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Preliminary Environmental Information Report

Volume 3: 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 quantitatively assess the risks in relation to land contamination identified within the Preliminary Risk Assessment (PRA) (Ref. 1). It presents a detailed quantitative risk assessment relating to controlled waters for Area A which is an historical landfill. It is intended that this report is read in conjunction with the PRA and GQRA. (Ref. 2).

1.1.3 The proposed development is described in detail in **Section 2.4** of the GQRA.

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. Results of the most recent ground investigation completed in 2018 are presented in the GQRA. Data from these reports has been used in preparing this assessment.

1.3 Limitations

This report has been prepared for Luton Rising and takes into account their particular instructions and requirements. The benefit of this report may not be assigned to any third party. All reasonable skill, care and diligence have been exercised within the timescale available in accordance with the technical requirements of the brief. Notwithstanding the efforts made by the professional team by undertaking the assessment and preparing the report, it is possible that other ground contamination or conditions as yet undetected may exist and consequently reliance on the findings of this report must be limited accordingly.

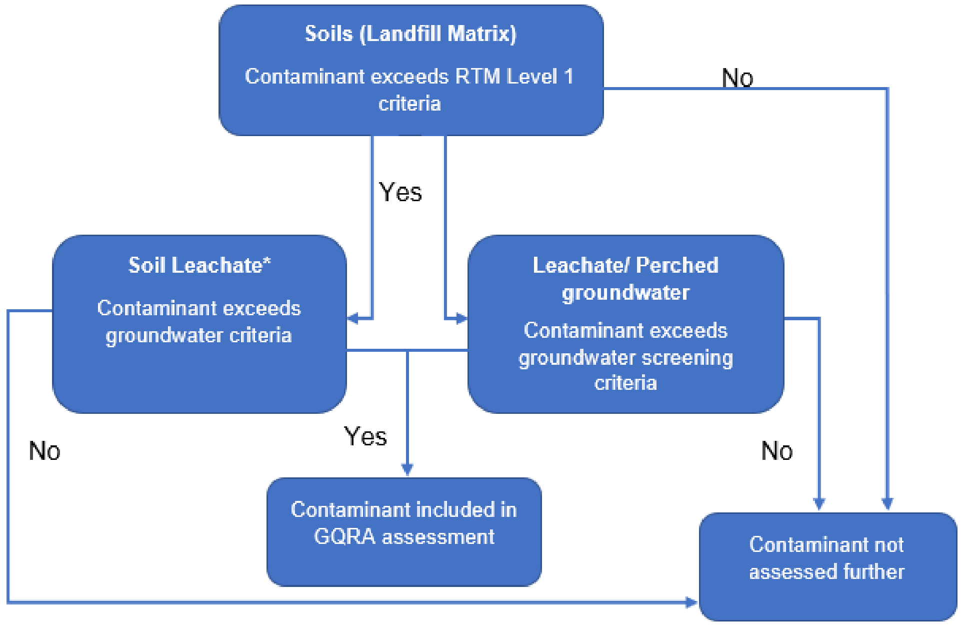
[1] LCRM was published in 2020 and replaced "CLR11 Model Procedures for the Management of Contaminated Land" (2004).

2 BASELINE CONTROLLED WATERS DETAILED QUANTITATIVE RISK ASSESSMENT

2.1 Contaminants of concern

2.1.1 A GQRA 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 **Error! Reference source not found.**. 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)[3]



*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 undertaken indicated that overall 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 within the groundwater.

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

The contaminants of concern identified from the GQRA which required further detailed assessment are summarised **in Table 2.1.**

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 perfluorinated 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 it is likely that 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 it is pertinent to note that 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. Further monitoring and assessment will be required once this guidance is available. Whilst the GQRA 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 identified that the controlled waters PCLs shown in **Table 2.2** below and **Figure 1** required further DQRA. **Table 2.3** includes the PCLs which were assessed in the GQRA as not requiring further detailed assessment, but measures are required to be included in the Remediation Strategy

2.2.2 It has been indicated within Table 2.2 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:

(orange)	Confirmed relevant contaminant linkage (RCL) require inclusion in the Remediation Strategy
(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 Remediation Strategy.
(green)	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[4]	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 undertaken indicated that overall 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 localised areas. 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						

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

Table 2.3: PCLs which do not require further assessment but require further consideration in the remediation strategy

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 has indicated that there are isolated hot spots of contaminants present and a localised area of free product was encountered at location WS224. Care will be required during construction not to create a pathway. This may involve localised remove of hotspots in locations where works may create a pathway. Incorporation of localised removal at select locations in remediation strategy for site to reduce potential for creation of pathways. Risk from piling and construction can be mitigated by completion of piling 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	GQRA indicated that perched water was present in some locations within the landfill. The GQRA indicated that there are isolated hot spots of contaminants present and a localised area of free product. Care will be required during construction not to create a pathway. This may involve localised remove of hotspots in locations where works may create a pathway. Risk from piling and construction can be mitigated by completion of piling risk assessment report to

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative assessment of risk	Justification of Qualitative Assessment of Risk
						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	Survey and assessment of purpose of drain passing through landfill to be undertaken and incorporated into design. Measure to be incorporated in design to prevent creation of preferential pathway.
39	CON	Contaminants in Made Ground (car park, capping material)	Balancing pond	Principal aquifer in Chalk	Very Low	Thames Water balancing pond present in the north of the former landfill area, it 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 hydrogeological regime

3.1.1 The hydrogeological regime is discussed in detail in the GQRA and a detailed review of the hydrogeological conditions beneath the site has been undertaken and is provided in the following report:

a. Luton Rising (2021) Hydrogeological Characterisation Report. LLADCO-3B-ARP-00-00-RP-CG-0001 (Ref. 4).

