AN APPLICATION FOR AN ENVIRONMMENTAL PERMIT TO AUTHORISE THE DEPOSITION OF WASTE ON LAND AS A RECOVERY ACTIVITY FOR THE RESTORATION OF PHASES 12, 13A, 13C AT BROOKSBY QUARRY, MELTON ROAD, BROOKSBY, LEICESTERSHIRE

HYDROGEOLOGICAL RISK ASSESSMENT (HRA)

Report reference: TAR/BRO/JRC/20021/01/HRA
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1. Introduction

1.1 MJCA is commissioned by Tarmac Trading Limited (Tarmac) to prepare an application for a bespoke Environmental Permit (EP) for the deposition of waste on land as a recovery activity in order to restore Phases 12, 13a and 13c to agriculture at Brooksby Quarry, Melton Road, Brooksby, Leicestershire. This report comprises the hydrogeological risk assessment (HRA) to support the EP application. Throughout this application Phases 12, 13a and 13c are referred to as the site.

1.2 The site which forms part of the wider Brooksby Quarry complex is centred on National Grid Reference (NGR) SK 66813 15092 approximately 1.1km east of Rearsby and 1.6km south east of Thrussington in Leicestershire. Phases 12, 13a and 13c the subject of this EP application are located in the north western part of the Brooksby Quarry complex. The location of the site the subject of this EP application is shown on Figure ESSD 1 of the Conceptual Site Model, Environmental Setting and Site Design (ESSD) report which is provided at Appendix F of the application. The layout of the Brooksby Quarry complex including the phasing at the site is shown on Figure ESSD 2.

1.3 Mineral extraction operations in Phases 1 to 10 are complete and parts of Phases 8 and 9 and Phase 10 are being restored as an inert landfill pursuant to EP number EPR/CB3504CQ. With the exception of the site and the area of the Brooksby Quarry complex the subject of EP number EPR/CB3504CQ all the other phases of the Brooksby Quarry complex are being restored to agriculture, open water and nature conservation using onsite overburden and quarry reject materials. It is understood that a total of approximately 555,907m^3 of overburden and sand and gravel mineral will be excavated from Phases 12 to 13c of which approximately 281,645m^3 comprises the overburden and approximately 247,262m^3 comprises the mineral deposit.

1.4 The HRA is based on the Conceptual Site Model (CSM) presented in the ESSD report. Details of the environmental setting of the site, the geology, hydrology and hydrogeology, the history of the site, potential contamination migration pathways and receptors are described in the ESSD report. The acceptance at the site of inert waste materials only will be the subject of waste acceptance procedures which are described in the ESSD and are presented at Appendix M of the application report.

1.5 The structure of this HRA report generally is based on Environment Agency (EA) guidance[1] updated in October 2022. The hydrogeological risk assessment and technical precautions sections specified in the EA guidance are presented in the subsequent sections of this report. Additional subheadings have been included as appropriate.

1.6 It is concluded in the HRA that there is no significant risk from the proposed deposition of inert waste as a recovery activity to groundwater and surface water quality in the vicinity of the site over the whole life cycle of the site.

1 https://www.gov.uk/guidance/landfill-operators-environmental-permits/what-to-include-in-your-hydrogeological-risk-assessment

2. Hydrogeological risk assessment – Qualitative risk screening (Tier 1)

2.1 The hydrogeological risk assessment is undertaken in accordance with EA guidance[1] and follows a tiered approach to risk assessment[2] with the level of risk assessment proportional to the risks to groundwater and surface water from the recovery operation. Information on the geology, hydrology and hydrogeology of the site is presented in the ESSD report. The information in the ESSD report is used to identify the relationships between the source, pathways and the identified potential receptors.

Nature of the hydrogeological risk assessment

Potential risks presented by the site

2.2 The areas in which imported inert restoration material will be deposited comprise Phases 12, 13a and 13c (Figure ESSD 2). As set out in the ESSD, inert waste is defined in the EU Landfill Directive (Council Directive 1999/31/EC) as:

> *"…waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will 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 health. The total leachability and pollutant content of the waste and the eco toxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and/or groundwater."*

2.3 The waste types that it is proposed may be accepted at the site are presented in Table ESSD 1 and comprise inert waste types only. As set out in the ESSD, the majority of the waste types are consistent with those specified in the guidance[3] as waste types that a producer may not need to test. Detailed waste acceptance procedures will be in place to minimise the risk that unacceptable waste materials are accepted at the site. Procedures will be in place for the rejection of non-conforming loads. The waste acceptance procedures are presented at Appendix M of the

3 https://www.gov.uk/government/publications/deposit-for-recovery-operators-environmental-permits/waste-acceptance-procedures-for-deposit-for-recovery

application report. The receipt, handling and storage of materials are the subject of procedures in the company management system which is the subject of the ISO 14001 Environmental Management System (EMS) a summary of which is presented at Appendix K of the application report.

