6.2.2 Boron was detected in the soils within the landfill matrix, landfill leachate and in groundwater beneath the landfill. Boron is a known component of landfill leachate and published literature suggests the highest concentrations of boron are associated with leachates from cinders, slag and plastic wastes (Ref 14). Groundwater concentrations observed suggest that the concentrations decline rapidly away from the landfill as shown in **Figure 2** and **Table 6.1** of this document.

Table 6.1: Summary of chemical analysis in all media tested for boron.

Media	Assessment criteria	Units	No. of exceedances/ (no. samples)	Maximum concentration (mg/l)
Soils (landfill matrix)	8.69	mg/kg	36/(478)	62.2

Media	Assessment criteria	Units	No. of exceedances/ (no. samples)	Maximum concentration (mg/l)
Leachate	1	mg/l	23/(42)	28
Groundwater beneath landfill			7/(61)	4.06
Groundwater downgradient			1/(112)	1.1

6.2.3 The Level 3a groundwater assessment supported this, indicating that the retarded travel time to reach the 50 m compliance point was 312 years and 826 years to reach BH55, which suggests it is not a particularly mobile contaminant.

6.2.4 The low mobility of boron is further supported as concentrations detected in groundwater in BH55 are low (0.082-0.24 mg/l) and within the background range of reported literature concentrations of 0.1-0.6 mg/l (see **Table 6.2** of the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02].**

6.2.5 Boron is not considered to present a significant risk to groundwater and is likely to be a component of a weak leachate plume from site, which is rapidly dispersed/attenuated.

Mecoprop

6.2.6 Mecoprop is found in soil/subsoil and groundwater as a result of agricultural or horticultural application as a herbicide, as a result of disposal of waste herbicide (or herbicide contaminated materials, such as grass cuttings) to landfill or as tank washings to the ground. Common applications of mecoprop are sports fields, drainage ditches and rights-of-way. It has been used since circa 1956 and is still available for use (Ref. 15).

6.2.7 It is frequently present in landfill leachate and was detected in 98% of UK leachates sampled (Ref. 16). The Environment Agency consider is one of the key indicators of pollution from landfill and is often selected for consideration within the risk assessment process because it is commonly found, relatively mobile, and a List I substance under the Groundwater Regulations 1998.

6.2.8 The Environment Agency (Ref. 15) review indicated that agricultural and horticultural applications of Mecoprop are likely to result in diffuse low level influx to soil and groundwater and concentrations in groundwater are typically less than 1 µg/l. However, in contrast disposal of mecoprop to landfill either directly or on grass cutting can result in located high herbicide loadings to the groundwater. Studies from landfills in Helpston UK, where approximately 40 tonnes of mecroprop from tank washings were deposited during the 1980s, indicated concentrations up to 432,000µg/l in leachate are still observed and up to 3,000µg/l in groundwater downgradient of the landfill (Ref. 15). In addition, another study of 50 UK landfill sites identified mecroprop in 98% of the samples, at concentration up to 140µg/l (mean 21.8µg/l and median 11µg/l) (Ref. 17).

6.2.9 Mecoprop was not detected above the LOD in the soils within the landfill, but it was detected within the leachate and groundwater beneath the landfill. **Table 6.2** below and **Figure 2** of this document summarises the chemical analysis for mecoprop from within the landfill, leachate, groundwater beneath the landfill and downgradient.

Table 6.2: Summary of chemical analysis in all media tested for mecoprop.

Media	Assessment criteria (µg/l)	Units	No. of exceedances/ (no. samples)	Maximum concentration (µg/l)
Soils (landfill matrix)	n/a	n/a	0	Not detected above LOD
Leachate	0.1	µg/l	6 /(14)	3.51
Groundwater beneath landfill			29/ (87)	0.841
Groundwater downgradient			15/ (109)	0.49

6.2.10 The ConSim Level 3a groundwater assessment indicated that the travel time for mecoprop is rapid with it predicted to reach the 50m compliance point within 6 years and BH55 within 16 years. However, the predicted concentrations of mecoprop were below groundwater assessment criteria at the 50m compliance point.

6.2.11 In order to assess the validity of the modelling, the predicted concentration at BH55 from the ConSim assessment was compared to measured concentrations. The travel times to BH55 suggest that if this contaminant were to originate from the landfill, now, 80 years after it was first established mecoprop should be detected within the groundwater. A comparison to the predicted concentrations to the actual concentrations recorded in BH55 in **Table 6.3** below. The maximum measured concentrations at BH55 were below the guideline value but higher than predicted by ConSim. This may be due to the presence of additional diffuse sources associated with agricultural or horticultural use.

Table 6.3: Comparison of predicted groundwater concentration from ConSim at 80 years versus those measured within BH55 for mecoprop.

Contaminant	Guideline value (µg/l)	Maximum measured concentration BH55 (µg/l)	Predicted concentration at receptor (95% of values less than (mg/l) at 80 years)
Mecoprop	0.1	0.09	0.00022

6.2.12 The following is noted regarding the significance of the concentrations of mecoprop detected in the leachate in the landfill:

a. The results indicate that mecoprop was not detected within the soils (landfill matrix) and the concentrations within both the leachate and groundwater were low when compared to the studies described above on similar landfills within the UK. The concentrations detected were more typical of the diffuse low levels from agricultural and horticultural use reported in literature.

b. Mecoprop is water-soluble and subject to relatively little retardation by sorption processes. It is therefore subject to relatively rapid transport in soil pore water and groundwater. Given these properties it is possible that historic concentrations of mecoprop in the landfill may have been higher but are no longer present at significant concentrations.

c. The concentration of mecoprop are not significantly elevated above the assessment criteria, with largely marginal exceedances. The exceedances in groundwater beneath the landfill are general close to where it was detected in leachate, the spatial distribution of the results do not suggest a significant plume migrating off site as shown in **Figure 2** of this document. This is supported by the ConSim Level 3a groundwater modelling which indicated that the concentrations did not exceed the criteria, at 6 years, at the 50m compliance point.

6.2.13 Given these factors, there is not considered to be a significant source of mecoprop at the landfill site and it is not considered to present a significant risk to groundwater.

Ammoniacal nitrogen

6.2.14 Ammoniacal nitrogen was detected in the soils within the landfill, landfill leachate, groundwater beneath and downgradient of the landfill (see **Table 6.4** below). Ammoniacal nitrogen is a common constituent of landfill leachate, as well as sewage and liquid manure.

6.2.15 Groundwater concentrations observed suggest that the concentrations decline rapidly away from the landfill as shown in **Figure 2** of this document. The highest recorded concentration of ammoniacal nitrogen down gradient of the landfill site was 7.2mg/l in BH13 which is located adjacent to the landfill boundary.

Table 6.4: Summary of chemical analysis in all media tested for ammoniacal nitrogen.

Media	Assessment criteria	Units	No. of exceedances/ (no. samples)	Maximum concentration (mg/kg or mg/l)
Soils (landfill matrix)	0.11	mg/kg	20/(50)	242
Leachate	0.39	mg/l	37/(42)	293

Media	Assessment criteria	Units	No. of exceedances/ (no. samples)	Maximum concentration (mg/kg or mg/l)
Groundwater beneath landfill			18/(80)	5.93
Groundwater downgradient			22/(142)	7.2

6.2.16 The ConSim Level 3 soils modelling indicated that ammoniacal nitrogen in the leachate had the potential to break through the base of the unsaturated zone and migrate to the 50m compliance point and BH55 above the groundwater assessment criteria within 1,000 years.

6.2.17 The ConSim Level 3a groundwater assessment predicted groundwater concentrations of ammoniacal nitrogen were capable of migrating to the 50m compliance point and BH55 above the groundwater assessment criteria within 1,000 years. The modelling did not predict that ammoniacal nitrogen would reach the groundwater abstraction at concentrations exceeding the groundwater assessment criteria within 1,000 years.

6.2.18 The concentrations of ammoniacal nitrogen in groundwater were predicted to reach BH55 at concentrations exceeding the groundwater assessment criteria within 56 years. The travel times to BH55 suggest that if this contaminant were to originate from the landfill, now, 80 years after it was first established ammoniacal nitrogen should be detected within the groundwater. A comparison to the predicted concentrations to the actual concentrations recorded in BH55 is provided in **Table 6.5** below.

Table 6.5: Comparison of predicted groundwater concentration from ConSim at 80 years versus those measured within BH55 for ammoniacal nitrogen.

Contaminant	Guideline value (mg/l)	Maximum measured concentration BH55 (mg/l)	Predicted concentration at receptor (95% of values less than (mg/l) at 80 years)
Ammoniacal nitrogen	0.39	0.35	0.77

6.2.19 The ammoniacal concentrations predicted at BH55 by the Consim modelling are slightly higher than the maximum levels measured at BH55. The maximum measured concentrations at BH55 were below the guideline value. This suggests that ammoniacal nitrogen is not as mobile as predicted by ConSim.

