MICK GEORGE

ENVIRONMENTAL PERMIT APPLICATION
HYDROGEOLOGICAL RISK ASSESSMENT

HUSBANDS BOSWORTH QUARRY
WELFORD ROAD
HUSBANDS BOSWORTH
LEICESTERSHIRE
LE17 6JH

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HYDROGEOLOGICAL RISK ASSESSMENT – HUSBANDS BOSWORTH QUARRY, WELFORD ROAD, HUSBANDS BOSWORTH, LEICESTERSHIRE, LE17 6JH

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1.0 INTRODUCTION

1.1 Scope & Background

1.1.1 Sirius Environmental Limited (Sirius) has been commissioned by Mick George Limited (Mick George) to prepare an Environmental Permit Application to operate an Inert Landfill facility to support the restoration of Husbands Bosworth Quarry, Husbands Bosworth, Leicestershire.

1.1.2 The location of Husbands Bosworth Quarry is presented in **Drawing No. MG1001/14/01**.

1.1.3 The inert waste landfill will fill the void created by sand and gravel extraction operations. A total landfill void space requiring an approximate volume of restoration material of 1,300,000m^3 of inert waste will be imported, which is a low-risk waste type.

1.1.4 This assessment is prepared in accordance with the Environment Agency guidance: Groundwater risk assessment for your environmental permit (last updated 3rd April 2018). The Environment Agency is required to ensure that the activities are subject to prior investigation and a pollution risk assessment.

1.1.5 This report should also be read in conjunction with the Environmental Setting and Site Design report *(Doc. Ref.: MG1001/07)* which accompanies the wider Environmental Permit application.

2.0 Conceptual Hydrogeological Model

2.1 General

2.1.1 The details of the proposed design and the environmental setting of the site are set out in the Environmental Setting and Site Design (ESSD) Report *(Doc. Ref:* MG1001/07*)* and are summarised below:

- infilling will take place in a void created by the extraction of superficial sand and gravel deposits;
- the mineral extraction operations will result in the removal of a significant proportion of the storage and recharge potentially of the superficial deposits;
- the inert landfill will be constructed within the superficial sand and gravel deposits with an engineered sidewall geological barrier with a maximum permeability equivalent to 1m at $1x10^{-7}$ m/s.
- the base of the landfill will be formed over the underling mudstones of Dyrham Formation and Charmouth Formation, which are approximately 10m and 132m thick locally respectively and have field permeabilities of approximately between $5x10^{-6}$m/s to $1x10^{-9}$m/s and the Charmouth Formation is approximately $1x10^{-7}$m/s respectively;
- the site will accept only inert waste; and
- due to the nature of the waste streams, leachate collection systems and an artificial sealing liner are not required.

2.1.2 Comprehensive details on the hydrogeological setting of the site are provided within the ESSD report *(Doc Ref.: MG1001/07)*, and include the following:

- aquifer characteristics;
- groundwater flow and quality;
- groundwater quality;
- licensed groundwater abstractions; and
- Source Protection Zones.

2.1.3 The conceptual hydrogeological site model is based on the source-pathway-receptor linkages. The conceptual model is shown in **Drawing No. MG1001/14/13** and key elements of the hydrogeological model are discussed in further detail below.

2.2 Source

2.2.1 The restoration operations of Husbands Bosworth Quarry will principally be carried out as an inert landfill site within the void of the sand and gravel quarry. The landfill source term has accordingly been determined from inert WAC thresholds allowed under the Council Decision of 2003/33/EC, taking into account the site's hydrogeological setting

<u>Site Design and Construction</u>

2.2.2 The site design is detailed within the accompanying ESSD (*Doc Ref.: MG1001/0*7) and is summarised below.

2.2.3 The inert landfill void will be located within superficial deposits that principally comprised Glacio-fluvial sands and gravels with variable thicknesses of the overlying till, river terrace and alluvium. The permeabilities of the sand and gravels at the site have not been tested. A study carried out by MacDonald et al. (2009) returned median permeabilities for glaciofluvial deposits between the range of $7x10^{-5}$ m/s and $1x10^{-4}$ m/s. A study further carried out by Hafren (2001) indicated that the glaciofluvial and fluvial sand and gravels deposits within the vicinity of Colchester retuned a permeability range of 5.79×10^{-5} m/s and 6.24×10^{-4} m/s; with an average permeability of 3.4×10^{-4} m/s.

2.2.4 The base of the inert landfill void will be constructed on top of the underlying mudstones and siltstones of the Dyrham Formation shales and mudstones of the Charmouth Formation. Both lithologies are described to comprise some or impersistent sandy beds or sandstones, although no such horizons have been encountered within the exploratory holes drilled through the upper weathered sections of these units within the and immediately surrounding the quarry. BGS recorded boreholes logs within 1km of the site show that these formations extent to depths of over 130m. The permeability of these formations are recorded to be less than 10^{-7} m/s. These bedrock units are therefore considered to represent natural geological barriers that meets with the standard requirements of the Landfill Directive for inert landfills.

2.2.5 An Artificially Enhanced Geological Barrier (AEGB) will therefore need to be constructed across the sidewalls of the quarry to meet the minimum standards set-out in the Landfill Directive. The proposed sidewall geological barrier will be at least 1m thick with a maximum permeability of 1×10^{-7} m/s (or an equivalent specification) and a gradient of 1 in 3. However, it should be recognised that the AEGB will be constructed using selected uncontaminated, cohesive waste materials (i.e. clay and silt rich soils with minimal sand, gravel or stone content) which will be suitably compacted upon construction. Such materials are therefore more likely to achieve bulk permeabilities in region of 10^{-9} to 10^{-8} m/s, with the potential to achieve permeabilities in the region of 10^{-11} m/s (ASRTE, 1999; Carter & Bentley, 1991; Leonards, 1962, Dysli and Steiner, 2011).

2.2.6 The restored landform for Husbands Bosworth Quarry will incorporate the inert landfill site into the surrounding topographic profile. The aim of the restoration scheme for the quarry site and its environs is to create a wide range of historic landscape features and habitats which will integrate into the existing landscape and complement local and national biodiversity objectives. No surface water features are proposed within the inert landfill footprint.

Waste Quality and Priority Contaminants

2.2.7 There is no confirmed waste stream for the site, although typically the wastes types are likely to predominantly comprise cohesive soils for which there are generally limited beneficial reuse options locally. A representative landfill source term has therefore been derived in cognisance of the standard WAC threshold for inert landfills; shown in **Table HRA1**.

Table HRA1: Standard WAC and Equivalent Inert Waste 'Leachate' Quality

Parameter	Inert Waste WAC (L/S 10 l/kg) [mg/kg]	Equivalent Liquid Concentration [mg/l]
Hazardous Substances		
Arsenic	0.5	0.05
Lead	0.5	0.05
Mercury	0.01	0.001
Non-Hazardous Pollutants		
Barium	20	2
Cadmium	0.04	0.004
Chromium	0.5	0.05
Copper	2	0.2
Molybdenum	0.5	0.05
Nickel	0.4	0.04
Antimony	0.06	0.006

Parameter	Inert Waste WAC (L/S 10 l/kg) [mg/kg]	Equivalent Liquid Concentration [mg/l]
Selenium	0.1	0.01
Zinc	4	0.4
Chloride	800	80
Fluoride	10	1
Sulphate	1000	100
Phenol Index	1	0.1

2.2.8 As part of this risk assessment, it has been determined that there is sufficient capacity with the remaining aquifer to enable an increase by up to 3 times the standard inert WAC for a number of parameters, in accordance with the Council Decision (2003/33/EC).

2.2.9 **Table HRA2** presents the proposed Husbands Bosworth Quarry inert landfill WAC as well as an assessment of the risk factor *[leachate concentration ÷ Environmental Assessment Levels (EAL)]* to screen which contaminants potentially presents the most significant risk to controlled waters.

2.2.10 Further clarification on the selected EALs presented in **Section 2.4**.

Table HRA2: Proposed WAC and Equivalent Inert Waste 'Leachate' Quality

Parameter	Proposed Waste WAC (L/S 10 l/kg) [mg/kg]	Equivalent Liquid Concentration [mg/l]	EAL [mg/l]	Risk Factor
Hazardous Substances				
Arsenic	1.5	0.15	0.005	30
Lead	1.5	0.15	0.0034	44
Mercury	0.01	0.001	0.00001	100
Non-Hazardous Pollutants				
Barium	60	6	0.1	60
Cadmium	0.12	0.012	0.00034	35
Chromium	1.5	0.15	0.016	9
Copper	6	0.6	0.0054	111
Molybdenum	1.5	0.15	0.03	5
Nickel	1.2	0.12	0.0089	14
Antimony	0.18	0.018	0.005	4
Selenium	0.3	0.03	0.0039	8
Zinc	12	1.2	0.066	18
Chloride	2400	240	174	1.4
Fluoride	30	3	4.76	0.6
Sulphate	3000	300	318	0.9
Phenol Index	3	0.3	0.0077	39

2.2.11 The assessment indicated that the potential maximum leachable concentrations of hazardous substances are greater than the EALs, with the greatest risk factor presented by mercury. Of the maximum allowable leachable concentrations of non-hazardous pollutants typically tested for within the wastes the metal ions barium, cadmium, chromium, copper, nickel, zinc and antimony have the largest risk factors.