2.4 Based on the above and as set out in the ESSD, it is considered that the waste does not comprise a contaminant source with the potential to have a significant detrimental effect on groundwater quality. As the restoration materials imported to the site will comprise inert waste only there will be no significant concentrations of hazardous substances and no significant concentrations of non-hazardous pollutants in water that has percolated through the waste mass. Based on the proposed use of inert imported restoration materials and on site materials only it is considered that there will be no significant risks to human health or to the environment from the proposed development.

Sensitivity of surrounding water environment

2.5 As set out in the ESSD, the superficial geology at the site at Phases 12, 13a and 13c comprises Quaternary age alluvium, colluvium, the Wolston Glaciogenic Formation comprising the Thrussington Till Member and the Bytham Sand and Gravel Formation. The Bytham Sand and Gravel Formation comprises the main mineral deposit at the site and is designated as a Secondary A aquifer. The Wolston Glaciogenic Formation comprises mainly diamicton, clay and silt and is designated as a Secondary (undifferentiated) aquifer (Thrussington Till Member). The Wolston Glaciogenic Formation generally comprises the overburden at the site. The superficial deposits at site overlie the Triassic age Mercia Mudstone Group which comprises mainly mudstones and siltstones and is classified as a Secondary B Aquifer.

2.6 There are surface water bodies potentially in continuity with groundwater in the superficial deposits including the Rearsby Brook which flows through the wider site complex and adjacent to the southern boundaries of Phases 12 and 13a. The level of the Rearsby Brook is approximately 63mAOD to the south of Phase 12 (Appendix ESSD B and Figure ESSD 7). It is considered that the Rearsby Brook is elevated above and hydraulically separate from the groundwater in the main Bytham Sand and

Gravel Formation deposits as it flows through the in the north east and central areas of Brooksby Quarry Complex. It is likely that groundwater discharges to the Rearsby Brook from the area of the site in the west of Brooksby Quarry Complex and to the west and down hydraulic gradient and downstream of the site.

2.7 As set out in the ESSD, groundwater flow in the Bytham Sand and Gravel Formation at the site is towards the west generally parallel to the direction of flow of the Rearsby Brook. It is considered that groundwater in the Bytham Sand and Gravel Formation in the vicinity of the site discharges to the Rearsby Brook and the River Wreake.

2.8 The site is not located within a groundwater Source Protection Zone of a public water supply and there are no SPZs within 5km of the site. It is considered that the deregulated and private groundwater abstractions located to the west and to the west south west of the site are located down hydraulic gradient of the site (reference numbers 5, 6, 7, 9 and 10 on Figure ESSD 5). The source of the deregulated and private groundwater abstractions is not available. It is assumed, conservatively, that the source of the abstractions comprise groundwater in the sand and gravel superficial deposits.

2.9 During excavation and restoration operations at Phases 12, 13a and 13c pumping to facilitate dewatering is and will continue to be carried out to facilitate dry working of the mineral and the placement of restoration materials comprising the site derived overburden and imported inert materials until the restoration materials are above the natural groundwater level. Groundwater and incident rainfall will continue to be pumped as necessary to the settlement ponds at the site prior to use in the wash plant under abstraction licence MD/028/0055 or consented discharge to the Rearsby Brook. The ponds at the site are labelled on Figure ESSD 4. The discharge of water from the site surface water management system to Rearsby Brook is the subject of the Environmental Permit Number T/55/46030/T (Appendix ESSD H). Following restoration of the site, dewatering operations will cease and the groundwater levels will return to levels similar to pre-extraction levels.

2.10 Based on the Conceptual Site Model the site is in a moderately sensitive setting as the site is located in a Secondary A aquifer and the site is sub-water table hence groundwater provides a direct pathway to surface water receptors from the site comprising the Rearsby Brook and pathways to groundwater abstractions down hydraulic gradient of the site.