6.2.20 The landfill is likely to be the main contributing source to the ammoniacal nitrogen concentration in groundwater beneath the landfill. However, the concentrations rapidly decline away from the landfill, which suggests a weak leachate plume which is rapidly dispersed/attenuated. The measured concentrations and ConSim groundwater assessment do not suggest remediation is warranted to protect the receptors. In addition, the works associated with the Proposed Development are likely to lead to betterment of the current situation (see **Section 6.3** of this document). Therefore, ammoniacal nitrogen is not considered to pose a potential significant risk to groundwater.

Nitrate

6.2.21 Nitrate can occur naturally but can also be present in elevated concentrations due to anthropogenic sources and the decomposition of organic material in soils. Ammoniacal nitrogen also oxidises to form nitrate. Therefore, it can be both an indicator of the presence of landfill leachate and be common in agricultural areas.

6.2.22 The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated nitrate was not detected at elevated concentrations in leachate within the landfill and only one location exceeded the Level 1 RTM value. However, it was detected in the groundwater both beneath the landfill and down-gradient. A summary of the chemical analysis for all media is provided in **Table 6.6** below. Down gradient boreholes only had localised exceedances of nitrate in groundwater (see **Figure 2** of this document). One location (BH51) was a considerable distance from the landfill and the exceedance appears to be associated with a farm in that area.

Table 6.6: Summary of chemical analysis in all media tested for nitrate.

Media	Assessment criteria	Units	No. of exceedances/ (no. samples)	Maximum concentration (mg/kg or mg/l)
Soils (landfill matrix)	23.2	mg/kg	1/(50)	38.9
Leachate	50	mg/l	0/(39)	30.9
Groundwater beneath landfill			9/(80)	88.3
Groundwater downgradient			2/(142)	71.1

6.2.23 The ConSim Level 3a groundwater assessment predicted that the groundwater concentrations of nitrate were capable of migrating and reaching the groundwater abstraction point within 325 years at concentrations exceeding the groundwater assessment criteria.

6.2.24 In order to assess the validity of the modelling, the predicted concentration at BH55 from the ConSim assessment was compared to measured concentrations. The ConSim Level 3a groundwater assessment indicated that nitrate were contaminants was predicted to reach BH55 at concentrations exceeding the groundwater assessment criteria within 16 years. The travel times to BH55 suggest that if this contaminant were to originate from the landfill, now, 80 years after it was first established nitrate should be detected within the groundwater. A comparison to the predicted concentrations to the actual concentrations recorded in BH55 is provided in **Table 6.7** below.

Table 6.7 Comparison of predicted groundwater concentration from ConSim versus those measured within BH55

Contaminant	Guideline value (mg/l)	Maximum measured concentration BH55 (mg/l)	Predicted concentration at receptor (95% of values less than (mg/l) at 80 years)
Nitrate	50	1.19	88.3

6.2.25 The nitrate concentrations predicted at BH55 by the ConSim modelling are significantly higher than the maximum levels measured at BH55. The maximum measured concentrations at BH55 were well below the guideline value. This suggests that nitrate may not be as mobile as predicted by ConSim. It is possible that it is being attenuated in either the landfill body itself or the unsaturated zone.

6.2.26 Therefore, given the localised nature of the exceedances the landfill may not be the only source of nitrate and agricultural practices across the area have likely contributed to the observed concentrations.

6.2.27 The measured concentrations show that a rapid decline downgradient from the landfill. Therefore, the nitrate concentration may be associated with a weak leachate plume which is rapidly dispersed/attenuated. The measured concentrations and ConSim groundwater assessment do not suggest remediation is warranted to protect the receptors. In addition, the works associated with the Proposed Development are likely to lead to betterment of the current situation (see **Section 6.3** of this document). Therefore, the nitrate concentrations are not considered to pose a potential significant risk to groundwater.

Vinyl chloride

6.2.28 Vinyl chloride was detected in the groundwater beneath the landfill at relatively low concentrations (within an order of magnitude of the assessment criteria) but was not detected within the landfill material or down gradient, with the exception of low concentrations of vinyl chloride in a localised area of perched groundwater in the landfill. A summary of the chemical analysis for all media is provided in **Table 6.8** below.

Table 6.8: Summary of chemical analysis in all media tested for vinyl chloride.

Media	Assessment criteria	Units	No. of exceedances/ (no. samples)	Maximum concentration (µg/kg or µg/l)
Soils (landfill matrix)	0.0007	mg/kg	0/(191)	LOD
Leachate			2/(40)	7.04
Groundwater beneath landfill	0.5	µg/l	15/(80)	7.1
Groundwater downgradient			0/(152)	LOD

6.2.29 The ConSim Level 3a groundwater assessment indicated that the vinyl chloride was predicted to reach BH55 at concentrations exceeding the groundwater assessment criteria within 16 years. The travel times to BH55 suggest that if these contaminants were to originate from the landfill, now, 80 years after it was first established vinyl chloride should be detected within the groundwater. A comparison to the predicted concentrations to the actual concentrations recorded in BH55 is provided in **Table 6.9** below.

Table 6.9: Comparison of predicted groundwater concentration from ConSim versus those measured within BH55.

Contaminant	Guideline value (mg/l)	Maximum measured concentration BH55 (mg/l)	Predicted concentration at receptor (95% of values less than (mg/l) at 80 years)
Vinyl chloride	0.0005	<0.001	0.0016

6.2.30 Vinyl chloride was not detected in water samples recovered from BH55. This suggests that it is not mobile in the way suggested by ConSim. It is possible that it is being attenuated in either the landfill body itself or the unsaturated zone.

6.2.31 The concentrations of vinyl chloride in the groundwater are not considered to pose a significant risk for the following reasons:

a. vinyl chloride was not detected in the soil samples taken from the landfill or in groundwater down gradient; and

b. the absence of vinyl chloride in groundwater down gradient suggests that if it was present in the landfill and not been detected that it is being attenuated.

6.2.32 The measured concentrations and ConSim groundwater assessment do not suggest remediation is warranted to protect the receptors. In addition, the works associated with the Proposed Development are likely to lead to betterment of the current situation (see **Section 6.3** below). Therefore, the vinyl chloride concentrations are not considered to pose a potential significant risk to groundwater.

Poly and perfluorinated substances (PFAS)

6.2.33 There is work ongoing by the Environment Agency to understand the risks and develop pragmatic approaches to PFAS assessment. Further monitoring and assessment is required. Monitoring suggests that the risks from PFAS is low at the development site they should be considered contaminants of concern until the guidance is available and any further assessment work completed.

6.3 Proposed Development

6.3.1 The sensitivity analysis indicated that minimising the rate of infiltration into the landfill is key for preventing contaminants leaching, breaking through the base of the unsaturated zone and reaching receptors. With infiltration minimised to 1% there was no contaminant break through. Therefore, installation of a cover system with a drainage system to collect all infiltration in the area of the landfill will prevent any future risks from leaching of contaminants within the landfill to groundwater.

6.3.2 A significant risk to controlled waters from the Proposed Development is from the driving of contaminants into the aquifer during piling. A foundation works risk assessment will be required to determine the appropriate pile design and construction method to ensure that contaminated material is not pushed down into the aquifer or a pathway is created through the unsaturated zone.

Summary of risk to controlled waters

6.3.3 The DQRA indicated that whilst there is evidence of a weak leachate plume in groundwater down-gradient of the site, on-site groundwater monitoring provides little evidence that the landfill is causing significant contamination of the groundwater.

6.3.4 Isolated hotspots of contaminants are present within the landfill and a small amount of free product was encountered at location WS224.It is proposed in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]** that this material is removed.

6.3.5 The risk assessment has been based on current contaminants concentrations and degradation or declining source has not been assumed. Contaminant concentrations in the landfill are likely to reduce over time, therefore the assessment is considered conservative. It’s also conservatively based on a 1,000 year travel time.

6.3.6 Leaching of contaminants from the landfill through the unsaturated zone are likely to be inhibited by localised layers of Clay-with-Flints, lower permeability layers of weathered putty chalk and marl and flint bands. The presence of these features may contribute to contaminants being attenuated more in the unsaturated zone than predicted by ConSim.

6.3.7 The DQRA indicated that whilst there are contaminants present in the landfill material, leachate and groundwater beneath the landfill, they are not currently considered sufficient concentrations to pose a risk to controlled water receptors.

6.3.8 Constraining the rate of infiltration is key to preventing contaminants breaking through the base of the unsaturated zone and reaching receptors. Installation of a cover and drainage system to collect surface run-off and prevent infiltration is therefore required to minimise the infiltration below 1% and prevent any future risks to the groundwater from contaminants within the landfill.

6.3.9 The GI provided sufficient information to characterise the condition of the landfill and inform this assessment, but it is recognised that the landfill is heterogenous in nature. It is likely to contain accumulations of material that may not be large enough or have sufficient concentrations to impact the groundwater quality, as indicated by the extensive monitoring undertaken, however these accumulations may have the capacity to cause short term local impacts if exposed/mobilised during works and not treated appropriately. The ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]** includes measures to detect and appropriately deal with such accumulations.