2.2.12 Total concentration limits are also stipulated for organic parameters, including PAHs, PCBs, BTEX and mineral oils. It is therefore prudent to consider the presence of such contaminants within a rogue load of wastes deposited at the site. For this purpose, the benzo-a-pyrene will be considered assuming an effective solubility of 0.00019mg/l . When compared against a WFD EQS for fresh waters of 0.00017µg/l, the risk factor equates ~1118.

2.2.13 Due to the proposal to increase the WAC for all substances above the standard inert WAC Landfill Site threshold values, each determinand presented in **Table**

HRA2 will be considered as priority contaminants and carried forward as the worst-case leachate quality source term for this hydrogeological risk assessment. Benzo(a)pyrene will also be taken forward in this assessment as a priority contaminant as consideration of contamination within rogue loads.

2.3 Pathways

Geology

2.3.1 The quarry operations will principally exploit the glacio-fluvial sand and gravel deposits, whilst working or removing variable thicknesses of overlying till, river terrace and alluvium deposits. The till overlies (or overlaid) the western section of the quarry void and extends to the northwest, west and southwest. Alluvium and river terrace deposits are also found along the fluvial channel and associated flood plains of the River Welland and it tributary that traverses the northern and eastern sections of the quarry. The tributary and its associated deposits will be removed as quarrying operations progress across it route.

2.3.2 Exploratory holes drilled across the quarry footprint and surrounding areas indicate that the quarry will result in typical excavation depths of approximately 16m relative to surface levels along the northern edge of the quarry, potentially reducing to depth of less than 10m and extending to depths of 20m in some sections.

2.3.3 The bedrock geology of the application site and the surrounding area comprises of the Dyrham Formation and the Charmouth Mudstone Formation; both part of the Lias Group. The Dyrham Formation is shown to underlie the western edge of the proposed landfill footprint, whilst the Charmouth Formation underlies the eastern quarry extension area and the Dyrham Formation within the western section of the quarry.

2.3.4 The Dyrham Formation consists of pale to dark grey and greenish grey, silty and sandy mudstone, with interbeds of silt or very fine-grained sand (locally muddy or silty). Exposures of this lithology were encountered during intrusive site investigation works undertaken in 2016. These intrusive investigations extended up to 3m into the bedrock geology and identified the presence of a clay dominated lithology with occasional references to silt.

2.3.5 The Charmouth Mudstone Formation underlies the Dyrham Formation and comprises dark grey laminated shales, and dark, pale and bluish grey mudstones. Additionally, the Charmouth Mudstone Formation contains locally concretionary and tabular limestone beds and phosphatic or ironstone nodules in some areas.

Aquifer Characteristics and Groundwater Flow

2.3.6 The superficial sand and gravel deposits (glaciofluvial, river terrace and alluvial deposits) are classified as a ‘Secondary A’ Aquifers in which the groundwater is perched above the underlying bedrock units. Groundwater within this aquifer has been monitored in seven boreholes located around the periphery of the quarry since June 2021. Groundwater level data and a hydrograph is presented in in **Appendix HRA1**, whilst a statistical summary is presented in **Table HRA3**.

Table HRA3: Statistical summary of monitored groundwater levels within the superficial deposits surrounding Husbands Bosworth Quarry between June 2021 and November 2021 (mAOD)

BH ID	BH1	BH2	BH3	BH4	BH5	BH6	BH7
Min	138.76	133.96	127.00	124.17	121.07	125.08	130.23
Mean	138.92	134.46	127.79	124.28	121.34	125.51	130.35
Max	139.11	136.12	129.90	124.43	121.85	126.18	130.39

2.3.7 Examination of the recorded groundwater indicates a variation in groundwater depths across Husbands Bosworth Quarry. Groundwater levels recorded in monitoring boreholes situated between the eastern edge of the proposed landfill void and the site's eastern boundary (the River Welland); recorded in BH5, BH6 and BH7, are noticeably closer to surrounding ground levels than groundwater levels around the rest of Husbands Bosworth Quarry. As depicted in **Table HRA3** average groundwater levels within BH5, BH6 and BH7 were recorded at 121.34mAOD, 125.51mAOD and 130.35mAOD respectively. Whilst a noticeable variation of range of groundwater elevations has been recorded between, comparison of these levels against surrounding ground levels indicates that the groundwater levels in BH5, BH6 and BH7 are encountered at similar depths beneath surrounding ground levels. Examination of groundwater monitoring data indicates that groundwater levels in BH5, BH6 and BH7 range from 0.67mbgl to 2.27mbgl with an average depth of 1.36mbgl.

2.3.8 Comparing the recorded groundwater levels in BH5, BH6 and BH7 against surrounding elevation data indicates that the groundwater levels strongly correlate to the change in topographic levels as well as the level of adjacent River Welland.

2.3.9 The groundwater levels recorded in the remaining boreholes show similar trends to those discussed for BH5, BH6 and BH7, with groundwater levels correlating to the surrounding topographic levels.

2.3.10 Based on the recorded groundwater elevations within the monitoring boreholes, groundwater is considered to flow across the site in an east-south-easterly direction.

2.3.11 Graphical plotting of these groundwater contours, as depicted in **Drawing No. MG1001/14/09** supports this interpretation and demonstrates that groundwater levels decrease towards the east of the quarry i.e. towards the River Welland. Based on the recorded groundwater levels and associated groundwater contours a hydraulic gradient of c.0.02 has been calculated for the site.

2.3.12 During infilling, all surface waters, and groundwaters draining from the adjacent sand and gravel deposits and waste deposits will be managed. These operations are considered to limit the level of saturation within the waste deposits to below groundwater levels within the surrounding aquifer, therefore creating an inward hydraulic gradient across the AEGB constructed over the sidewalls.

2.3.13 It is considered that water levels within the wastes will be principally governed by the final restoration levels within the landfill footprint. The final restoration levels is presented in **Drawing No. H37/3/21/04**.

2.3.14 The physical characteristics of the waste deposits are likely to be variable depending on the types and associated quantities of the materials deposited (e.g. cohesive or granular) but are most likely to comprise similar bulk permeability than the AEGB constructed over the sidewalls of the site that consist of exposed sands and gravels.

2.3.15 The AEGB will constructed to a minimum thickness of 1m at a maximum permeability of 1 x 10^{-7} m/s over the sidewalls of the exposed sand and gravel aquifer or buttresses formed from suitable engineered materials.

2.3.16 In comparison, the permeability of the sands and gravels surrounding the landfill void is considered to have a permeability of between $5x10^{-5}$ m/s to $5x10^{-4}$ m/s (Hafren, 2001 and MacDonald et. al, 2009), in which waters flowing through the AEGB are unlikely to significantly influence groundwater levels within the aquifer.

2.3.17 A study into the geotechnical properties of the Lias Group undertaken by Hobbs et al., (2012) indicated that the permeabilities of the Dyrham Formation and Charmouth Formation are typically less than 10^{-7} m/s.

2.4 Receptor

2.4.1 The primary receptor to the landfill facility is the superficial sand and gravel aquifers, which is classed as a Secondary 'A' Aquifers and provide base flow to the River Welland to the east and southeast of the landfill.

2.4.2 Future quarry operations will however result in the excavation of a large proportion of the sand and gravels units that make up the Secondary A aquifer designations, with reserves to the west of the landfill footprint already having be exploited. Any remaining sand and gravel reserves to the north of the quarry are overlain by a minimum of 2m of low permeability clay till, which increases in thickness northwards as the glaciofluvial sands and gravel thin out. The remaining sand and gravel reserves to the north will therefore have limited recharge and resource potential going forward. To the south of the quarry the remaining sand and gravels of will continue to provide baseflow to the River Wellend, although the baseflow will be reduced due to the removal of a significant proportion of the storage capacity of the aquifer units and its replacement with significantly lower permeability waste materials, which will also reduce the quantity of waters that infiltrate to recharge any remaining aquifers units.

2.4.3 Whilst thin sand and gravel lenses have been encountered within the glacial till deposit, these laterally impersistent, with boreholes logs indicating that they are typically encounter as damp rather than saturated. The glacial till therefore has no significant resource potential locally.

2.4.4 Similarly, whilst sands and sandstone horizons are included within the BGS descriptions for the underlying bedrock formations, none have been encountered locally, with the upper sections dominated with weathered clays and mudstones. The Dyrham and Charmouth Formations therefore have no significant resource potential locally.

2.4.5 There are currently no licensed groundwater or surface water abstractions between the site and the River Welland. Furthermore, the proposed Inert Landfill Site is not located within a Source Protection Zone.