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. 3).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. 5) 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, 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 (1219 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. The following assumptions have been considered for the initial DQRA assessment, these include:

a. The GQRA suggested that there is 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;**

b. As detailed above no obvious accumulations of contamination were noted in the analysis in the chemistry. However, the landfill was operated during a period where there were no controls on disposal and as such it is heterogenous in nature. Therefore, given the likely 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);**

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. 6) 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. The Level 3 assessment allows concentrations of each contaminant of concern in soil to be modelled at compliance points downstream 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 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**):

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 in groundwater flow direction on the flowpath 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 south east of the landfill. As this is opposite to the predominant groundwater flow direction, it is considered that use of the above as receptors will also be protective of the private water supplies.

Input parameters

3.4.12 The main hydrogeological model input parameters are provided in **Table 3.1** and **Error! Reference source not found.**. The following assumptions have been made and modelled during the production of the ConSim 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 assumed in the unsaturated zone;

e. No biodegradation is assumed;

f. Background groundwater concentrations have been assumed to be zero;

g. 1001 iterations of the simulation have been applied;

h. Time slices varying from 10-7000 years have been modelled; and

i. Mixing zone thickness is calculated in ConSim. ConSim estimated 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	1.20	g/cm3	Value for sandy clay loam, listed in Table 4.4 of the CLEA Report SR3, pg.62
Air filled soil porosity	0.16	fraction	Value for sandy clay loam, listed in Table 4.4 of the CLEA Report SR3, pg.62
Water filled soil porosity	0.37	fraction	Value for sandy clay loam, listed in Table 4.4 of the CLEA Report SR3, pg.62
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)
Source term- concentrations			
Soils (landfill matrix)	Log-triangular distribution		Soil leachate or leachate/perched leachate concentration. Source input concentrations provided in **Appendix A.**
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.**
Aquifer properties			
Saturated aquifer thickness	5	m	Assumed saturated thickness for the Chalk. This is considered to be conservative value.

Parameter	Value	Units	Data Source
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/cm3	Average site data for Chalk (range of 1.23 mg/m3 to 2.26 mg/m3)
Effective matrix porosity of aquifer	0.3	fraction	Table 4.7 of CIRIA C574, 2002, Engineering Properties of Chalk
Effective porosity of fissures	0.1	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 [1].
Groundwater flow			
Infiltration – current state	611	mm/yr	Long term average rainfall (1961-1990) for Lee-Chalk (pg.26 of Atkins, 2007, Environment Agency Vale of St Albans Groundwater Model, Phase 1)
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

Parameter	Value	Units	Data Source
			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
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. 3)			

3.5 Criteria for determining significance

3.5.1 A line of evidence approach has been used when determining the significant of the results in relation to the groundwater receptors. 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 contaminant concentration occurring above assessment criteria at modelled compliance points based on the predicted ConSim travel times; and

d. The magnitude, consistency and frequency of exceedances of contaminants in the groundwater has been considered when defining their significance. This is consistent with Environment Agency guidance on defining trivial exceedances (Ref. 7). 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 provides an assessment of concentration of contaminants entering the water table (base of the unsaturated zone) from the landfill (either as soil leachate or landfill leachate) and a prediction of the concentration of these 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.**

4.2.2 The results in indicated that the following contaminants were predicted 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

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

- The highest concentrations of these contaminants were detected within the perched water at WS224. Other locations only marginally exceed the assessment criteria and were within an order of magnitude. WS224 was noted within GQRA as an having heavy black staining between 4-5m bgl, suggesting the presence of localised product (see Section 10.2.8 GQRA). 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;
- The presence of these contaminants in the landfill leachate and perched water suggests that although these contaminants are present in the landfill, they are not reaching the groundwater either because they are being attenuated in the unsaturated zone or sorbed to organic material within the landfill, as such there is not a significant source of these contaminants. Therefore, further consideration of these contaminants is not required.

Anthracene and benzo(a)pyrene

- Concentrations of anthracene and benzo(a)pyrene observed in the groundwater beneath the landfill have only been marginally above the detection limit on two occasions and were below the groundwater assessment criteria. Neither of these contaminants have been detected in the groundwater downgradient of the landfill above the limit of detection. The exceedances beneath the landfill were noted in different locations on individual monitoring rounds, all other occasions these contaminants were below limit of detection;
- 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 the CL:AIRE guidance (Ref. 8) which indicates that 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;
- These contaminants are not being continuously detected and have not been detected in the groundwater downgradient despite significant monitoring being undertaken, the detections appear to be random spikes and 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. 7). Given the factors discussed above and that the travel times suggest these contaminants are not particularly mobile, further consideration of these contaminants is not required.