Appropriate precautions will also be required during works to ensure no preferential pathways are created, particularly during intrusive activities such as piling.

7 REVISED CONCEPTUAL SITE MODEL

7.1.1 The conceptual site model summarised in **Figure 1** of this document has been updated for the baseline condition, following the quantitative risk assessment. The updated CSM with respect to controlled water PCLs is provided in **Table 7.1** below. It is indicated within the Table below whether the PCLs required further consideration within the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

7.1.2 The PCLs have been classified as follows:

(orange)	Confirmed relevant pollutant linkage (RCL) require inclusion in the ORS
(pink)	PCL requires further consideration through Detailed Quantitative Risk Assessment (DQRA)
(light blue)	Impact is possible but can be mitigated by design and/or managed under an alternative regime such as permitted operation or occupational safety. Measure should be included in the ORS.
(green)	Impact ruled out no further assessment required

Table 7.1: Updated controlled waters CSM.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative assessment of risk	Justification of Qualitative Assessment of Risk
23	DEV	Leachate in former landfill[4]	Downward migration of leachate	Principal aquifer in Chalk	Moderate/ Low	The DQRA has identified the potential of downward migration of leachate from the landfill. A weak leachate plume appears to be present immediately downgradient of the landfill, however groundwater monitoring completed to date does not suggest the plume is significant or affecting the aquifer. The sensitivity analysis identified that minimising the rate of infiltration will prevent contaminants breaking through the base of the unsaturated zone and reaching receptors. Installation of a cover system with a drainage system to collect surface run off in the area of the landfill will minimise any future risks to the groundwater from contaminants within the landfill.
40	DEV	Contaminants in groundwater (dissolved phase)	Lateral migration of contaminants in groundwater	Controlled waters (including potable water groundwater abstraction and private	Moderate	Relatively few exceedances of potential contaminants of concern have been recorded in groundwater beneath the site. The DQRA has indicated that whilst there is evidence of a weak leachate plume in groundwater down-gradient of the site, on-site groundwater monitoring provides little

[4] The source of the leachate in assumed to be the landfill waste material

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative assessment of risk	Justification of Qualitative Assessment of Risk
				water supplies)		evidence that the landfill is causing significant contamination to groundwater. The sensitivity analysis indicated that minimising the rate of infiltration will prevent contaminants breaking through the base of the unsaturated zone and reaching receptors. Installation of a cover system with a drainage system to collect surface run-off and prevent infiltration in the area of the landfill will minimise any future risks to the groundwater from contaminants within the landfill.
KEY: CON- PCL during excavation, remediation and construction phase DEV- PCL associated with future use of Proposed Development						

8 CONCLUSIONS AND RECOMMENDATIONS

8.1.1 A GI has been carried out that has gathered sufficient information to characterise the condition and chemistry of the landfill.

8.1.2 A detailed assessment of the risk that the landfill presents to controlled waters has been undertaken and has been based upon a cautious assessment of the GI data and reasonably conservative assumptions about ground conditions and the hydrogeology of the site.

8.1.3 ConSim modelling undertaken to inform the DQRA has indicated that there are contaminants within the landfill material which have the potential to break through the base of the unsaturated zone and migrate to identified receptor/compliance points. Concentrations of ammoniacal nitrogen, and benzene are predicted to reach the potable abstraction within 1,000 years.

8.1.4 Whilst there is evidence of a weak leachate plume in groundwater down-gradient of the site, on-site groundwater monitoring provides little evidence that the landfill is causing significant contamination of the groundwater.

8.1.5 Leaching of contaminants from the landfill through the unsaturated zone is likely to be inhibited by localised layers of Clay-with-Flints, lower permeability layers of weathered putty chalk and marl and flint bands. The presence of these features may contribute to contaminants being attenuated more in the unsaturated zone than predicted by ConSim.

8.1.6 The Proposed Development will result in the landfill being covered within buildings and hardstanding which will significantly reduce the volume of infiltration into the landfill waste material and generation of landfill leachate. ConSim modelling has predicted that in this scenario none of the potential contaminants of concern would break through the base of the unsaturated zone within a 1,000-year time period.

8.1.7 In addition, the earthworks proposed as part of the airport development will result in the excavation of waste across the southern end of the landfill. The materials will be processed and where suitable reused to build the development platform. As part of this excavation, any significant contamination (e.g. free product) identified in the waste would be removed from site and only materials considered suitable for re-use (to be protective of both human health and controlled waters) would be incorporated into the development platform.

8.1.8 A risk to controlled waters from the Proposed Development is considered to be from the driving of contaminants into the aquifer during piling. A foundation works risk assessment will be required to determine the appropriate pile design and construction method to ensure that contaminated material is not pushed down into the aquifer or a pathway is created through the unsaturated zone.

8.1.9 The exposure of landfill material during earthworks will require careful control to ensure that infiltration into the waste is not temporarily increased.

8.1.10 A ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]** was developed to ensure that appropriate mitigation measures are in place during the earthworks to ensure risks are appropriately managed. Measures may include:

a. groundwater quality monitoring pre-, post and during construction;
b. installation of leachate interception drains; and
c. removal of significantly contaminated material for disposal off-site, e.g. free product.

8.1.11 The GI provided sufficient information to characterise the condition of the landfill and inform this assessment, but it is recognised that the landfill is heterogenous in nature. It is likely to contain accumulations of material that may not be large enough or have sufficient concentrations to impact the groundwater quality, as indicated by the extensive monitoring undertaken, however these accumulations may have the capacity to cause short term local impacts if exposed/mobilised during works and not treated appropriately. ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]** includes measures to detect and appropriately deal with such accumulations.

8.1.12 Further assessment with respect to perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) will be required as guidance develops.

8.1.13 Further monitoring and liaison with the Environment Agency is required.

GLOSSARY/ABBREVIATIONS

Term	Definition
Abbreviations	
AOD	Above Ordnance Datum
CL:AIRE	Contaminated Land: Applications in Real Environments
CIRIA	Construction Industry Research and Information Association
CLR	Contaminated land report
CLEA	Contaminated land exposure assessment
CSM	Conceptual site model
DCO	Development Consent Order
DQRA	Detailed Quantitative Risk Assessment
DWS	Drinking water standards
ES	Environmental Statement
FEQS	Freshwater environmental quality standards
FOC	Fraction of organic carbon
GQRA	Generic Quantitative Risk Assessment
GQMP	Groundwater quality monitoring points
GI	ground investigation
LCRM	Land Contamination Risk Management
LOD	Limit of Detection
PAH	polyaromatic hydrocarbons
PCB	polychlorinated biphenyls
PCL	potential contaminant linkage
PFAS	per- and polyfluoroalkyl substances
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulphonate
PPE	personal protective equipment
PRA	Preliminary Risk Assessment
RTM	Remedial target methodology
RCL	Relevant Contaminant Linkage
SVOC	Semi-volatile organic compounds
TPH	total petroleum hydrocarbons
TPHCWG	total petroleum hydrocarbon criteria working group
UXO	unexploded ordnance
VFA	Volatile fatty acids
VOC	volatile organic compound
WVP	Wigmore Valley Park
ZOI	zone of influence
Glossary	
Above ordnance datum (AOD)	Above ordnance datum (AOD) is a vertical measurement used by ordnance survey as the basis for deriving altitudes on maps, usually by comparison with the mean sea level.
Aquifer	An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt).

Glossary	
Baseline	A description of the current state of the environment without implementation of the project.
Conceptual Site Model (CSM)	A representation of the characterisation of a site in diagrammatic and/or written form that shows the possible relationships between the contaminants, pathway and receptors. This helps to evaluate the potential risks that the site poses given the intended operations and future use of the site.
Controlled waters	These are fully defined in section 104 of the Water Resources Act 1991. Controlled waters include, in summary: a. Relevant territorial waters which extend seaward for three miles from the low-tide limit from which the territorial sea adjacent to England and Wales is measured b. Coastal waters from the low-tide limit to the high-tide limit or fresh-water limit of a river or watercourse c. Inland freshwaters: natural and artificial lakes, ponds, reservoirs, rivers or watercourses above the fresh-water limit d. Natural and artificial underground rivers and watercourses e. Surface water sewers, ditches and soakaways that discharge to surface or groundwater it also includes those that may be currently dry f. Groundwaters – any waters contained in underground strata.
Detailed assessment	Method applied to gain an in-depth appreciation of the beneficial and adverse consequences of the project and to inform project decisions. Detailed Assessments are likely to require detailed field surveys and/or quantified modelling techniques.
Development Consent Order (DCO)	A Development Consent Order (DCO) is the means of obtaining permission for developments categorised as Nationally Significant Infrastructure Projects. This includes energy, transport, water and waste projects.
Effect	Term used to express the result/consequence of an impact (expressed as the 'significance of effect').