2.4.6 The final restored landform includes the formation of a wide range of historic landscape features and habitats which will integrate into the existing landscape and complement local and national biodiversity objectives. Contaminants within the waste deposits have the potential to leach out of the wastes into groundwater held in the superficial deposits.

Compliance Points

2.4.7 The following compliance points have been identified:

Hazardous Substances

2.4.8 In line with current EA guidance, the point of compliance for Hazardous Substances are the down-gradient boundaries of the site relative to the direction of groundwater flow within the vertical mixing depth of the surrounding sand and gravel deposits.

Non-Hazardous Pollutants

2.4.9 Due to its proximity and the baseflow provided by the superficial sand and gravel aquifer units, the primary receptor to the input of non-hazardous pollutants to groundwater is considered to be the River Welland. The point of compliance for Non-Hazardous Pollutants is therefore the River Welland.

Groundwater Quality

2.4.10 Prior to the installation of the groundwater monitoring boreholes around the periphery of Husbands Bosworth Quarry, no groundwater monitoring had been undertaken. As such groundwater quality data has been collected monthly since between May 2021 and November 2021 to establish baseline groundwater quality conditions. A statistical summary of groundwater quality within the superficial deposits between May 2021 and November 2021 is presented in **Table HRA4**. Full datasets and time-series charts are presented in **Appendix HRA2**.

2.4.11 To identify whether the existing quarrying operations have any pre-existing impacts on baseline groundwater quality, the perimeter monitoring boreholes were separated into two categories determined by their location to the site relative to the local groundwater flow regime. The first category is the upgradient monitoring boreholes and consists of BH1, BH2 and BH3. The second category is downgradient boreholes and comprise BH4, BH5, BH6 and BH7.

2.4.12 It is noted that during the monitoring period that whilst there was water in BH4 to enable for groundwater levels to be recorded there was insufficient recharge to facilitate the collection of samples post-purging for hydrogeochemical analysis.

2.4.13 The initial statistical analysis of individual boreholes indicates that for a large number of the monitored determinands, no significant variations in recorded concentrations are observed. However, small, but notable variation in recorded concentrations were observed in a small number of parameters; namely, chloride, molybdenum, nickel, selenium, and sulphate.

2.4.14 The recorded concentrations of chloride and sulphate fluctuate throughout the monitoring period. The consistency of these fluctuations and the absence of sudden increases in recorded concentrations suggests that the observed fluctuations are indicative of natural baseline conditions present in the groundwater surrounding the proposed inert landfill site.

2.4.15 In contrast, the concentrations of molybdenum, nickel and selenium show a slightly different trend. Recorded concentrations start at relatively low-levels and then suddenly display elevated concentrations between June and September 2021, before returning to pre-June 2021 concentrations. These observations do not correlate to any noticeable changes in groundwater levels, as such it is considered that these determinands were influenced by existing operations undertaken in the vicinity of Husbands Bosworth Quarry.

2.4.16 In light of the absence of any existing landfill deposits within the proposed Husbands Bosworth Quarry Inert Landfill Site and that these elevated concentrations are recorded in all perimeter monitoring boreholes, it is considered that these concentrations are likely the result of an off-site source which has migrated into the proposed Husbands Bosworth Quarry Inert Landfill Site. It is therefore considered that the recorded elevated concentrations should also be considered as baseline concentrations as they provide a representative picture of the groundwater conditions prior to the commencement of inert landfill activities.

2.4.17 Furthermore the review of baseline hydrogeochemical data indicates a strong correlation between groundwater conditions upgradient and downgradient of the site.

2.4.18 The statistical methodology utilised in analysing the recorded background groundwater quality is that outlined in the Environment Agency Research and Development document "Techniques for the Interpretation of Landfill Monitoring Data Guidance Notes, Report No. P1-471". Accordingly, the groundwater monitoring records were screened utilising the P1-471 outlier test methodology discussed in Section A.3 of Report No. P1-471 and the critical values (P=1%) for the statistical Tmax presented in Table A.1 of Report No. P1-471.

2.4.19 Prior to the application of this outlier assessment tool, histograms were generated for each dataset (where applicable) to aid in the identification of whether the examined dataset of presents Normal or logNormal distribution. This confirmation of data distribution guided the subsequent statistical analysis by indicating whether the statistical analysis needed to be undertaken on the logs of the recorded datapoints. The histograms also allowed for initial visual identification of potential statistical outliers which were later confirmed during subsequent statistical analysis.

Surface Water Quality

2.4.20 Surface water quality monitoring has been undertaken to determine baseline conditions ahead prior to the commencement of inert landfill activities.

2.4.21 Surface water quality data has been collected monthly since May 2021 to establish baseline surface water quality conditions. A statistical summary of groundwater quality within the superficial deposits between May 2021 and November 2021 is presented in **Table HRA5**. Full datasets and time-series charts are presented in **Appendix HRA3**.

2.4.22 To identify whether the existing site operations have any pre-existing impacts on baseline surface quality, the surface water monitoring points were separated into two categories determined by their location to the site relative to the local surface water flow regime. The first category is the upgradient monitoring points and consists of SW1 and SW3. The second category is downgradient monitoring points and comprise SW2 and SW4. Monitoring points SW1 and SW2 are located in the River Welland and SW3 and SW4 are located in a tributary that runs along the quarry and that will be removed as mineral operations progress.

2.4.23 It is noted that during the monitoring period there was insufficient water at SW3 to facilitate the collection of samples for analysis. Additionally, the other surface water monitoring points were recorded as dry during certain monitoring rounds.

This also reduced the number of samples that could be collected for hydrogeochemical analysis during the monitoring period. This is observed in the first recorded datapoint presented in the accompanying spreadsheets. Whilst surface water monitoring commenced in May 2021, the first sample was collected in June 2021 due to absence of sufficient flow in the channel to enable sampling in May 2021.

2.4.24 The initial statistical analysis of surface water monitoring points indicates that for a large number of the monitored determinands, no significant variations in upgradient and downgradient recorded concentrations are observed. However, variation in recorded concentrations was noted in a small number of the recorded parameters, namely, total suspended solids, alkalinity, chloride, and sulphate.

2.4.25 It is noted that upgradient concentrations for the abovementioned four determinands are higher than those recorded downgradient. The largest discrepancy between upgradient and downgradient concentrations is observed in the total suspended solids concentrations, where upgradient concentrations are at least four times has higher than those recorded downgradient.

2.4.26 Examination of the land-use surrounding the upgradient monitoring point SW1 identified three surface water discharges in the vicinity of this monitoring point. Two of the identified surface water discharges correlate to mineral workings discharges associated with the existing mineral working operations within Husbands Bosworth Quarry and the existing Inert Landfill Site located to the southwest of the proposed Inert Landfill Site. The third surface water correlates to the treated sewage/effluent discharge associated with an airfield.

2.4.27 In light of the observed reduced total suspended solids, alkalinity, chloride and sulphate concentrations at the downgradient monitoring points, it is considered that the concentrations recorded at SW1 undergo an element of dilution prior to arriving at the downgradient monitoring points (SW2 and SW4).

2.4.28 The statistical methodology utilised in analysing the recorded background groundwater quality is that outlined in the Environment Agency Research and Development document “Techniques for the Interpretation of Landfill Monitoring Data Guidance Notes, Report No. P1-471”. Accordingly, the groundwater monitoring records were screened utilising the P1-471 outlier test methodology discussed in Section A.3 of Report No. P1-471 and the critical values (P=1%) for the statistical Tmax presented in Table A.1 of Report No. P1-471.

2.4.29 Prior to the application of this outlier assessment tool, histograms were generated for each dataset (where applicable) to aid in the identification of whether the examined dataset of presents Normal or logNormal distribution. This confirmation of data distribution guided the subsequent statistical analysis by indicating whether the statistical analysis needed to be undertaken on the logs of the recorded datapoints. The histograms also allowed for initial visual identification of potential statistical outliers which were later confirmed during subsequent statistical analysis.