Aromatic TPHs

- Aromatic TPHs were detected at elevated concentrations within the landfill leachate at several locations **(see Figure 2).** 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 should reach borehole BH55 (150m from landfill boundary) within 40, 82 and 576 years respectively. Therefore, 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, the groundwater monitoring indicated that none of the TPH fractions exceeded the groundwater criteria below the landfill or downgradient **(see Figure 2).** Figure 2 shows the exceedances of these contaminants within the landfill leachate and perched water overlaid on the groundwater concentration contours;
- These compounds are known to have a relatively low mobility in groundwater [2]. This suggests that although these contaminants are present in the landfill, they are not reaching the groundwater either because they are being attenuated in the unsaturated zone or sorbed 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.**

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 groundwater criteria in the groundwater sampled from beneath the landfill in the GQRA **(see Section 0)** 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 4.7.** The source concentrations and physiochemical parameters used in the modelling are presented in **Appendix A.**

4.2.7 The following contaminants are predicted to reach the 50m compliance point above the groundwater 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.**

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
Nitrate	50	325	65.4

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	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
Trichloroethene	0.01	6	0.028

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)
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 proposed development

Earthworks

4.3.1 As detailed in the GQRA 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 will be detailed in the Remediation Strategy. 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.**

4.3.3 Without the development the following contaminants are predicted to reach the 50m compliance point **(see Table 4.8)** 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) **(Table 4.7)** with the exception of anthracene.

4.3.5 The following contaminants were predicted to reach the groundwater abstraction point above the groundwater guideline value within 1,000 years (**Table 4.5**):

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

4.3.6 The results indicate that the reduced infiltration that will result 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

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.**

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
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.**

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	-	-

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	0.08	0.080	0.12	223.6	-	-
TPH Ali C12-C16	0.66	0	0	4,716	-	-
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 modelling are adjusted. This analysis lets the most sensitive parameters be identified 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. 9) **Table 5.1** 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- GQRA). Hydraulic conductivity can vary due to weathered chalk and also 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 onto which hydrophobic contaminants may be sorbed and so slows contaminant transport. No further data available to refine estimate. 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. There is also steepening of the hydraulic gradient during periods of high groundwater (Ref. 4). 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 (Ref. 4) 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 available. Literature values are often inappropriate as are not specific to site 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 an important potential direct pathway to the aquifer from the landfill. As noted in Section 5.5.3 of the GQRA, the GI noted solution pipes and infilled fissures to be present beneath the landfill. The particle size analysis undertaken on the infill of solution features **(provided in Appendix C)** 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 4×10^{-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 present in **Error! Reference source not found.** 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 $\times 10^{-6}$		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. 4) 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 Hydrogeological Characterisation report (Ref. 4)			

5.4 Results

Infiltration

5.4.1 The results of the sensitivity analysis indicated that infiltration is a key parameter in determining both the concentration and travel time of contaminants to the receptors.

5.4.2 The results indicated reducing the infiltration to 1% resulted in no contaminants of concern breaking through the base of the unsaturated zone and reaching the receptors within 1,000 years. At 5% and 10% infiltration rates several contaminants of concern still break through the unsaturated zone and reach the receptors. Full results are provided in **Appendix B.**

5.4.3 Minimising infiltration 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 the retarded travel time. Full results are provided in **Appendix B.** Similar contaminants were found to break through the unsaturated zone when compared to the 17.5m unsaturated zone which was previously modelled. However, the 5m unsaturated zone predicted that contaminants reach the receptor faster. For example, for ammoniacal nitrogen the retarded travel time was precited to be 16 years for a 5m unsaturated zone and 24 years for the 17.5m unsaturated zone.

5.4.5 Therefore, during 1 in 100-year groundwater events there is the potential for transport of contaminants to occur quicker 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.

Hydraulic conductivity

5.4.6 Hydraulic conductivity is a sensitive parameter in relation to rate of contaminant transport and arrival at the receptor (Ref. 9) 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, however, the travel times were slower and predicted concentrations were slightly less. Overall it does not make a significant difference to the assessment.

6 DISCUSSION

6.1.1 The ConSim Level 3 assessment for soils indicated that based on current baseline conditions at the landfill the following contaminants were predicted 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 The potential risk to groundwater that the presence of these contaminants of concern in the soils in the landfill presents is discussed further below in Section 5.2. These contaminants were assessed further in the ConSim Level 3a assessment.

6.1.3 The ConSim Level 3a assessment analysed the contaminants identified in the GQRA as contaminants of concern in groundwater. In addition, the boron, ammoniacal nitrogen and mecoprop identified as contaminants of concern from the Level 3 assessment were also included.

6.1.4 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 1000 years. However, the following contaminants were also predicted to reach BH55 at concentrations exceeding the groundwater guideline values within 1000 years:

a. ammoniacal nitrogen;

b. boron;

c. nitrate; and

d. vinyl chloride.

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

6.2 Contaminants of concern

Boron

6.2.2 Boron was detected in the soils within the landfill, 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 10). Groundwater concentrations observed suggest that the concentrations decline rapidly away from the landfill as shown in **Figure 2 and Table 6.1.**

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
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 concentrations of boron detected in groundwater in BH55 also suggest this is the case as the detected concentrations 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 GQRA).**

6.2.5 Therefore, 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, this is discussed further in the ammoniacal nitrogen section below.

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. 11).

6.2.7 It is frequently present in landfill leachate and was detected in 98% of UK leachates sampled (Ref. 12). 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 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 3000µg/l in groundwater downgradient of the landfill [11]. 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. 13).