Glossary	
Environment Agency	The Environment Agency is responsible for environmental protection and regulation in England and plays a central role in implementing the government's environmental strategy. The Environment Agency is the main body responsible for managing the regulation of major industry and waste, treatment of contaminated land, water quality and resources, fisheries, inland river, estuary and harbour navigations, and conservation and ecology. They are also responsible for managing the risk of flooding from main rivers, reservoirs, estuaries and the sea.
Environmental Statement (ES)	A statutory report (this document) produced by the developer including: a. A description of the project b. A description of the likely significant effects of the project on the environment c. A description of the features of the project and/or measures envisaged in order to avoid, prevent or reduce and, if possible, offset likely significant adverse effects on the environment d. A description of the reasonable alternatives e. A non-technical summary f. Any additional information relevant to the characteristics of a project
Groundwater	Groundwater is the water present beneath Earth's surface in rock and soil pore spaces and in the fractures of rock formations.
Groundwater divide	The boundary between groundwater basins; defined by a line connecting the high points on the water table or other potentiometric surface. Groundwater flows away from a groundwater divide.
Impact	The change or action. Either beneficial or adverse.
Limit of Detection (LOD)	The lowest contaminant concentration that can be detected by the apparatus used, usually dependent on the resolution of the equipment.
Leachate	A liquid that forms within waste accumulations such as landfills that contain increased concentrations of contaminants, specifically heavy metals, ammoniacal nitrogen and organic compounds. It is therefore hazardous and either must be indefinitely contained within the landfill or collected and suitably disposed of.
Made Ground	Made Ground is an area where the pre-existing (natural or artificial) land surface is raised or filled by artificial deposits consisting of materials such as refuse, demolition rubble etc.
Main Application Site	The airport site excluding off-site works.

Glossary	
Pollutant	A substance that pollutes something, especially water or the atmosphere.
Potable water	Water that is safe to drink/consume.
Potential contaminant linkage	The potential contaminant linkage determines how contaminant travels from the contaminant source to a receptor.
Preliminary Environmental Information (PEI) Report	The PEI Report was prepared in compliance with the EIA Regulations to enable the local community, any other interested person and stakeholders to understand the environmental effects of the Proposed Development and enable an informed response to the consultation. The document set out how each environmental topic area is being assessed, the potential environmental effects of the Proposed Development based on the information available at the time, and measures proposed to avoid or reduce such effects. This is to support consultees in developing an informed view of the likely significant environmental effects of the Proposed Development, and allow them to provide additional information for inclusion in the EIA.
Proposed Development	The proposed expansion of Luton Airport with new terminal and stands and associated developments (as described in **Chapter 4** of the ES **[TR020001/APP/5.01]**).
Receptor (sensitive)	A component of the natural, created, or built environment such as human
Relevant Contaminant Linkage	Where a PCL has been identified and mitigation measures inherent in the construction or operation of the Proposed Development might not be sufficient to break the pollutant linkage, these are assessed to be a RCL and would require specific remediation measures to be implemented.
Resource	A defined but generally collective environmental feature usually associated with soil, water, air, climatic factors, landscape, material assets, including the architectural and archaeological heritage that has potential to be affected by a project.
Surface water	Water that collects on the surface of the ground.
Topography	The natural and man-made features of an area collectively.
Volatile Fatty Acids (VFA)	Monocarboxylic acids that are strongly malodorous, created by the anaerobic degradation of waste materials.

Glossary	
Volatile Organic Compounds (VOC)	Organic compounds that are volatile under normal environmental/atmospheric conditions. They may be found in the ground in a solid or liquid phase form as well as in a gaseous phase form.
Waste	Waste is defined in Article 3(1) of the European Waste Framework Directive 2008/98/EC (OJL 312/3) as any substance or object which the holder discards or intends or is required to discard. The term 'holder' is defined under article 3(6) as 'the waste producer or the natural or legal person who is in possession of the waste'. The waste 'producer' is defined under article 3(5) as 'anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of the waste'. Waste can be further classified as hazardous, non-hazardous or inert.
Water quality	Water quality refers to the chemical, physical, and biological characteristics of water based on the standards of its usage.
Worst-case (scenario)	The definition of a 'worst-case' varies by the field to which it is being applied, however ultimately it is the most unfavourable foreseen scenario. Often assessments use a worst-case scenario.

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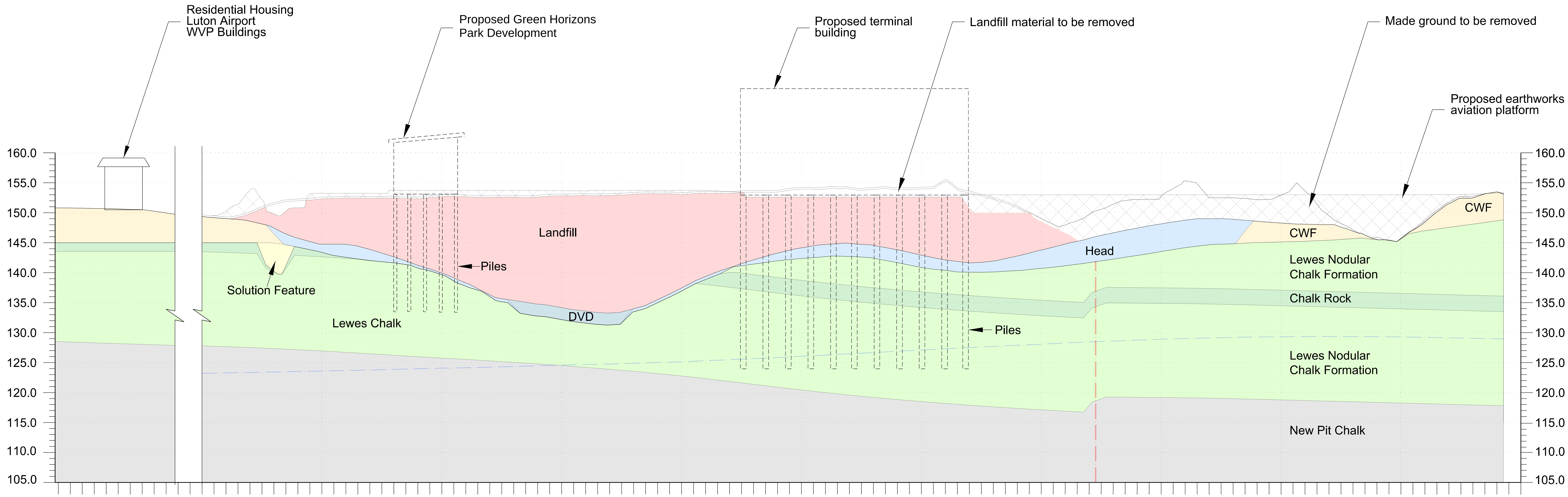
FIGURES

Section A-A



Interactive Buttons

Please Note: This is an interactive PDF. Either the Conceptual Site Model Potential Contaminant Linkage No. (see GQRA Table 13-1) or the sources below can be clicked to display the relevant pathway and receptors.

Conceptual Site Model Potential Contaminant Linkage No.

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41

PCL requires further consideration through Detailed Quantitative Risk Assessment (DQRA).

Sources	Pathways	Receptors
1 Landfill ground gas + vapour	i Migration	A Future site users
2 Volatile radionuclides in landfill	ii Inhalation	B Adjacent site users
3 Landfill waste	iii Dermal contact/ingestion	C Construction workers
4 Japanese knotweed	iv Driving of contaminants downwards by piling	D Future maintenance workers
5 Landfill leachate	v Direct contact	E Principal chalk aquifer
6 Perched water in landfill	vi Plant uptake	F Foundations /floor slabs and buried concrete
7 Made ground contaminants		G Planting
8 Contaminants in groundwater		H Potable water extraction
9 UXO		J Drainage and pavements

Legend

Key Plan

Notes

1. Do not scale from this drawing.
2. All levels are in metres above ordnance datum unless noted otherwise.
3. These drawings are primarily intended to be viewed electronically. Some details may not be clear or visible on a printed version.
4. Strata and other levels have been drawn from interpolated 3D models of various boundaries logged in trial pits and boreholes, topographical data and data from geological maps etc.
   It is intended to provide a guide as to likely ground conditions and as such should be regarded as indicative. It is recommended that design decisions made on the basis of this information are confirmed by investigation.
5. This is an interactive 2D PDF. For full interactivity it is recommended that the original digital version it is opened and viewed using Adobe Reader 7.0 or higher.
6. Bing Maps Aerial - © 2021 Microsoft Corporation © 2021 Maxar ©CNES (2021) Distribution Airbus DS

Revision History	Drawn	Checked / Approved	Date	Rev.
Issue	IJ	RB / TB	30/09/22	P02
Issue	IJ	RB / TB	16/12/21	P01

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Our community
Our planet.