Table HRA4: Baseline groundwater quality summary (statistical outliers removed) between May 2021 and November 2021

Statistic	Arsenic (µg/l)	Barium (µg/l)	Cadmium (µg/l)	Chloride (mg/l)	Chromium (µg/l)	Copper (µg/l)	Fluoride (mg/l)	Lead (µg/l)	Mercury (µg/l)	Molybdenum (µg/l)	Nickel (µg/l)	Antimony (µg/l)	Phenol (mg/l)	Selenium (µg/l)	Sulphate (mg/l)	Zinc (µg/l)
BH1																
Min	<0.20	8.4	<0.11	26	0.61	<0.5	0.22	<0.5	<0.01	<0.2	<0.5	<0.5	<0.03	<0.5	40	0.57
Mean	0.28	63.1	<0.11	27	5.4	1	0.23	<0.5	<0.01	0.96	1.44	<0.5	<0.03	0.75	51	12.9
Max	0.37	88	0.23	29	7.7	1.7	0.24	<0.5	<0.01	2.9	4.9	<0.5	<0.03	<2.5	95	66
Stdev	0.07	34.3	0.06	1	2.2	0.5	0.01	0	0	1.07	1.62	0	0	0.6	20	26.0
Count	7	7	7	7	7	6	3	6	7	7	7	7	7	7	7	6
BH2																
Min	<0.20	7.9	<0.11	14	<0.5	<0.5	0.15	<0.5	<0.01	<0.2	<0.5	<0.5	<0.03	<0.5	32	0.66
Mean	0.23	46.0	0.13	21	4.1	2	0.18	<0.5	<0.01	8.85	2.0	<0.5	<0.03	0.8	48	6.9
Max	0.42	68	0.34	29	7.2	3.1	0.2	<0.5	<0.01	30	3.1	<0.5	<0.03	<2.5	65	21
Stdev	0.12	21.7	0.11	6	3.4	1.2	0.03	0	0	13.53	1.21	0	0	0.7	11	8.0
Count	6	6	6	6	5	5	3	5	6	6	5	6	6	6	6	6
BH3																
Min	0.41	35	<0.11	13	<0.5	<0.5	0.42	<0.5	<0.01	<0.2	<0.5	<0.5	<0.03	<0.5	34	<2.5
Mean	1.00	43.3	<0.11	15	4.7	2.4	0.43	0.9	<0.01	8.84	4.1	<0.5	<0.03	1.2	46	13.4
Max	1.7	50	<0.11	18	15	5.4	0.43	2	<0.01	27	8.9	<0.5	<0.03	3.9	69	40
Stdev	0.62	6.4	0	2	5.4	1.7	0.01	0.8	0	11.52	2.7	0	0	1.4	14	16.1
Count	5	6	6	6	6	6	2	6	6	6	6	6	6	6	6	6
BH4																
Min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Count	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Statistic	Arsenic (µg/l)	Barium (µg/l)	Cadmium (µg/l)	Chloride (mg/l)	Chromium (µg/l)	Copper (µg/l)	Fluoride (mg/l)	Lead (µg/l)	Mercury (µg/l)	Molybdenum (µg/l)	Nickel (µg/l)	Antimony (µg/l)	Phenol (mg/l)	Selenium (µg/l)	Sulphate (mg/l)	Zinc (µg/l)
BH5																
Min	<0.20	48	<0.11	36	<0.5	0.68	0.28	<0.5	<0.01	<0.20	<0.5	<0.5	<0.03	<0.5	63	<2.5
Mean	0.40	55.9	<0.11	45	0.7	1.47	0.31	<0.5	<0.01	3.38	2.6	<0.5	<0.03	0.59	72	3.0
Max	0.85	65	<0.11	53	2	2.9	0.32	0.82	<0.01	18	3.4	<0.5	<0.03	<2.5	77	5.4
Stdev	0.27	6.9	0	7	0.6	0.77	0.02	0.17	0	6.55	1.0	0	0	0.57	6	1.4
Count	7	7	7	7	7	7	3	7	7	7	7	7	7	7	7	7
BH6																
Min	0.86	25	<0.11	7.2	<0.5	1.2	0.25	<0.5	<0.01	0.74	1.6	<0.5	<0.03	<0.5	130	<2.5
Mean	1.79	29.0	<0.11	10.6	1.3	2.3	0.31	<0.5	<0.01	2.06	2.6	<0.5	<0.03	0.94	145	3.0
Max	3.5	33	<0.11	12	3	4.4	0.36	0.53	<0.01	3.9	4	0.6	<0.03	1.6	170	5.1
Stdev	1.19	4.1	0	2.3	1.5	1.4	0.08	0.08	0	1.32	1.0	0.1	0	0.65	19	1.9
Count	4	4	4	4	3	4	2	4	4	4	4	4	4	4	4	3
BH7																
Min	0.71	80	<0.11	46	<0.5	0.63	0.21	<0.5	<0.01	0.33	<0.5	<0.5	<0.03	<0.5	60	<2.5
Mean	1.24	90.9	<0.11	48	0.9	1.96	0.22	<0.5	<0.01	1.12	2.2	<0.5	<0.03	0.58	67	3.2
Max	2	100	<0.11	50	2.3	3.1	0.24	0.59	<0.01	3.1	2.8	<0.5	<0.03	0.87	78	6.2
Stdev	0.42	8.1	0	1	0.9	0.79	0.02	0.09	0	1.16	0.9	0	0	0.19	7	1.7
Count	7	7	7	7	7	7	3	6	6	6	6	6	6	6	6	6
Upgradient Monitoring Boreholes (BH1, BH2 and BH3)																
Min	<0.20	7.9	<0.11	13	<0.5	<0.5	0.15	<0.5	<0.01	<0.2	<0.5	<0.5	<0.03	<0.5	32	0.57
Mean	0.46	51.4	<0.11	21	4.8	1.8	0.26	0.6	<0.01	5.94	2.49	<0.5	<0.03	0.9	48	11.1
Max	1.7	88	0.34	29	15	5.4	0.43	2	<0.01	230	8.9	<0.5	<0.03	3.9	95	66
Stdev	0.46	24.9	0.07	6	3.7	1.3	0.11	0.5	0	10.17	2.23	0	0	0.9	15	17.4
Count	18	19	19	19	18	17	8	17	19	19	18	19	19	19	19	18

Statistic	Arsenic (µg/l)	Barium (µg/l)	Cadmium (µg/l)	Chloride (mg/l)	Chromium (µg/l)	Copper (µg/l)	Fluoride (mg/l)	Lead (µg/l)	Mercury (µg/l)	Molybdenum (µg/l)	Nickel (µg/l)	Antimony (µg/l)	Phenol (mg/l)	Selenium (µg/l)	Sulphate (mg/l)	Zinc (µg/l)
Downgradient Monitoring Boreholes (BH4, BH5, BH6 and BH7)																
Min	<0.20	25	<0.11	7.2	<0.5	0.63	0.21	<0.5	<0.01	<0.20	<0.5	<0.5	<0.03	<0.5	60	<2.5
Mean	0.89	63.5	<0.11	38.2	0.9	1.84	0.28	<0.5	<0.01	2.21	2.4	<0.5	<0.03	0.73	87	3.1
Max	2	100	<0.11	53	3	4.4	0.36	0.82	<0.01	17	3.4	0.6	<0.03	<2.5	170	6.2
Stdev	0.55	25.6	0	15.9	0.9	0.95	0.05	0.12	0	4	0.9	0.1	0	0.55	33	1.5
Count	17	18	18	18	17	18	8	16	17	17	17	18	18	18	18	16

Note: Statistical analysis carried out with the assumption that results below the method limit of detection are equivalent to a concentration of 75% of the limit value

Table HRA5: Baseline surface water quality summary (statistical outliers removed) between May 2021 and November 2021

Statistic	Suspended Solids (mg/l)	Alkalinity (mg/l)	Arsenic (µg/l)	Cadmium (µg/l)	Chloride (mg/l)	Chromium (µg/l)	Copper (µg/l)	Fluoride (mg/l)	Lead (µg/l)	Mercury (µg/l)	Nickel (µg/l)	Phenol (mg/l)	Sulphate (mg/l)	Zinc (µg/l)
SW1														
Min	140	210	0.75	<0.11	43	<20	1.9	0.2	<0.5	<0.01	1.6	<0.03	70	<2.5
Mean	277	350	1.14	<0.11	63	<20	2.4	0.22	3.3	<0.01	2	<0.03	74	4.1
Max	480	530	1.7	<0.11	76	<20	3	0.24	9.1	<0.01	2.5	<0.03	82	5.6
Stdev	180	164	0.5	0	18	0	0.6	0.03	5	0	0.5	0	7	2
Count	3	3	3	3	3	3	3	2	3	3	3	3	3	3
SW2														
Min	36	150	1.2	<0.11	38	<20	1.9	0.19	<0.5	<0.01	0.84	<0.03	56	<2.5
Mean	55	330	1.3	<0.11	41	<20	2.2	0.2	<0.5	<0.01	1.18	<0.03	68	<2.5
Max	88	530	1.5	<0.11	45	<20	2.6	0.2	<0.5	<0.01	1.7	<0.03	75	<2.5
Stdev	28	191	0.17	0	4	0	0.4	0.01	0	0	0.46	0	11	0
Count	3	3	3	3	3	3	3	2	3	3	3	3	3	3