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** and **Figure 2** 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.** 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; and
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.** This is supported by the ConSim Level 3a groundwater modelling which indicated that the concentrations did not exceed the DWS, 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).** 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**. 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 also predicted that the 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 guideline values 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.**

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 may not be 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).** 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 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**. Down gradient boreholes only had localised exceedances of nitrate in groundwater **(see Figure 2).** 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 guideline values 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**.**

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 concentrations rapidly decline away from the landfill. Therefore, the nitrate concentration may be associated with a weak leachate plume which is rapidly dispersed/attenuated **(as discussed above in Section 6.2.20).** 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).** 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 levels (within an order of magnitude of the groundwater criteria) but was not detected within the landfill material or down gradient, with the exception of low levels 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**

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

Media	Assessment criteria	Units	No. of exceedances/ (no. samples)	Maximum concentration (µg/kg or µg/l)
Leachate	0.5	µg/l	2/(40)	7.04
Groundwater beneath landfill			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 guideline values 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.**

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).** 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 may be required once this guidance is available. So although monitoring suggests that the risk with respect to 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 piling 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 hot spots of contaminants are present within the landfill and a small amount of free product was encountered at location WS224.It is proposed in the remediation strategy 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 1000 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 The sensitivity analysis indicated that minimising the rate of infiltration into the landfill is key for preventing contaminants 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 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 remediation strategy will include measures to detect and appropriately deal with such accumulations.

6.3.10 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 **Section Error! Reference source not found.** 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 require further consideration within the remediation strategy.

7.1.2 The PCLs have been classified as follows:

(orange)	Confirmed relevant pollutant linkage (RCL) require inclusion in the Remediation Strategy
(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 Remediation Strategy.
(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[5]	Downward migration of leachate	Principal aquifer in Chalk	Moderate/ Low	DQRA has identified the potential for downward migration of leachate from the landfill. A weak leachate plume appears to be present immediately down gradient of the landfill, however groundwater monitoring completed to date does not suggest there is a significant contaminant plume affecting the aquifer. 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 all infiltration 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	Overall there were relatively few exceedances of potential contaminants of concern recorded in groundwater beneath the site. DQRA indicated that whilst there is evidence of a weak leachate plume in groundwater down-gradient of the site, on-site

[5] 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)		groundwater monitoring provides little evidence that the landfill is causing significant contamination of the 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 all 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, it was based upon a cautious assessment of the GI data and reasonably conservative assumptions about ground conditions and hydrogeology.

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 100 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, it should be noted that 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 it is anticipated that 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 piling 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 remediation strategy should be 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. The remediation strategy will include 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 in this regard.

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

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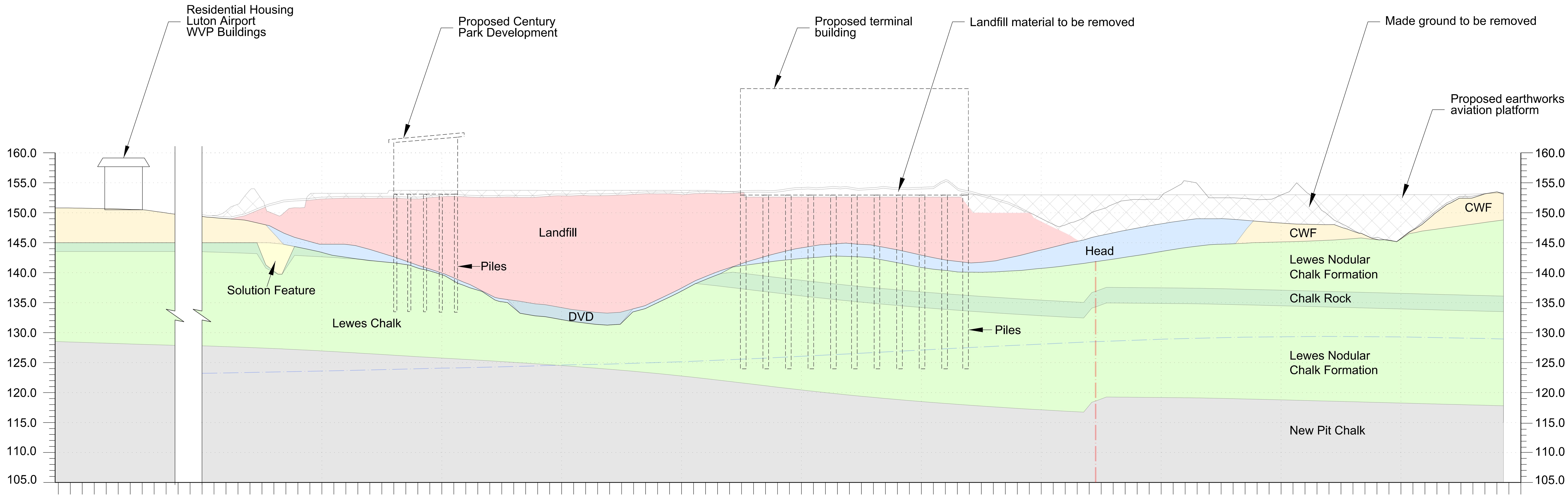
FIGURES

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.