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Drawing Title

Figure 01
Conceptual Site Model (CSM)

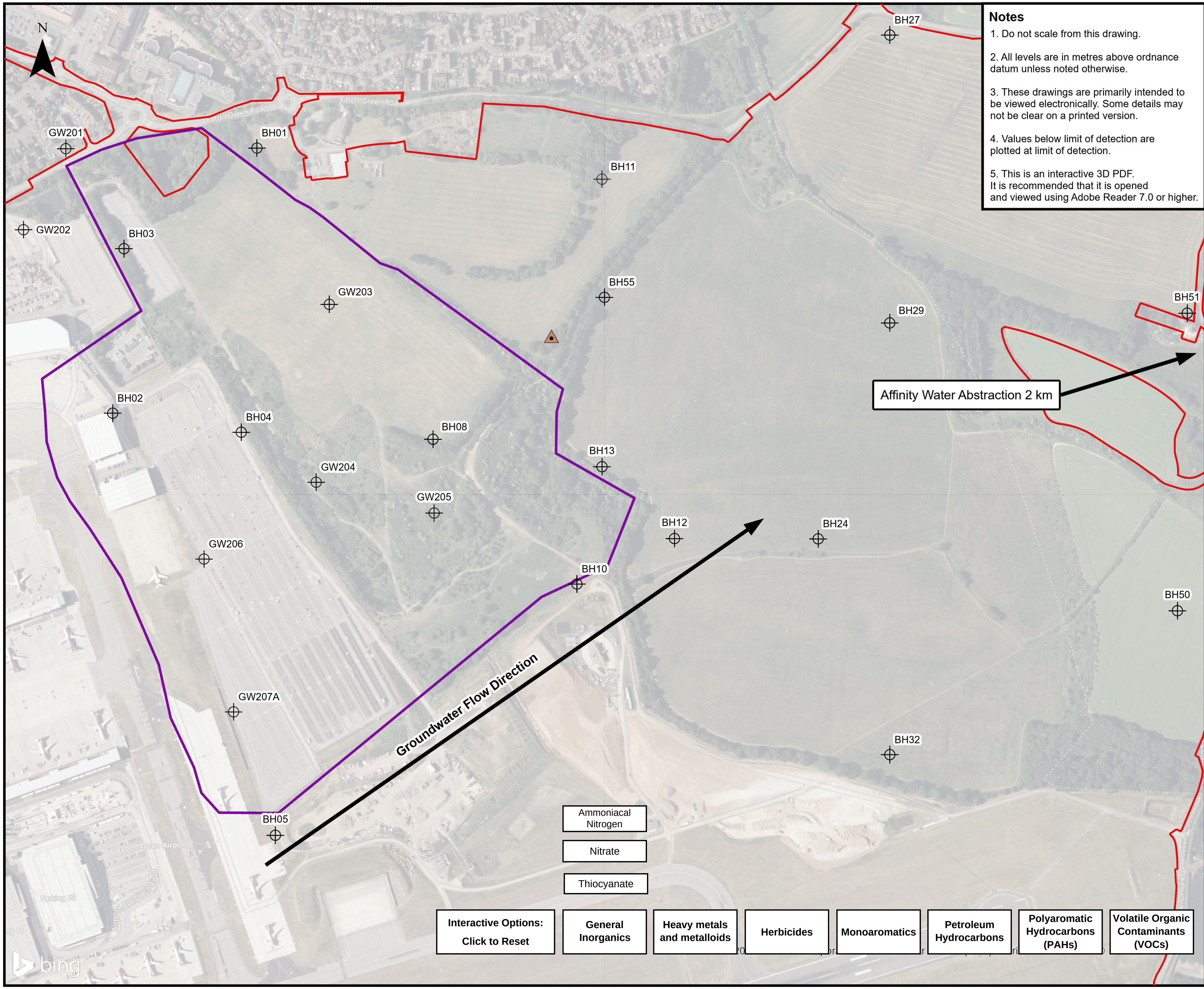
Purpose of issue	Suitability
SUITABLE FOR COORDINATION	S2

Drawn	Checked	Approved	Date	Scale	Size
IJ	RB	TB	30/09/22	NTS	A1

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	APFP 5(2)(a)	TR020001/APP/5.03

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0183	P02

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number



Notes

1. Do not scale from this drawing.
2. All levels are in metres above ordnance datum unless noted otherwise.
3. These drawings are primarily intended to be viewed electronically. Some details may not be clear on a printed version.
4. Values below limit of detection are plotted at limit of detection.
5. This is an interactive 3D PDF. It is recommended that it is opened and viewed using Adobe Reader 7.0 or higher.

All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

Legend

- Order Limits
- Interpreted Landfill Boundary
- Groundwater Monitoring Boreholes
- 50m Compliance Point

Revision History	Drawn	Checked / Approved	Date	Rev.
First Issue	AB	RB / TB	23/09/22	P02

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Drawing Title

Figure 2
Controlled Waters Risk Assessment Results

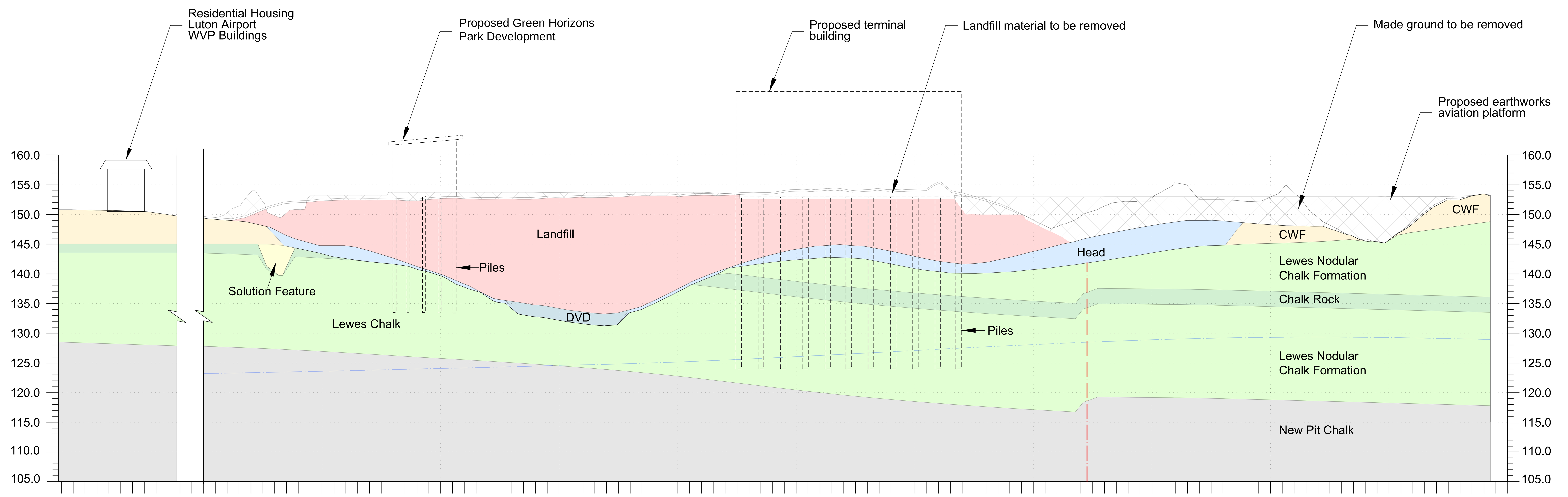
Purpose of issue					Suitability
SUITABLE FOR INFORMATION					S2
Drawn	Checked	Approved	Date	Scale	Size
AB	RB	TB	23/09/22	1:5,000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	APFP 5(2)(a)	TR020001/APP/5.03

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0275	P02

Project - Phase - Originator - Asset/Zone - Sub Asset - Type- Discp. - Number

Section A-A



Interactive Buttons

Please Note: This is an interactive PDF. Either the Conceptual Site Model Potential Contaminant Linkage No. (see DQRA - CW Table 7-1) or the sources below can be clicked to display the relevant pathway and receptors.