Statistic	Suspended Solids (mg/l)	Alkalinity (mg/l)	Arsenic (µg/l)	Cadmium (µg/l)	Chloride (mg/l)	Chromium (µg/l)	Copper (µg/l)	Fluoride (mg/l)	Lead (µg/l)	Mercury (µg/l)	Nickel (µg/l)	Phenol (mg/l)	Sulphate (mg/l)	Zinc (µg/l)
SW3														
Min	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Max	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Count	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SW4														
Min	12	150	1.1	<0.11	38	<20	2	0.19	<0.5	<0.01	0.96	<0.03	56	<2.5
Mean	16	330	1.3	<0.11	40	<20	2.2	0.2	<0.5	<0.01	1.21	<0.03	70	<2.5
Max	22	530	1.4	<0.11	44	<20	2.3	0.2	<0.5	<0.01	1.7	<0.03	81	<2.5
Stdev	5	191	0.17	0	3	0	0.2	0.01	0	0	0.42	0	13	0
Count	3	3	3	3	3	3	3	2	3	3	3	3	3	3
Upgradient Monitoring Points (SW1 and SW3)														
Min	140	210	0.75	<0.11	43	<20	1.9	0.2	<0.5	<0.01	1.6	<0.03	70	<2.5
Mean	277	350	1.14	<0.11	63	<20	2.4	0.22	3.3	<0.01	2	<0.03	74	4.1
Max	480	530	1.7	<0.11	76	<20	3	0.24	9.1	<0.01	2.5	<0.03	82	5.6
Stdev	180	164	0.5	0	18	0	0.6	0.03	5	0	0.5	0	7	2
Count	3	3	3	3	3	3	3	2	3	3	3	3	3	3
Downgradient Monitoring Points (SW2 and SW4)														
Min	12	150	1.1	<0.11	38	<20	1.9	0.19	<0.5	<0.01	0.84	<0.03	56	<2.5
Mean	36	290	1.3	<0.11	41	<20	2.2	0.2	<0.5	<0.01	1.2	<0.03	69	<2.5
Max	88	530	1.5	<0.11	45	<20	2.6	0.2	<0.5	<0.01	1.7	<0.03	81	<2.5
Stdev	28	171	0.15	0	3	0	0.2	0.01	0	0	0.39	0	11	0
Count	6	6	6	6	6	6	6	4	6	6	6	6	6	6

Note: Statistical analysis carried out with the assumption that results below the method limit of detection are equivalent to a concentration of 75% of the limit value

Environmental Assessment Levels

2.4.30 The setting of Environmental Assessment Levels (EALs) is necessary in order to access whether the requirements of the Environmental Permitting Regulations 2016 are likely to be met.

2.4.31 As discussed previously, the proposed waste deposits will comprise of inert waste located in a quarry void with sidewalls comprised of superficial sand and gravel deposits and a base formed of in-situ mudstones and clay.

2.4.32 Despite this inert nature, due to the potential for groundwater to pass through the inert waste deposits and interact with groundwater and surface water receptors, it is considered appropriate for EALs specific to the proposed inert waste deposits to be set so as to assess whether the requirements of the Environmental Permitting Regulations 2016 are likely to be met

2.4.33 To ensure that EALs representative to the Site are selected and that the subsequent Hydrogeological Risk Assessment provides a site assessment of groundwater pollution potential, the following selection criteria have been employed.

2.4.34 For Hazardous Substances, to demonstrate that they're the discernible input to groundwater has been prevented the EALs have been set the highest of either the Minimum Reporting Value/Limit Of Quantification or the baseline groundwater concentration.

2.4.35 For Non-Hazardous Pollutants, the EALs has been derived to either prevent an exceedance of the surface water (freshwater) EQS value (or DWS, if an EQS is not available) to protect the quality in the River Welland, taking into account background concentrations. Where baseline groundwater concentrations are higher than the EQS, the EALs for non-hazardous pollutants will be set at the maximum recorded baseline concentration. This assumes that protection of current groundwater quality will prevent any significant change in surface water quality. For substances in which no EQS or DWS is available the EAL has been set at 20% above the baseline groundwater concentration.

2.4.36 Surface Water EALs have been subsequently derived by subtracting the monitored baseline surface water concentration from the corresponding EQS value. In instances where no baseline concentration was recorded, the EQS has been selected as the EAL.

2.4.37 It is noted that the EQS for copper, nickel and zinc correspond to bioavailable concentrations rather then total concentrations. Accordingly, the total concentrations for these determinands recorded at SW1 were converted to bioavailable concentrations using the Environment Agency's Metal Bioavailability Assessment Tool (M-BAT). Each total concentration for these three parameters was entered into this the M-BAT alongside the corresponding pH, DOC and calcium concentrations. The calculated bioavailable concentrations were then averaged to arrive at the monitored baseline concentrations. A copy of the M-BAT spreadsheet used to calculate the bioavailable concentrations is presented in **Appendix HRA4**.

2.4.38 During the completion of the M-BAT spreadsheet, it was noted that the recorded calcium concentrations (120mg/l and 130mg/l) exceeded the upper model operating ranges for both copper (93mg/l) and nickel (88mg/l). Additionally the recorded pH for one monitoring round (8.5) exceeded the upper model operational range for zinc (8). In accordance with the Operating boundaries of

M-BAT published by United Kingdom Advisory Group in July 2014[1] in these instances the exceeding values were substituted with the corresponding upper model operational range value.

2.4.39 Details of the EALs to be taken forward for assessment purposes are presented in **Table HRA6**.

Table HRA6: Environmental Assessment Levels (mg/l)

Parameter	MRV/LoQ[1]	Laboratory Limits of Detection	DWS/EQS[2]	Monitored Baseline (GW/SW)	Selected EAL
Groundwater					
Hazardous Substances					
Arsenic	0.005	0.0002	0.01/0.05	0.0035	0.005[3]
Benzo(a)pyrene	0.000005	NA	0.00001/$1.7x10^{-6}$	NR	0.000005[3]
Lead	0.0002	0.0005	0.01/(0.012)	0.0034	0.0034[4]
Mercury	0.00001	0.00001	0.001/0.07	NR	0.00001[3]
Non-Hazardous Pollutants					
Barium	-	0.005	-	0.1 / NR	0.1[4]
Cadmium	-	0.00011	0.00025	0.00034 / NR	0.00034[4]
Chromium	-	0.0005	0.0047	0.016 / NR	0.016[4]
Copper	-	0.0005	(0.001)[9]	0.0054 / 0.00024	0.0054[4]
Molybdenum	-	0.0002	-	0.03 / NR	0.03[4]
Nickel	-	0.0005	0.02 / 0.004	0.0089 / 0.001	0.0089[4]
Antimony	-	0.0005	0.005 / -	NR / NR	0.005[5]
Selenium	-	0.0005	0.01 / -	0.0039 / NR	0.0039[4]
Zinc	-	0.0025	(0.0077)[9]	0.066 / 0.0017	0.066[4]
Chloride	-	1	250 / 250	53 / 76	174[11]
Fluoride	-	0.05	1 / 5	0.43 / 0.24	4.76[11]
Sulphate	-	1	- / 400	170 / 82	318[11]
Phenol Index	-	0.03	0.1 / 0.0077	NR	0.0077[5]

[1] – applies to hazardous substances only
[2] – based on concentrations corresponding to Freshwater EQS or Drinking Water Standards
[3] – EAL derived from MRV / LoQ Value
[4] – EAL derived from maximum recorded background concentration
[5] – EAL Derived from 100% of DWS/EQS Value
[6] – Bioavailable Concentration
[7] – EAL Derived from Corresponding EQS Value minus monitored baseline concentration
NR – Not Recorded

[1] *M-BAT Method Statement, Published by the United Kingdome Advisory Group (UKTAG), July 2014* https://www.wfduk.org/sites/default/files/Media/Environmental%20standards/MBAT%20UKTAG%20Method%20Statement.pdf *– Accessed February 2022*

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 Nature of the Risk Assessment

3.1.1 As set out within the Environment Agency's "Inert Waste Guidance" the *"appropriate complexity of assessment for a site should be determined from the potential risks presented by the site, which are linked to the nature of potential hazards, the sensitivity of the surrounding environment, degree of uncertainty and likelihood of a risk being realised.*"

3.1.2 The site will accept inert waste, which is defined as follows;

- it does not undergo any significant physical, chemical or biological transformations;
- it does not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health; and
- total leachability, pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater.

3.1.3 Based on this definition of inert waste, the site should not produce any leachate that could result in any significant discharge of Hazardous Substances or Non-Hazardous Pollutants throughout the lifecycle of the site.

3.1.4 Therefore, with regard to this inert waste stream, the site:

- presents a limited risk to groundwater and surface water quality;
- falls outside the scope of the Environmental Permitting Regulations 2016 (Schedule 22 Groundwater Activities); and
- does not require environmental management systems (artificial sealing liner, leachate management or other engineering and management structures, with the exception of a geological barrier), or the consideration of the degradation of such systems.

3.1.5 However, notwithstanding the above, it is considered that a quantitative risk assessment is required given that the EPR Inert Waste Guidance and decision framework for Position Statement E1 under "The Environment Agency's Approach to Groundwater Protection" (v1.2.; February 2018) states that such an assessment is likely to be necessary for an inert landfill where the receiving environment is particularly sensitive, for example below the water table in a Principal or Secondary A Aquifer or with a direct pathway to a sensitive surface water.

3.1.6 The proposed site is located sub-water table to the locally important sand and gravel aquifer, which provides baseflows to nearby rivers.

3.1.7 In order to assess the risk to the environment, it is considered appropriate to assess the potential worst-case leachate quality that could potentially be generated based on the proposed Waste Acceptance Criteria and the deposit of a rogue load at the site.