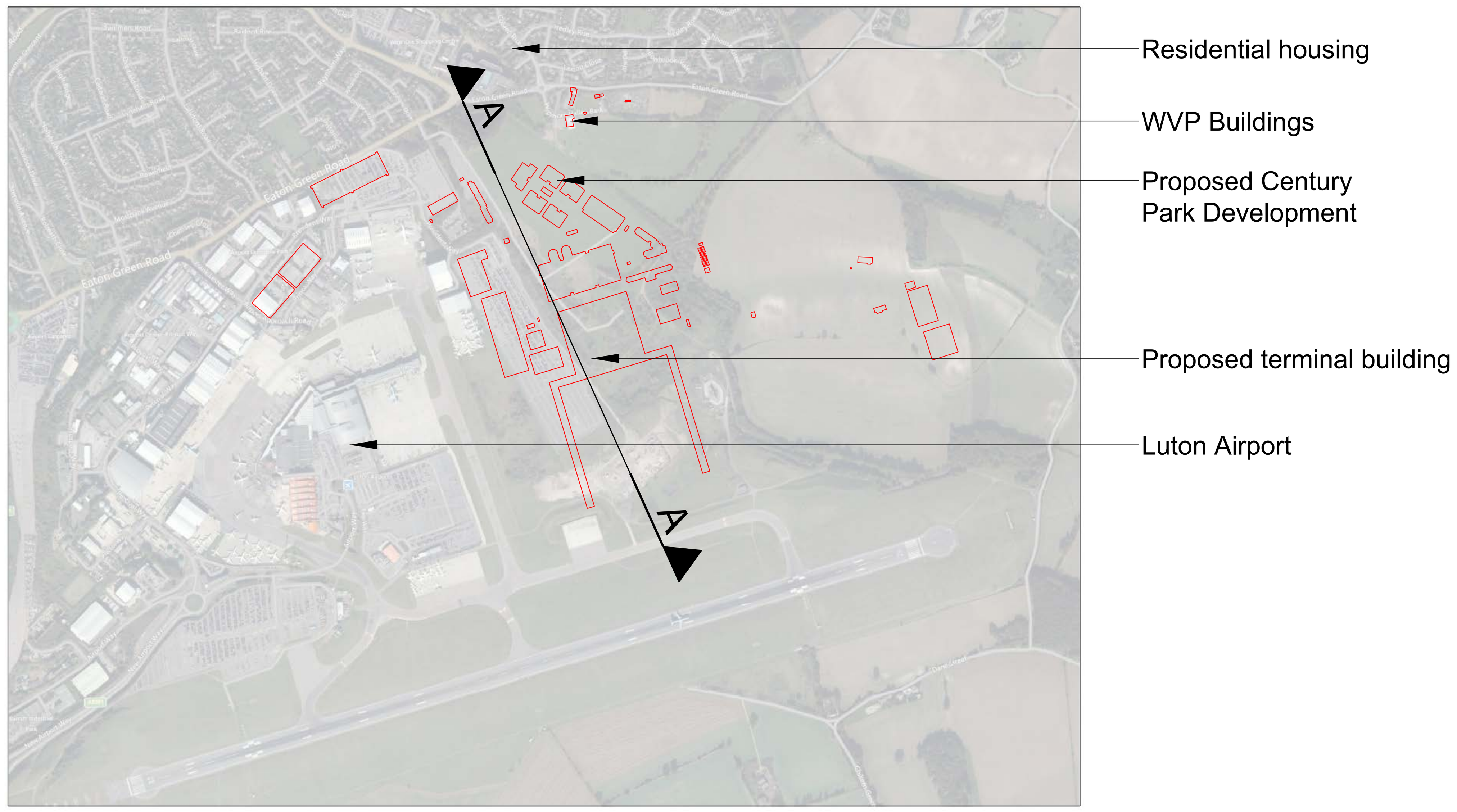
Conceptual Site Model Potential Contaminant Linkage No.

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	16/12/21	P01

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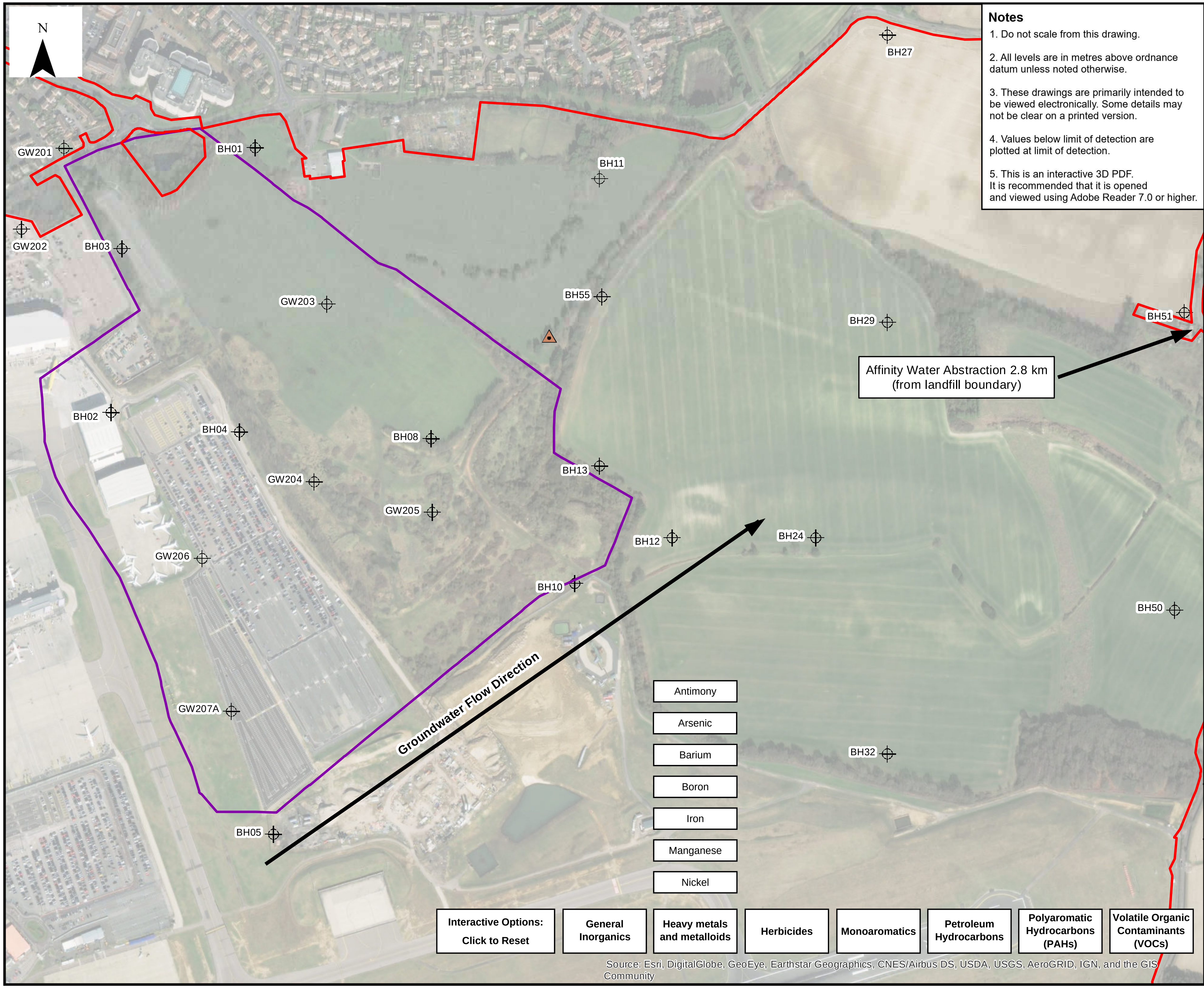
Drawing Title