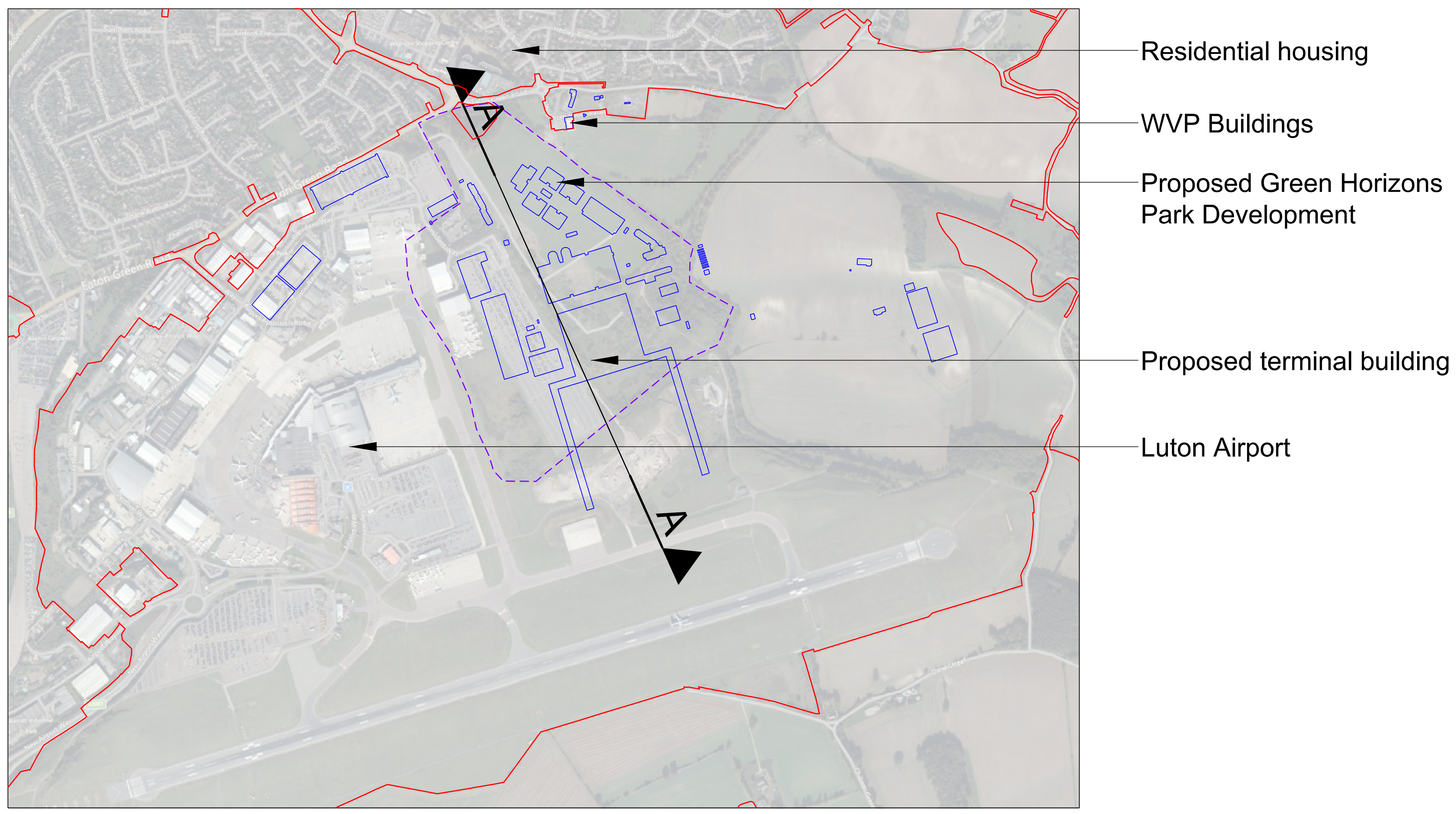
Conceptual Site Model Potential Contaminant Linkage No.

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41

(Orange-filled box) Confirmed Relevant Contaminant Linkage (RCL) requires inclusion in Remediation Strategy.

Sources	Pathways	Receptors
1 Landfill ground gas + vapour	i Migration	A Future site users
2 Volatile radionuclides in landfill	ii Inhalation	B Adjacent site users
3 Landfill waste	iii Dermal contact/ingestion	C Construction workers
4 Japanese knotweed	iv Driving of contaminants downwards by piling	D Future maintenance workers
5 Landfill leachate	v Direct contact	E Principal chalk aquifer
6 Perched water in landfill	vi Plant uptake	F Foundations /floor slabs and buried concrete
7 Made ground contaminants		G Planting
8 Contaminants in groundwater		H Potable water extraction
9 UXO		J Drainage and pavements

Legend



Key Plan

Notes

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Revision History	Drawn	Checked / Approved	Date	Rev.
Issue	IJ	RB / TB	30/09/22	P02
Issue	IJ	RB / TB	16/12/21	P01

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London Luton Airport Expansion
Development Consent Order

Drawing Title
Figure 03
Updated Conceptual Site Model (CSM)

Purpose of Issue				Suitability	
SUITABLE FOR COORDINATION				S2	
Drawn	Checked	Approved	Date	Scale	Size
IJ	RB	TB	30/09/22	NTS	A1
DCO Application Ref.	APFP Regulation	DCO Document Ref.			
TR020001	APFP 5(2)(a)	TR020001/APP/5.03			

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0185	P02

Project - Phase - Originator - Asset/Zone - Sub Asset - Type - Discp. - Number

Appendix A – Summary of chemical parameters used for risk assessment

Determinand	Source concentration (mg/l)			Screening criteria (mg/l)	Screening criteria source	Kd (l/kg)	Koc	Half-life (years)
	Min	Median	Max					
Soils assessment								
Thiocyanate	0.05	0.05	0.45	0.05	DWS	1,259[f]	-	-
Ammoniacal nitrogen	0.022	19.1	29.3	0.39	DWS	0.5[c]	-	-
Antimony	0.0004	0.00164	0.459	0.005	DWS	251[a]	-	-
Arsenic	0.00018	0.00426	0.0169	0.01	DWS	500 [a]	-	-
Barium	0.00714	0.211	3.08	0.7	WHO	112 [f]	-	-
Boron	0.010	0.529	28	1	DWS	8,4 [j]	-	-
Iron	0.007	0.688	38.1	0.2	DWS	220 [c]	-	-
Manganese	0.003	0.28	5.59	0.05	DWS	50 [c]	-	-
Nickel	0.0004	0.0125	0.146	0.02	DWS	500[a]	-	-
Benzene	0.001[1]	0.001[1]	0.0024[1]	0.001	DWS	-	67.6[d]	-
Xylene	0.001[1]	0.002[1]	0.0414[1]	0.03	FEQS	-	446.68 [d]	-
Anthracene	0.000005	0.00012	0.996	0.0001	FEQS	-	28,184 [j]	-
Fluoranthene	0.000005	0.00141	3.05	0.0000063	FEQS	-	18,197[d]	-
Benzo(a)pyrene	0.000005	0.00042	0.644	0.00001	DWS	-	128,825 [d]	-
Aliphatic TPH C12-C16	0.01[1]	0.13[1]	2.22[1]	0.3	WHO	-	5,011,872 [b]	-
Aliphatic TPH C16-C21	0.01[1]	0.073[1]	12[1]	0.3	WHO	-	398,107,170 [k]	-
Aliphatic TPH C21-C35	0.01[1]	0.32[1]	77.6[1]	0.3	WHO	-	398,107,170 [k]	-

Determinand	Source concentration (mg/l)			Screening criteria (mg/l)	Screening criteria source	Kd (l/kg)	Koc	Half-life (years)
	Min	Median	Max					
Aromatic TPH C12-C16	0.01[1]	0.01[1]	1.47[1]	0.09	WHO	-	6,309 [k]	-
Aromatic TPH C16-C21	0.01[1]	0.016[1]	5.17[1]	0.09	WHO	-	15,849 [b]	-
Aromatic TPH C21-C35	0.01[1]	0.06[1]	18.5[1]	0.09	WHO	-	125,892 [b]	-
1,2,4-Trimethylbenzene	0.001	0.001	4.49	0.001	DWS	-	4,266 [j]	-
Mecoprop	0.00001	0.00026	0.00351	0.0001	DWS		1,348 [i]	-
Groundwater assessment								
Ammoniacal nitrogen	-	-	5.93	0.39	DWS	0.5[c]	-	6 [g]
Nitrate as NO_3	-	-	88.3	50	DWS	-	1.62[b]	1E+30 [h]
Manganese	-	-	0.964	0.05	DWS	50[c]	-	1E+30 [h]
Trichloroethene (TCE)	-	-	0.131	0.01	DWS	-	141.25[d]	3[c]
1,2-dichloroethane	-	-	0.00744	0.003	DWS	-	19.95 [d]	1[b]
Vinyl chloride	-	-	0.0071	0.0005	DWS	-	57 [c]	8[b]
Mecoprop	-	-	0.000841	0.0001	DWS	-	1,348 [i]	1[i]
Diuron	-	-	0.000290	0.0001	DWS	-	478.6 [i]	1[i]
Boron	-	-	4.06	1	DWS	8,4 [j]	-	-

Determinand	Source concentration (mg/l)			Screening criteria (mg/l)	Screening criteria source	Kd (l/kg)	Koc	Half-life (years)
	Min	Median	Max					
Iron	-	-	0.7	0.2	DWS	220 [c]	-	-
Nickel	-	-	0.025	0.02	DWS	500[a]	-	-
Fluoranthene	-	-	0.0001	0.00001	FEQS	-	18,197[d]	-

Note:

[1] source concentration inputs do not include results from wells WS224 and BH231, during sampling of these locations an oily sheen was noted on the water and therefore the analytical results for these samples likely to be representative of free product rather than dissolved phase contamination

[a] CLEA 1.071 database

[b] GSI Environmental, Chemical Properties Database (2014) [redacted] *[May 2017]*

[c] ConSim database

[d] Environment Agency (2008) Compilation of Data for Priority Organic Pollutants for Derivation of Soil Guideline Values, Science Report SC050021/SR7

[e] The LQM/CIEH generic Assessment Criteria for Human Health Risk Assessment, 2nd edition, 2009

[f] USEPA (2005) Partition coefficients for metals in surface water, soil and waste (http://epa.gov/athens/publications/reports/Ambrose600R05074PartitionCoefficients.pdf)