3.2 Proposed Assessment Scenarios

Groundwater

3.2.1 Based on the site conceptual hydrogeological model, as outlined within **Section 2.0**, it is considered appropriate to assess the risk to groundwater within the superficial sand and gravel aquifer and the River Welland. As discussed in **Section 2.3**, intrusive site investigation works undertaken in 2016 identified that the geology underlying the proposed inert landfill void comprised of clay dominated lithologies, with limited groundwater resource potential locally. Consequently, consideration of the risk to any remaining groundwater bearing sand and gravel deposits. Similarly, following the working of the mineral reserve at the site, the groundwater resource potential of any remaining sand and gravel deposits to the north that are buried beneath low permeability till will be significant limited. The assessment therefore focuses on the risk to groundwater flow to the south its linkage to the River Welland.

3.2.2 The landfill deposits will be located wholly within a void formed by mineral extraction activities. The base of the quarry void will be formed from the underlying Dyrham and Charmouth Formations. The landfill sidewalls will consist of an AEGB located over an engineered buttress be installed in front of quarry sidewalls which comprise varying thicknesses of sand and clay (either Dyrham Formation or diamicton moraines).

3.2.3 Upon restoration of the quarry, it is assumed that the permeability of the wastes and AEGB will be significantly lower than that of the surrounding aquifer units causing waters to dome in the approximate centre of the landfill and flow radially towards the edges to the of the level of groundwater in the surrounding aquifers units.

3.2.4 The assessment therefore considers the advective migration of 'leachate' from the waste mass through the sidewall AEGB into the remaining aquifer to the south. As the quarry the sidewalls are formed against the sand and gravel units to the south.

3.2.5 Water levels in the waste deposits are likely to be lower that groundwater levels within the surrounding aquifer during the operational period of the landfill therefore creating a hydraulic gradient into the landfill. The models therefore focus on the post-closure phase of the landfill when any in-waste water levels are likely to be higher than external levels in the aquifer.

Lifecycle Analysis

3.2.6 It is considered that a risk assessment of lifecycle phases is not required, given that the technical precautions included within the construction and management of the site will not be subject to long-term degradation.

3.3 Review of Technical Precautions

Capping

3.3.1 An engineered cap is not required for the Husbands Bosworth Quarry landfill facility since the only waste to be accepted will be inert.

Basal and Side-Sloped Engineering

Geological Barrier

3.3.2 The base of the landfill will be formed directly over the underlying mudstones of the Dyrham and Charmouth Formations. The full thickness of the Dyrham Formation has not been proven beneath the quarry, although a thickness of at least 10m is depicted on the BGS Sheet 170 which depicts the solid and drift geology in the vicinity of Market Harborough. Furthermore, BGS Sheet 170 indicates that the underlying Charmouth Mudstone formation is at least 152m thick. This thickness is supported by the published records of a borehole located approximately 800m of the proposed Husbands Bosworth Quarry Landfill Site. The borehole (Reference SP68SW75) is located within the Charmouth Mudstone Formation and the corresponding logs indicate the presence of silty clay (and mudstones) to a depth of 132mbgl, where the borehole was terminated.

3.3.3 As discussed in Hobbs et al., (2012), the field permeability of both the Dyrham Formation and Charmouth Mudstone Formation can vary depending on stresses offered by the depth of cover and prevalence of fissuring. As indicated in Hobbs et al., the field permeability for the Dyrham and Charmouth Formations are typically greater than 10^{-7} m/s. It is considered that this substantial thickness of clay and mudstone form a natural geological barrier that meets the requirement set out under Annex I of the Landfill Directive in order to protect to the underlying geological units.

3.3.4 The quarry sidewalls will comprise variable thicknesses of clay, silt, and gravel horizons of the glaciofluvial deposits, glacial till river terrace and alluvium, with some potential exposure of the bedrock units towards toe of the sidewalls.

3.3.5 The natural physical characteristics of the sand and gravel horizons within the superficial deposits are not considered to provide the necessary attenuation requirements specified under Annex I to the Landfill Directive. It is therefore proposed to construct an Artificial Established Geological Barrier (AEGB) over the sidewalls of the proposed landfill area utilising either site-won or imported clays. This AEGB is proposed to be constructed to achieve a maximum permeability of 1×10^{-7} m/s at 1m.

3.3.6 AEGB details are presented in **Drawing No. MG1001/14/06**.

Leachate Management

3.3.7 Due to the inert nature of the waste to be deposited at the site no leachate management will be required. The quality of leachate will be principally controlled by the implementation of strict waste characterisation testing as part of the overall Duty of Care requirements.

Groundwater Management System

3.3.8 Groundwater encountered at Husbands Bosworth Quarry is managed by a series of collection ditches and lagoons which form the surface water management system.

Surface Water Management System

3.3.9 During infilling within the footprint of the landfill surface waters draining from unfilled and waste filled areas will continue to be managed within a network of lined settlement lagoons and subsequently used in on-site operations including mineral processing.

3.3.10 Following restoration of the site, surface water run-off will follow the topographic surface and flow either overland or via attenuation ponds and drainage ditches into the River Welland or a tributary thereof.

Waste Deposits

3.3.11 During the active infilling phase, it is considered that the inert waste deposits will comprise of material that will result in the inert waste mass bulk permeability achieve a permeability of $\leq 1x10^{-7}$m/s. This bulk permeability of the deposited inert materials will restrict the amount of precipitation infiltrating into the deposited qualifying materials during active infilling and encourage precipitation run-off to the surface water management systems which will direct the collected run-off into the site's surface water management system for subsequent discharge. Consequently, it is considered that the bulk permeability of the qualifying material will restrict the build-up of leachate within the inert waste deposits during the active infilling phase, and thereby restrict the outward movement of any leachate during this period of the landfill's lifecycle.

3.3.12 The compaction of the wastes deposits will also result in the waste deposits having a lower permeability than that of the surrounding aquifer units, which will result in the doming of leachate/groundwater within the waste mass. Furthermore, the bulk permeability of the inert waste be similar to that of the sidewall lining system, therefore, the waste will act as a barrier to ground water flow in the more permeable sand and gravel deposits. It is considered that groundwater will preferentially flow around the edge of the waste. In-waste water will subsequently discharge through the sidewalls of the landfill.

3.4 Numerical Modelling

Justification of Modelling Approach and Software

3.4.1 In the first instance, semi-analytical spreadsheet calculations have been prepared to support this risk assessment. These calculations conservatively consider if the sand and gravel aquifer to the south of the landfill alone will provide enough dilution of any contaminants that leak from the landfill, with any attenuation through the AEGB, buttress materials and aquifers ignored. The spreadsheet calculations are considered to provide conservative representation for the following reasons:-

- Leachate concentrations for priority inorganic substances and phenol are set at concentrations equivalent to the proposed Waste Acceptance Criteria (WAC) based on a liquid to solid ration of 10:1, with the benzo-a-pyrene concentrations set at the effective solubility values derived from CL:AIRE Research Bulletin 15 (RB15). In reality, the chemistry of any wastes deposited will vary significantly and result in bulk leachate concentrations that are less than the WAC threshold values;
- Any reduction in the source term during the initial filling period when an lower in-waste water levels will be present and an inward hydraulic gradient is anticipated has been conservatively ignored;
- Retardation and biological degradation processes within the selected AEGB and buttress materials, and aquifer pathways have been considered;

- The groundwater levels within the Sand and Gravel Deposits have been accounted for in the derivation of the mixing zone thickness;
- Vertical sidewalls have been modelled;
- Permeabilities for the Sand and Gravel Deposits have been derived in cognisance of published literature values, with the lowest published value selected;
- The hydraulic gradient applied in the modelling has been derived from site specific groundwater level data;
- The sidewall leakage rate has been calculated in cognisance of anticipated leachate mounding and associated in-waste hydraulic gradient;
- The waste mass and AEGB have been assumed to consist of similar physical characteristics, with a conservative bulk permeability of $1x10^{-7}$ m/s assumed.
- In-waste water levels are assumed to mound along the peak final waste levels, with a hydraulic gradient outward to the edges of the waste mass where they merge with groundwater levels within the surrounding sand a gravel aquifer.
- To calculations do not account for any subsequent dilution within the fluvial channel of the River Welland.

Model Parameterisation

3.4.2 The leakage rates were calculated following an assessment of the water balance of inert waste deposits following the cessation of landfill activities. The water balance is based on the assumption that the flux infiltrating the wastes must balance the flux discharging from the waste. The discharge through the sidewalls can be calculated landfill as the flow through the waste mass, assuming a hydraulic gradient controlled by a maximum head equal to the maximum elevation of the landfill surface and the average groundwater head at the boundary of the landfill; a hydraulic conductivity representative of the expected waste composition; the depth of the waste and the landfill perimeter in contact with groundwater.