Figure 01
Conceptual Site Model (CSM)

Purpose of issue				Suitability	
SUITABLE FOR COORDINATION				S2	
Drawn	Checked	Approved	Date	Scale	Size
IJ	RB	TB	16/12/21	NTS	A1
DCO Application Ref. TR020001	APFP Regulation	DCO Document Ref.			
Drawing Number LLADCO-3C-ARP-00-00-DR-YE-0183				Revision P01	
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.

Legend

- Proposed Development Boundary
- Interpreted Landfill Boundary
- 50m Compliance Point
- Groundwater Monitoring Boreholes

Revision History	Drawn	Checked / Approved	Date	Rev.
First Issue	AB	RB / TB	15/12/21	P01

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Drawing Title
Figure 2
Controlled Waters Risk Assessment Results

Purpose of issue	Suitability
SUITABLE FOR INFORMATION	S2

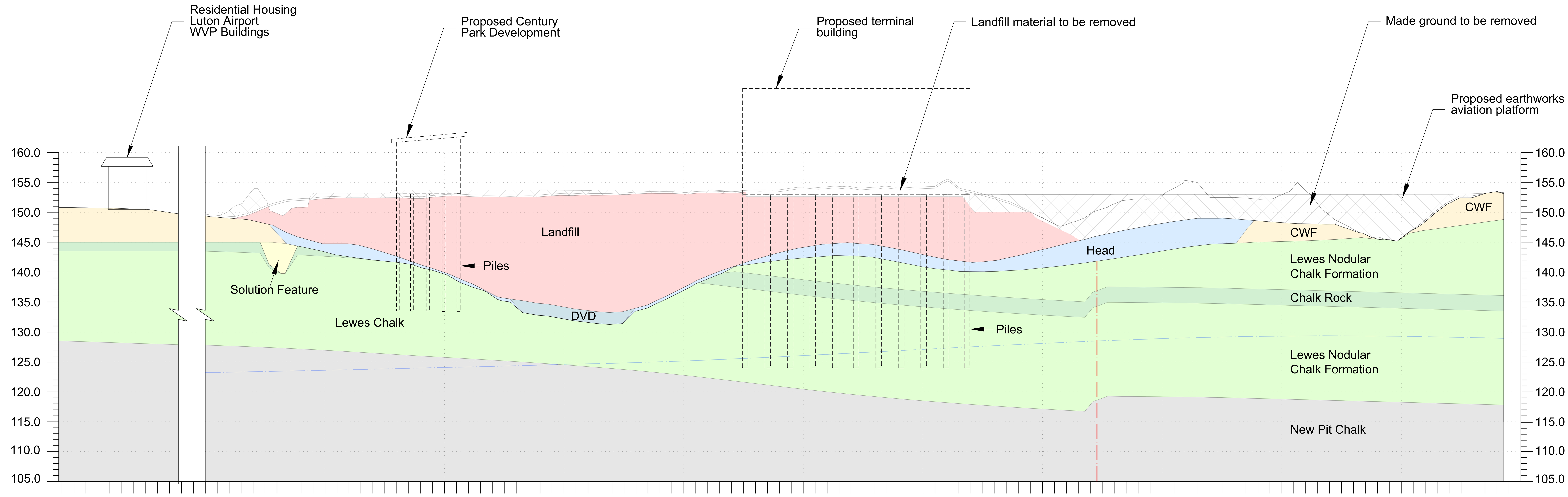
Drawn	Checked	Approved	Date	Scale	Size
AB	RB	TB	15/12/21	1:5,000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001		

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0184	P01

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 GQRA Table 13-1) or the sources below can be clicked to display the relevant pathway and receptors.