[g] Environment Agency (2003) Review of ammonium attenuation in soil and groundwater [redacted]

[h] No degradation assumed

[i] Pubchem online database [redacted] *accessed 1/10/2019*

[j] NIH- National Library of Medicine TOXNET Chem ID [redacted] *accessed 1/10/2019*

[k] TPHCWG (1997) Volume 3 Selection of representative TPH fractions based on fate and transport considerations

Appendix B- Sensitivity analysis

B1.1 Infiltration 5%

Output from Level 3 soils assessment for Proposed Development on the landfill at Potable abstraction (Affinity Water) receptor.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	92.042	92.042	212	31	349
Benzene	0.001	0.002	0.002	212	0.0007	398
Xylene	0.03	0.033	0.033	213	0.0091	689
Anthracene	0.0001	0.451	0.451	264	0	21977
Benzo(a)pyrene	0.00001	0.074	0.074	450	0	99218
TPH Aro C12-C16	0.09	0.468	0.468	223	0	5189
TPH Aro C16-C21	0.09	1.38	1.38	241	0	12510
TPH Aro C21-C35	0.09	4.42	4.42	445	0	96967
1,2,4-trimethylbenzene	0.001	0.687	0.687	220	0	3621

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Mecoprop	0.0001	0.003	0.003	214	0	1381

Note:
Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value

Output from Level 3 soils assessment for Proposed Development on the landfill BH55 – 150m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	91	91.11	212	45	290
Benzene	0.001	0.002	0.0021	212	0.0010	224
Xylene	0.03	0.032	0.03	213	0.0162	243
Anthracene	0.0001	0.387	0.39	264	0	1675
Benzo(a)pyrene	0.00001	0.075	0.08	450	0	6868
TPH Aro C12-C16	0.09	0.528	0.53	223	0.11	546
TPH Aro C16-C21	0.09	1.257	0.02	241	0	1038
TPH Aro C21-C35	0.09	5.44	5.44	445	0	6717
1,2,4-trimethylbenzene	0.001	0.687	0.69	220	0.24	441
Mecoprop	0.0001	0.003	0.0028	214	0.0014	290

Note:
Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value

Output from Level 3 soils assessment for proposed landfill development for Compliance Point – 50 m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	91	91	212	45	290
Benzene	0.001	0.002	0.002	212	0.0010	224
Xylene	0.03	0.032	0.03	213	0.0162	243
Anthracene	0.0001	0.387	0.39	264	0	1675
Benzo(a)pyrene	0.00001	0.075	0.08	450	0	6868
TPH Aro C12-C16	0.09	0.528	0.53	223	0.11	546
TPH Aro C16-C21	0.09	1.257	0.02	241	0	1038
TPH Aro C21-C35	0.09	5.44	5.44	445	0	6717
1,2,4-trimethylbenzene	0.001	0.687	0.69	220	0.24	441
Mecoprop	0.0001	0.003	0.003	214	0.0014	290

Note:
Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value

B1.2 Infiltration 1%

Output from sensitivity analysis for Level 3 soils assessment for Proposed Development on the landfill at Potable abstraction (Affinity Water) receptor with 1% infiltration rate.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	103	0	1,058	-	-
Benzene	0.001	0.002	0	1,059	-	-
Xylene	0.03	0.032	0	1,063	-	-
Anthracene	0.0001	0.397	0	1,320	-	-
Benzo(a)pyrene	0.00001	0.074	0	2,252	-	-
TPH Aro C12-C16	0.09	0.453	0	1,117	-	-
TPH Aro C16-C21	0.09	1.38	0	1,205	-	-
TPH Aro C21-C35	0.09	4.12	0	2,225	-	-
1,2,4-trimethylbenzene	0.001	0.894	0	1,098	-	-
Mecoprop	0.0001	0.003	0	1,071	-	-
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

Output from Level 3 soils assessment for proposed landfill development for BH55 – 150 m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	83	0	1,058	-	-
Benzene	0.001	0.002	0	1,059	-	-
Xylene	0.03	0.032	0	1,063	-	-
Anthracene	0.0001	0.326	0	1,320	-	-
Benzo(a)pyrene	0.00001	0.084	0	2,252	-	-
TPH Aro C12-C16	0.09	0.485	0	1,117	-	-
TPH Aro C16-C21	0.09	1.355	0	1,205	-	-
TPH Aro C21-C35	0.09	5.59	0	2,225	-	-
1,2,4-trimethylbenzene	0.001	0.650	0	1,098	-	-
Mecoprop	0.0001	0.003	0	1,071	-	-
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

Output from Level 3 soils assessment for proposed landfill development for Compliance Point – 50 m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	92	0	1,058	-	-
Benzene	0.001	0.002	0	1,059	-	-
Xylene	0.03	0.032	0	1,063	-	-
Anthracene	0.0001	0.274	0	1,320	-	-
Benzo(a)pyrene	0.00001	0.055	0	2,252	-	-
TPH Aro C12-C16	0.09	0.688	0	1,117	-	-
TPH Aro C16-C21	0.09	1.51	0	1,205	-	-
TPH Aro C21-C35	0.09	3.42	0	2,225	-	-
1,2,4-trimethylbenzene	0.001	0.655	0	1,098	-	-
Mecoprop	0.0001	0.003	0	1,071	-	-

Note:
Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value

B2 5m Unsaturated zone thickness

Sensitivity analysis output from Level 3 soils assessment for 5m unsaturated zone- Potable abstraction (Affinity Water) receptor.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Antimony	0.005	0.13	0	86,128	-	-
Arsenic	0.01	0.02	0	171,464	-	-
Barium	0.7	1.21	0	38,490	-	-
Boron	1	7.15	0	2,984	-	-
Iron	0.2	10.37	0	75,503	-	-
Manganese	0.05	1.88	0	17,242	-	-
Nickel	0.02	0.06	0	171,464	-	-
Ammoniacal nitrogen	0.39	96.35	96.4	105.7	43.0	197
Thiocyanate	0.05	0.36	0	431,586	-	-
Benzene	0.001	0.00	0.002	106	0.001	229
Xylene	0.03	0.03	0.032	106	0.014	422
Anthracene	0.0001	0.36	0.36	132	0	14,516
Fluoranthene	0.0000063	0.27	0	6,236,520	-	-

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Benzo(a)pyrene	0.00001	0.08	0.08	225	0	65,653
TPH Ali C12-C16	0.3	0.76	0	4,743	-	-
TPH Ali C16-C21	0.3	3.08	0	368,488	-	-
TPH Ali C21-C35	0.3	15.79	0	368,488	-	-
TPH Aro C12-C16	0.09	0.43	0.43	112	0	3,401
TPH Aro C16-C21	0.09	1.39	1.39	120	0	8,248
TPH Aro C21-C35	0.09	3.62	3.62	222	0	64,163
1,2,4-trimethylbenzene	0.001	0.70	0.70	110	0	2,363
Mecoprop	0.0001	0.0028	0.0028	107	0.0007	880

Note:
Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value

Sensitivity analysis output from Level 3 soils assessment for 5m unsaturated zone – BH55 – 150m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Antimony	0.005	0.125	0	2,443	-	-
Arsenic	0.01	0.02	0	4,864	-	-
Barium	0.7	1.27	0	1,092	-	-
Boron	1	6.46	0	85	-	-
Iron	0.2	10.41	0	2,142	-	-
Manganese	0.05	2.23	2.23	489	0.86	705
Nickel	0.02	0.06	0	4,864	-	-
Ammoniacal nitrogen	0.39	101.67	101.7	3.00	96.9	3.84
Thiocyanate	0.05	0.36	0	12,243	-	-
Benzene	0.001	0.00	0.0021	3	0.002	4.2
Xylene	0.03	0.03	0.033	3	0.030	6.0
Anthracene	0.0001	0.45	0.45	4	0	138
Fluoranthene	0.0000063	0.27	0	176,910	-	-
Benzo(a)pyrene	0.00001	0.06	0.061	6	0.005	616
TPH Ali C12-C16	0.3	0.63	0.630	135	0	23,838
TPH Ali C16-C21	0.3	3.29	0	10,453	0	1,893,210

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
TPH Ali C21-C35	0.3	12.77	0	10,453	0	7,813,940
TPH Aro C12-C16	0.09	0.50	0.50	3	0.47	34
TPH Aro C16-C21	0.09	1.34	1.34	3	1.20	79
TPH Aro C21-C35	0.09	4.23	4.23	6	0.55	603
1,2,4-trimethylbenzene	0.001	0.64	0.64	3	0.61	24
Mecoprop	0.0001	0.00	0.0028	3	0.0027	10
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