3.4.3 If this maximum value is greater than effective rainfall, then the flux out of the landfill is limited to effective rainfall and runoff from the landfill surface is considered to be 0. If the maximum value is less than effective rainfall, then the flux out of the landfill is set to the maximum value, the infiltration flux is also set to this maximum value and the difference between the effective rainfall and the infiltration flux is assumed to be runoff. For Husbands Bosworth Quarry, the maximum sidewall discharge rate is significantly less than equivalent volume generated by the regional effective rainfall value of 186 mm/yr. This value was derived from climate data presented in the accompany ESSD (*Doc Ref.: MG1001/07*) which indicated a total average annual rainfall of 674.83mm. The flood risk assessment presented in Appendix MP7 of the accompanying Management Plan (*Doc Ref.: MG1001/06*) indicated that 45% of rainfall would run-off the surface of the restored landfill meaning that only 55% (371.2mm) would infiltrate into the restored surface. Of this 371mm, it was conservatively assumed that 50% would be captured by evapotranspiration and the remainder would infiltrate into the inert waste deposits.

3.4.4 The specific infiltration rate utilised in the semi-quantitative model were calculated based on Darcy's Law:

$$Inf = k \times i \times A$$

Where:

k = *Hydraulic conductivity of the compacted qualifying materials* (ms^{-1})
i = *hydraulic gradient across the compacted qualifying materials*
A = *Area of Saturated receiving aquifer* (m^2)

3.4.5 As discussed in **Section 3.3**, it is considered that due to the anticipated nature of inert wastes that will be deposited in the quarry void, the deposited inert wastes will achieve a bulk permeability of ≤$1x10^{-7}$m/s. Consequently, this permeability was taken forward in the semi-quantitative modelling. Due to the nature of materials anticipated to be deposited in the quarry void, it is considered that lower permeability materials (e.g. clays and concrete) will also be deposited. Accordingly, it is considered likely that the deposited inert waste will achieve permeabilities lower than the ≤$1x10^{-7}$m/s modelled. Based on Sirius' experiences, permeability data derived from sites currently accepting similar materials as proposed for Husbands Bosworth Quarry Landfill Site have frequently returned compacted permeability values of a few of orders of magnitude lower than the value assume for under this assessment. Consequently, it is considered that the selected permeability utilised in the semi-quantitative modelling incorporates sufficient conservativism into the assessment.

3.4.6 The hydraulic gradient used in the modelling spreadsheets was derived from the average in-waste hydraulic gradient calculated between the top of the leachate mound and ground water levels at the edge of the landfill. As indicated above maximum water level in the inert material of would correlate to the restoration contours along the centreline of the final restoration profile. Due to the sloping nature of the final restoration profile, a range of in-waste hydraulic gradients were identified for each sidewall. These hydraulic gradients were then averaged to provide a representative in-waste hydraulic gradient to be utilised in the semi-quantitative modelling. The in waste hydraulic gradient were calculated by dividing the head difference between the restoration elevation contour along the centreline of the landfill and the average groundwater level in the modelled sidewall by the distance between the centreline of the inert landfill and the edge of the landfill void.

3.4.7 The sidewall lengths presented in the semi-quantitative models were derived from the basal length and wetted height of the sidewall lining system, respectively. The sidewall lengths for each of the modelled sidewall, the position of the inferred landfill centreline which acts as the in-waste water highpoint and the in-waste hydraulic gradients as well as other assessment criteria utilised in the modelling process are presented in **Drawing No. MG1001/14/13**.

3.5 Emissions to Groundwater

3.5.1 The results of the semi-quantitative modelling are summarised and discussed below. The semi-quantitative modelling spreadsheets used in this Hydrogeological Risk Assessment are presented in **Appendix HRA5**.

3.5.2 The results will be separated according to their classification as hazardous substances or non-hazardous pollutants.

3.5.3 The EALs selected for assessment purposes are take into consideration baseline groundwater concentrations.

Hazardous Substances

3.5.4 The predicted diluted (and unattenuated) groundwater concentrations of Hazardous Substances are presented in **Table HRA6**.

Table HRA7: Predicted Diluted (and unattenuated) groundwater concentrations of hazardous substances

Substances	EAL (mg/l)	Predicted Groundwater Concentration (mg/l)
Arsenic	0.005	0.00091
Benzo-a-pyrene	0.000005	0.0000012
Lead	0.0034	0.00091
Mercury	0.00001	0.000006

3.5.5 As mentioned previously, the modelling undertaken assesses the potential impact to groundwater from inert waste with individual substance concentrations set at up to three times the standard equivalent inert WAC threshold values. The only exception to this was mercury, the source concentration of which was retained at the standard equivalent inert WAC leachable threshold (0.01mg/kg) for this substance.

3.5.6 Note, the standard WAC threshold of PAHs are not capable of being increased. Consequently, the modelled benzo-a-pyrene concentration has modelled at the solubility value derived from RB15.

3.5.7 The calculations indicate that if the AEGB is constructed to a thickness of 1m and achieves a bulk hydraulic conductivity of $1x10^{-7}$m/s (or an equivalent specification) and an inert waste mass with a bulk hydraulic conductivity of ≤$1x10^{-7}$m/s the diluted concentrations of all determinands below the selected EALs.

3.5.8 In light of the dilution assessment concentrations falling below the selected EALs, it is considered that the dilution capacity of the adjacent aquifer units will prevent the discernible discharge of hazardous substances to groundwater for inert wastes with source term concentrations up to three times greater than the standard equivalent inert WAC threshold values. Accordingly, no further quantitative modelling is considered necessary.

Non-Hazardous Pollutants

3.5.9 The predicted diluted (and unattenuated) groundwater concentrations of non-hazardous pollutants are presented in **Table HRA7**.

Table HRA8: Predicted Diluted (and unattenuated) groundwater concentrations of non-hazardous pollutants (mg/l)

Substances	EAL	Predicted Groundwater Concentration (mg/l)
Barium	0.1	0.036
Cadmium	0.00034	0.00007
Chromium	0.016	0.00091
Copper	0.0054	0.0036
Molybdenum	0.03	0.00091
Nickel	0.003	0.00073
Antimony	0.005	0.000011
Selenium	0.0039	0.00018
Zinc	0.066	0.0073
Chloride	174	1.5
Fluoride	4.76	0.018

Substances	EAL	Predicted Groundwater Concentration (mg/l)
Sulphate	318	1.8
Phenols	0.0077	0.0018

3.5.10 As discussed above, the undertaken modelling assesses the potential impact to groundwater from inert waste with individual substance concentrations up to three times greater than the equivalent inert WAC threshold values.

3.5.11 The calculations indicate that the diluted concentrations of all determinands below the selected EALs. Consequently the landfill activity will not result in a deterioration (or pollution of) groundwater or the River Welland.

<u>Accidents and Their Consequences</u>

3.5.12 Details of accidental occurrences at the site that could present a potential risk to groundwater adjacent to the site are provided in

Hazard	Risk to Groundwater	Likelihood	Mitigation and Corrective Measures
Deposition of non-inert wastes	Generation of leachate containing Hazardous Substances or Non-Hazardous Pollutants.	**Low** – due to the essential and technical precautions.	Appropriate characterisation of wastes prior to delivery to the site will be provided by the customer, with the appropriate verification checks/tests performed wastes by the operator. Any incorrectly accepted wastes will be immediately returned to the customer or moved to a suitable storage area prior to removal to a suitable site.
Spillage of fuels from storage tanks or vehicles.	Release of hydrocarbons (Hazardous Substances) into the ground and migration to groundwater.	**Low** – fuel stores will be bunded in accordance with regulation requirements. A traffic management system and speed limit will be imposed at the site to reduce both the risk of accidents and the likelihood of spillage occurring.	Any spillage will be cleaned up immediately and any resulting contaminated soils removed to a suitable installation.

3.5.13 With respect to the deposition of potentially contaminated wastes, it is considered that the risks and potential consequences of such accidents are extremely low for the following reasons:-

- all waste deliveries will be pre-arranged and come from known sources to ensure no contaminated material is delivered;
- if deemed necessary, characterisation testing will be undertaken to demonstrate that the waste will not give rise to polluting leachate, prior to the acceptance of waste at the site;

- if deemed necessary compliance testing will be undertaken to ensure the continued acceptability of the waste stream;
- visual inspection will be undertaken of every waste load deposited at the site; and
- in the event of suspicion regarding the acceptability of the waste, quarantine procedures will be enforced.

3.5.14 In the unlikely event of contaminants from a rogue load being deposited at the site, attenuation processes will occur within the waste body, and most organic Hazardous Substances are very likely to be degraded and/or retarded during migration through the surrounding inert wastes within the landfill and the AEGB.

3.5.15 Other processes such as volatilisation can also be expected for volatile and semi-volatile organic substances resulting in a loss of contaminant from the waste.

4.0 REQUISITE SURVEILLANCE

4.1 Leachate Monitoring

4.1.1 Leachate testing will be limited to that required as part of the waste acceptance requirements, as detailed in the accompanying Supporting Statement (*Document Ref.: MG1001/06*).