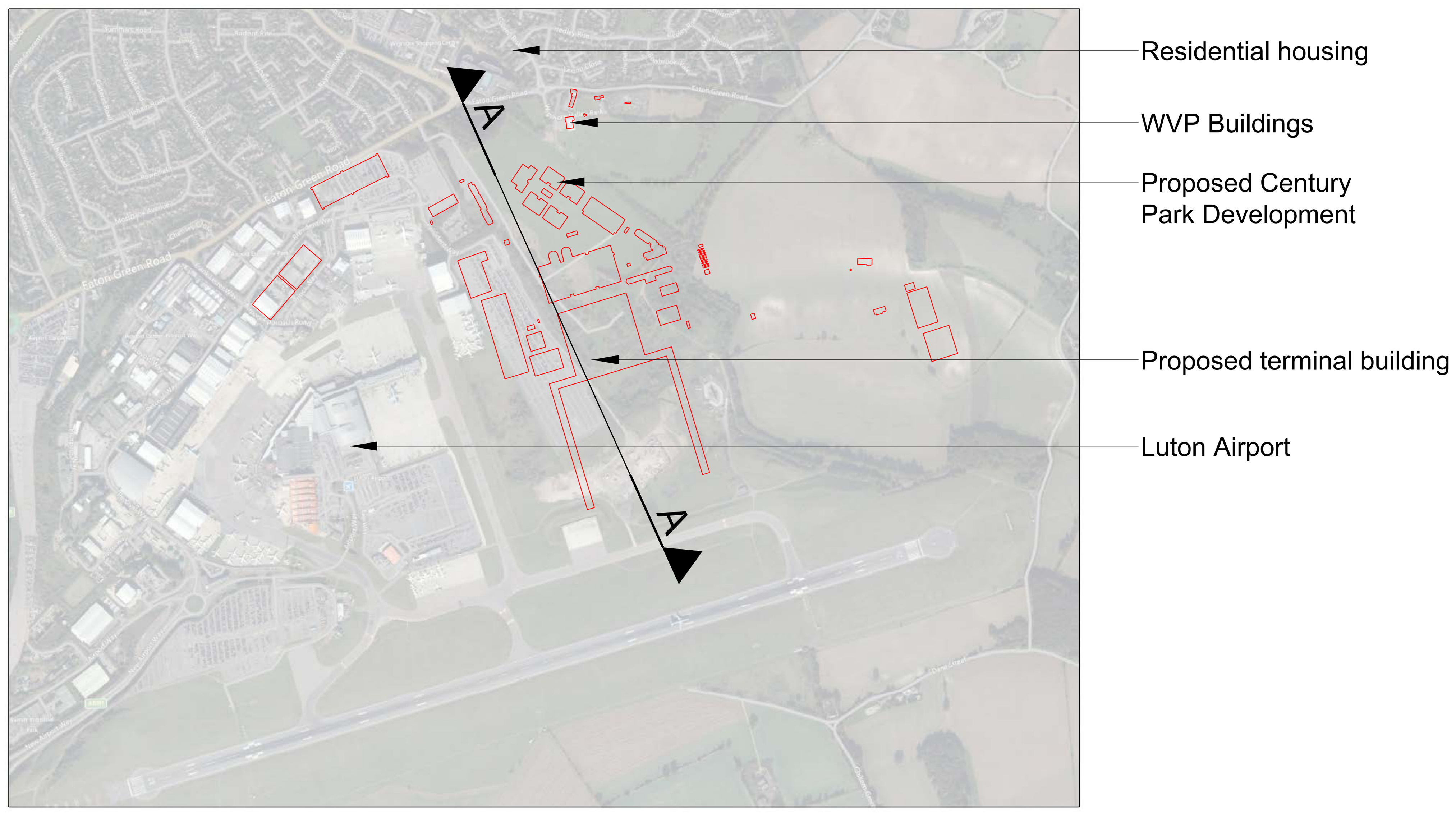
Conceptual Site Model Potential Contaminant Linkage No.

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

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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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	16/12/21	P01

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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	16/12/21	NTS	A1
DCO Application Ref.	APFP Regulation	DCO Document Ref.			
TR020001					

Drawing Number: LLADCO-3C-ARP-00-00-DR-YE-0185
Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Revision: P01

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) http://www.gsi-net.com/publications/gsi-chemical-database/list.html [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 (http://esinternational.com/wp-content/uploads/2003-08-01-EA-Ammonium-ISBN-1-84432-110-1.pdf)*

[h] *No degradation assumed*

[i] *Pubchem online database (https://pubchem.ncbi.nlm.nih.gov/) accessed 1/10/2019*

[j] *NIH- National Library of Medicine TOXNET Chem ID (http://chem.sis.nlm.nih.gov/chemidplus) 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	1098	-	-
Mecoprop	0.0001	0.003	0	1,071	-	-

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)
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	1098	-	-
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	1098	-	-
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

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)
Fluoranthene	0.0000063	0.27	0	6,236,520	-	-
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	1092	-	-
Boron	1	6.46	0	85	-	-
Iron	0.2	10.41	0	2142	-	-
Manganese	0.05	2.23	2.23	489	0.86	705
Nickel	0.02	0.06	0	4864	-	-
Ammoniacal nitrogen	0.39	101.67	101.7	3.00	96.9	3.84
Thiocyanate	0.05	0.36	0	12243	-	-
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	176910	-	-
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	23838

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	3.29	0	10453	0	1893210
TPH Ali C21-C35	0.3	12.77	0	10453	0	7813940
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	2443.16	-	-
Arsenic	0.01	0.021	0	4863.88	-	-
Barium	0.7	1.19	0	1091.84	-	-
Boron	1	9.2	0	84.66	-	-
Iron	0.2	10.3	0	2141.79	-	-
Manganese	0.05	1.940	1.94	489.09	0	3789
Nickel	0.02	0.061	0	4863.88	-	-
Ammoniacal nitrogen	0.39	92.2	92.2	3.00	54.0	15.95
Thiocyanate	0.05	0.37	0	12242.70	-	-
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	176910.00	-	-
Benzo(a)pyrene	0.00001	0.078	0.078	6.38	0	9334