Sensitivity analysis output from Level 3 soils assessment for 5m unsaturated zone – 50 m compliance point from landfill boundary.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Antimony	0.005	0.110	0	2,443.16	-	-
Arsenic	0.01	0.021	0	4,863.88	-	-
Barium	0.7	1.19	0	1,091.84	-	-
Boron	1	9.2	0	84.66	-	-
Iron	0.2	10.3	0	2,141.79	-	-
Manganese	0.05	1.940	1.94	489.09	0	3,789
Nickel	0.02	0.061	0	4,863.88	-	-
Ammoniacal nitrogen	0.39	92.2	92.2	3.00	54.0	15.95
Thiocyanate	0.05	0.37	0	12,242.70	-	-
Benzene	0.001	0.002	0.002	3.00	0.001	20.6
Xylene	0.03	0.033	0.033	3.01	0.021	48.0
Anthracene	0.0001	0.353	0.353	3.74		
Fluoranthene	0.0000063	0.333	0	176,910.00	-	-
Benzo(a)pyrene	0.00001	0.078	0.078	6.38	0	9,334
TPH Ali C12-C16	0.3	0.724	0.724	134.55	0	472

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
TPH Ali C16-C21	0.3	3.312	0.014	10,452.80	0	1,162
TPH Ali C21-C35	0.3	14.4	0	10,452.80	-	-
TPH Aro C12-C16	0.09	0.455	0.45	3.16	0.25	472
TPH Aro C16-C21	0.09	0.014	1.56	3.41	0	1,162
TPH Aro C21-C35	0.09	0.023	4.38	6.30	0	9,122
1,2,4-trimethylbenzene	0.001	0.500	0.50	3.11	0.31	324
Mecoprop	0.0001	0.003	0.00	3.03	0.0017	113

Note:
Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value

B3 Hydraulic conductivity

Output from Level 3 soils assessment for sensitivity analysis on hydraulic conductivity at Potable abstraction (Affinity Water) receptor.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	90	90	11	59.9	24
Benzene	0.001	0.002	0.002	11	0.0014	29
Xylene	0.03	0.033	0.0327	11	0.0217	58
Anthracene	0.0001	0.309	0.309	13	0	2,170
Benzo(a)pyrene	0.00001	0.098	0.0976	22	0	9,832
TPH Aro C12-C16	0.09	0.490	0.490	11	0.302	504
TPH Aro C16-C21	0.09	1.42	1.422	12	0	1,231
TPH Aro C21-C35	0.09	4.23	4.23	22	0	9,608
1,2,4-trimethylbenzene	0.001	0.653	0.653	11	0.457	349
Mecoprop	0.0001	0.003	0.0028	11	0.002	127
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

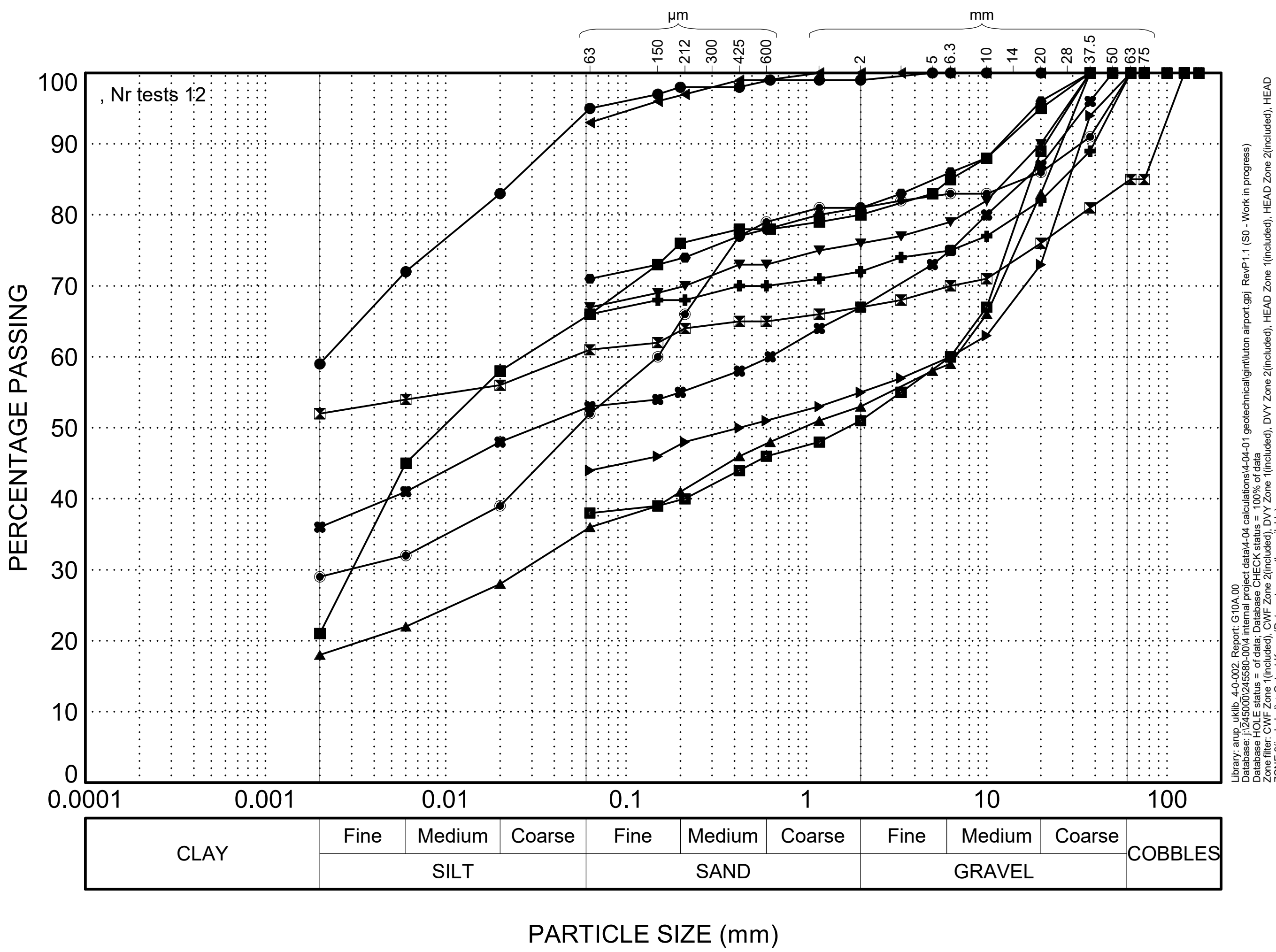
Output from Level 3 soils assessment for sensitivity analysis on hydraulic conductivity for BH55 – 150 m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	92	92	11	89.5	11.5
Benzene	0.001	0.002	0.0021	11	0.002	11.8
Xylene	0.03	0.032	0.032	11	0.032	13.7
Anthracene	0.0001	0.348	0.348	13	0.346	153.6
Benzo(a)pyrene	0.00001	0.078	0.078	22	0.002	661.4
TPH Aro C12-C16	0.09	0.464	0.464	11	0.462	43.3
TPH Aro C16-C21	0.09	1.360	1.360	12	1.357	91.4
TPH Aro C21-C35	0.09	3.57	3.57	22	0.333	646.6
1,2,4-trimethylbenzene	0.001	0.713	0.713	11	0.711	33.0
Mecoprop	0.0001	0.003	0.0027	11	0.003	18.2
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

Output from Level 3 soils assessment for proposed landfill development for sensitivity analysis on hydraulic conductivity for 50 m from landfill boundary.

Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to receptor (5% are less than)
Ammoniacal nitrogen	0.39	102	102	11	102	11
Benzene	0.001	0.002	0.0324	11	0.002	11
Xylene	0.03	0.032	0.0324	11	0.0322	12
Anthracene	0.0001	0.395	0.395	13	0.3938	67
Benzo(a)pyrene	0.00001	0.063	0.0631	22	0.0112	269
TPH Aro C12-C16	0.09	0.509	0.5092	11	0.5078	24
TPH Aro C16-C21	0.09	1.26	1.260	12	1.2571	43
TPH Aro C21-C35	0.09	3.80	3.801	22	1.3671	263
1,2,4-trimethylbenzene	0.001	0.716	0.716	11	0.7144	19
Mecoprop	0.0001	0.003	0.0027	11	0.0027	14
Note: Cells shaded indicate contaminants reaching receptor within 1,000 years at concentrations above guideline value						

Appendix C- Solution Features



- ● AEC18-LF-BH204, 131.4mOD
- ■ AEC18-LF-BH204, 131.4mOD
- ▲ AEC18-LF-BH212, 128.7mOD
- ✖ AEC18-LF-GW202, 143.1mOD
- ⬢ ARP16-CP-BH16, 133.9mOD
- ▼ ARP16-CP-BH40, 132.7mOD
- ✚ ARP16-CP-TP24, 133.3mOD
- ◘ ARP16-CP-TP39, 130.2mOD
- ◀ ARP16-CP-TP39, 127.8mOD
- ▶ ARP16-LF-BH03, 139.3mOD
- ⧗ ARP16-LF-BH05, 144.0mOD
- ◉ PFCPRC45 (SP), 142.0mOD

ARUP_gINT v8.30.003
Made by John-J Lucas on 1-Oct-19

Particle Size Distribution
Dissolution Features

245580-00

GRAPH 13-1