4.2 Groundwater Monitoring

4.2.1 The groundwater monitoring schedule during the operational phase of the landfill is presented in **Table HRA8.** The locations of the groundwater monitoring points are presented in **Drawing No. MG1001/07**.

Table HRA9: Groundwater monitoring schedule

Monitoring Point	Parameter[1]	Frequency
Upgradient Monitoring Boreholes: BH1, BH2, BH3, and any additional or replacement monitoring boreholes	Water Level, Electrical Conductivity, Chloride, Ammoniacal Nitrogen, pH, total Alkalinity, Arsenic, Lead, Nickel, Sulphate, BOD, COD, Dissolved Oxygen, Antimony, Barium, Cadmium, Chromium (VI), Copper, Fluoride, Mercury, Molybdenum, Selenium, zinc, Total Phenols.	Quarterly
	Magnesium, Potassium, Calcium, Sodium, Iron, Manganese	Annually
	Hazardous substances: Benzene, Toluene, Ethyl Benzene, Xylene, Poly Chlorinated Biphenyls (PCB), Polycyclic Aromatic Hydrocarbons (PAH)	Annually for the first six years of operation then every two years
Downgradient Monitoring Boreholes: BH4, BH5, BH6, BH7 and any additional or replacement monitoring boreholes	Water Level, Electrical Conductivity, Chloride, Ammoniacal Nitrogen, pH, Total Alkalinity, Arsenic, Lead, Nickel, Sulphate, BOD, COD, Dissolved Oxygen, Antimony, Barium, Cadmium, Chromium (VI), Copper, Fluoride, Mercury, Molybdenum, Selenium, Zinc, Total Phenols.	Quarterly
	Magnesium, Potassium, Calcium, Sodium, Iron, Manganese	Annually
	Hazardous substances: Benzene, Toluene, Ethyl Benzene, Xylene, Poly Chlorinated Biphenyls (PCB), Polycyclic Aromatic Hydrocarbons (PAH)	Annually for the first six years of operation then every two years
All Perimeter Monitoring Boreholes	Base of Monitoring Point (mAOD)	Annually

[1] – metals will be analysed for their dissolved concentrations only

4.2.2 Groundwater Compliance Limits are presented in **Table HRA9**.

Table HRA10: Groundwater Compliance Limits

Monitoring Point	Parameter	Frequency	Compliance Limit (mg/l)
Downgradient Monitoring Boreholes: BH4, BH5, BH6, BH7 and any additional or replacement monitoring boreholes	Arsenic	Quarterly	0.005
	Lead		0.0034
	Cadmium		0.00034
	Copper		0.0054

4.2.3 The parameters selected for groundwater compliance limits are those with the highest risk factors presented in **Table HRA2** that were detected in collected baseline groundwater quality samples (presented in **Table HRA3**).

4.2.4 To ensure that there will be no discardable input of these substances to groundwater, compliance limits have been set at the groundwater Environmental Assessment Levels presented **Table HRA6**. Furthermore, to ensure that the compliance limits are appropriate, these will be reviewed upon the collection of 12-months baseline groundwater monitoring.

4.2.5 In the even that any of the compliance limits are exceeded the borehole will be resampled and the non-complaint parameter(s) re-analysed within 1 week of the receipt of the original result. If the resulting concentration also exceeds the compliance limit the monitoring frequency will be increased to monthly and the source of increase investigated.

4.2.6 Details of post-closure groundwater monitoring requirements are presented in in the accompanying Supporting Statement (*Document Ref.: MG1001/06*).

4.3 Surface Water Monitoring

4.3.1 During the operational phase of the landfill, monitoring of surface waters and waters held in lagoons formed with the landfill will be visually monitored for evidence of hydrocarbon contamination. The surface water monitoring schedule during the operational phase of the landfill is presented in

Table HRA11: Surface Monitoring Schedule

Monitoring Point	Parameter[1]	Frequency
SWD1, SWD2, SW1, SW2 and any additional or replacement monitoring points	Ammoniacal Nitrogen, Chloride, Suspended Solids, Visual Oil and Grease, pH, Electrical Conductivity	Monthly
	Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel.	Quarterly

[1] – metals will be analysed for their dissolved concentrations only

4.3.2 Discharges of water from the site via the existing outlets to the River Welland authorised under the existing discharge consents (Refs.: PRNNF12734 and EPR/ZP3724XU). Landfill operations are not considered to influence the quality of waters discharged from the site. Accordingly, it is proposed that surface water compliance limits presented in **Table HRA10** correlate to discharge limits presented in the corresponding discharge consents. The location of the surface water compliance limits **Drawing No. MG1001/14/07**.

Table HRA12: Surface Water Compliance Limits

Monitoring Point Reference	Parameter	Source	Limit (incl. unit)	Reference Period	Monitoring Frequency
SWD1 (Discharge Consent Ref.: PRNNF12734)	Ammoniacal Nitrogen (Measured as N)	Settled mineral wash water in admixture within site drainage and groundwater	1 mg/l	Spot Sample	Monthly
	Suspended Solids		30 mg/l		
	pH		Between 6.0 and 9.0		
	Flow Rate		At a rate not exceeding 2000m^3 per Day		
	Visible Oil and Grease		None visible		
SWD2 (Discharge Consent Ref.: EPR/ZP3724XU)	Ammoniacal Nitrogen (Measured as N)	Settled dewatering via outlet and sample point	1 mg/l	Spot Sample	Monthly
	Suspended Solids		30 mg/l		
	pH		Between 6.0 and 9.0		
	Maximum Daily Discharge Volume		6,500 m^3 per day		
	Maximum Rate of Discharge		60 litres per second		
	Visible Oil and Grease		None visible		

4.3.3 The Environment Agency will be made aware when these monitoring points are removed from the monitoring schedule.

4.3.4 Details of post-closure surface water monitoring requirements are presented in in the accompanying Supporting Statement (*Document Ref.: MG1001/06*).

5.0 CONCLUSIONS

5.1 Summary

5.1.1 This Hydrogeological Risk Assessment has been undertaken in line with the Environment Agency guidance on Hydrogeological Risk Assessment reviews.

5.1.2 The aim of this Hydrogeological Risk Assessment was to assess the potential impact associated with the proposed restoration of Husbands Bosworth Quarry via landfilling of inert wastes.

5.1.3 The modelling undertaken in support of this Hydrogeological Risk Assessment indicates that whilst the proposed inert landfill presents a potential hazard to surrounding groundwater and surface water quality, the baseline concentrations and dilution available with the downgradient aquifer units means that the inert landfill's potential impact on these receptors is negligible.

5.1.4 Furthermore, the supporting modelling indicates that baseline conditions and available dilution is sufficient for the Waste Acceptance Limits to be increased up to three those of the standard Inert WAC Limits.

5.2 Compliance with the Landfill Directive

5.2.1 The results of this risk assessment have established the revisions to the landfill development will continue to comply with the relevant requirements of the Landfill Directive as follows:

- Due to the physical characteristics of the surrounding sand and gravel aquifer, the facility presents a potential hazard to groundwater quality if unabated;
- Consequently, an AEGB will be required across the sidewalls of the quarry, although no leachate management will be necessary;
- Compliance limits have been derived to ensure the adequate protection of ground and surface water resources.

5.3 Compliance with the Schedule 22 of the EPR2016

5.3.1 The results of this risk assessment have established the proposed inert landfill development will continue to comply with the relevant requirements of the Groundwater Regulations 2009 as follows:

- The inert landfill development poses a potential hazard to ground and surface water quality. Consequently, it continues to fall within the scope of the Schedule 22 of the EPR2016;
- this assessment forms a review of the "prior investigation" that must be carried out for this type of development;
- the proposed technical precautions are considered appropriate and reasonable to avoid the entry of Hazardous Substances into groundwater throughout the lifecycle of the facility;
- the proposed technical precautions will limit the introduction of Non-hazardous Pollutants into groundwater to avoid pollution throughout the lifecycle of the facility; and
- groundwater and surface water monitoring schedules will be used in accordance with the requisite surveillance requirements of the Schedule 22 to the EPR2016.

REFERENCES

Domenico, P. A., and F. W. Schwartz (1990). *Physical and Chemical Hydrogeology*, 824 pp., John Wiley, New York.

Hafren Water (2001). *An environmental assessment of the surface and groundwater regime in the vicinity of Colchester Quarry, Essex.*

Hobbs, P.R.N., Entwisle, D. C., Northmore, K. J., Sumbler, L. D., Kemp, S., Self, S., Barron, M. & Meakin, J. L. (2012). *Engineering Geology of British Rocks and Soils - Lias Group***.** British Geological Survey Internal Report**,** OR/12/032**.** 323pp

MacDonald, A., Maurice, L., Booth, D., Auton, C., Reeves, H. (2009). *Measuring in situ permeability of Quaternary deposits: examples from Forres, Morayshire*. [Lecture] In: Engineering Geology of the Quaternary Deposits, Reading, UK, 31 March 2009. British Geological Survey. (Unpublished)