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 C12-C16	0.3	0.724	0.724	134.55	0	472
TPH Ali C16-C21	0.3	3.312	0.014	10452.80	0	1162
TPH Ali C21-C35	0.3	14.4	0	10452.80	-	-
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	1162
TPH Aro C21-C35	0.09	0.023	4.38	6.30	0	9122
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	2170
Benzo(a)pyrene	0.00001	0.098	0.0976	22	0	9832
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	1231
TPH Aro C21-C35	0.09	4.23	4.23	22	0	9608
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

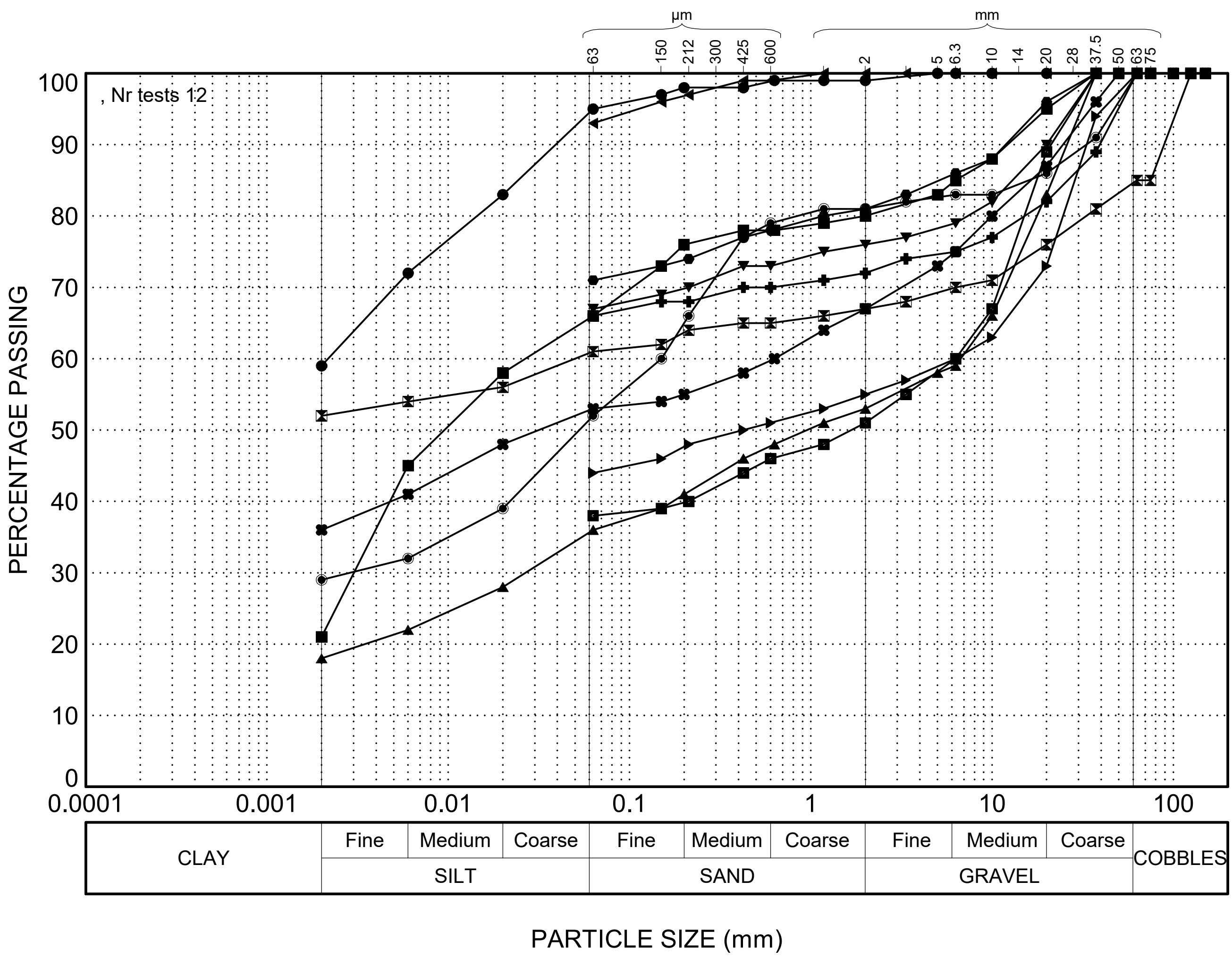
Contaminant	Guideline value (mg/l)	Made ground concentration (95% of values less than) (mg/l)	Base of unsaturated zone concentration (95% of values less than (mg/l) at 1,000 years)	Retarded travel time to base of unsaturated zone (5% are less than) (years)	Concentration at receptor (95% of values less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



Library: arup_uklib_4-0-002. Report: G10A.00
Database: j:\245000\245580-00\4 internal project data\4-04 calculations\4-04-01 geotechnical\gint\luton airport.gpj RevP1.1 (S0 - Work in progress)
Database HOLE status = of data; Database CHECK status = 100% of data
Zone filter: CWF Zone 1(included), CWF Zone 2(included), DVY Zone 1(included), DVY Zone 2(included), HEAD Zone 1(included), HEAD Zone 2(included), HEAD ZONE 3(included) + Output Keys: (Data not currently available)
Filter: None.
Range filter: Include Top, [GEOL].[Depth], [GEOL].[GEOL_BASE], [GEOL].[GEOL_GEOL], ([GEOL].[GEOL_GEOL] = 'PIPE')

- ● 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

Particle Size Distribution
Dissolution Features