Hazards posed and likelihood of the risk happening

2.11 Notwithstanding that it is concluded based on the proposed use of inert waste only that there will be no significant risks to human health or to the environment from the proposed operations and that waste acceptance procedures will be in place to minimise the risk that unacceptable waste materials are accepted consideration has been given to the mitigation of residual risk given the sensitivity of the site setting. Following the completion of mineral extraction activities at Phases 12, 13a and 13c the base of the void comprises the upper surface of the Mercia Mudstone Group. Site derived low hydraulic conductivity overburden has been and will continue to be placed along the side walls of the excavation forming a low hydraulic conductivity attenuation layer between the quarry void and the saturated sand and gravel deposits surrounding the site. The attenuation layer will comprise suitable clayey overburden from the mineral extraction operations at the site the subject to the requirements of the Quarry Regulations 1999 and the Environmental Management Systems. Given that the overburden comprises sandy gravelly clay it is considered highly likely that the replaced site derived overburden in the side slopes will comprise a minimum 1m thick mineral attenuation layer with a hydraulic conductivity no greater than 1×10^{-7}m/s and likely to be considerably lower. As a precaution and as a minimum, the top 1m of the backfilled site derived overburden will be the subject of Construction Quality Assurance (CQA) to confirm a hydraulic conductivity no greater than 1×10^{-7}m/s consistent with the conditions of the permit prior to the placement of imported inert restoration materials.

2.12 The placement of an attenuation layer of site derived clayey overburden comprising naturally occurring material at the site against the side slopes of the excavations at the site prior to the placement of imported inert restoration materials means there will be no direct discharge of hazardous substances to groundwater in the unlikely scenario where water percolating through the waste mass includes discernible concentrations of hazardous substances. The attenuation layer, as the name suggests, will attenuate the discharge of non-hazardous pollutants to groundwater in the unlikely scenario where water percolating through the waste mass includes significant concentrations of non-hazardous pollutants.

2.13 Any dewatering operations within the quarry void which may be necessary during the placement of inert waste have the potential to mobilise contaminants within the waste to the Rearsby Brook via the silt lagoon, clean water lagoon and discharge polishing lake. It is considered that any water accumulating within the quarry void during the placement of inert waste and which has been in contact with the inert waste will be the subject of significant dilution by rainfall and surface water incident to the quarry void along with further significant dilution within the silt lagoon, clean water lagoon and discharge polishing lake. It is therefore considered that the concentrations of any hazardous substances or non-hazardous pollutants originating from the inert waste and within water mobilised by any groundwater management operations are likely to be several orders of magnitude lower than those within water percolating through the waste mass and discharging indirectly via the site derived overburden to the groundwater in the Bytham Sand and Gravel Formation. The discharge of water from the site water management system to Rearsby Brook is the subject of a consent to discharge (Environmental Permit Number T/55/46030/T).

Proposed assessment scenarios

Quantitative risk screening (Tier 1)

2.14 A qualitative risk screening (Tier 1) is presented above with the Source – pathway – receptor linkages throughout the lifecycle of the site summarised in Table HRA 1. Based on this qualitative risk screening it is considered that there is no significant risk posed by the proposed deposition of inert restoration materials at the site to groundwater quality in the superficial Bytham Sand and Gravel Formation Secondary A aquifer or the surface water in the Rearsby Brook as it is considered that the waste does not comprise a contaminant source with the potential to have a significant detrimental effect on water quality. Due to the sensitivity of the site setting it is proposed that an attenuation layer equivalent to a natural geological barrier with a minimum thickness of 1m will be constructed against the base and side slopes of the excavations at the site prior to the placement of imported inert restoration materials such that there will be no direct discharge of hazardous substances and that non-hazardous pollutants will be attenuated in the unlikely scenario where water percolating through the waste mass includes discernible concentrations of hazardous substances or significant concentrations of non-hazardous pollutants. A schematic cross section of the site is presented on Figure HRA 1.

Consideration of further tiers of risk assessment

2.15 While it is considered that the Tier 1 qualitative risk screening demonstrates that there will be no significant risk posed by the proposed deposition of inert restoration materials at the site to surrounding groundwater and surface water quality and that a precautionary approach has been taken with the inclusion of an attenuation layer a further Tier 2 generic quantitative risk assessment (GQRA) has been undertaken to support these conclusions and is presented at Section 3 to this report. While the Tier 1 qualitative risk screening does not suggest there is an unacceptable risk, it is considered that due to the moderate sensitivity of the site setting the Environment Agency will expect a further Tier 2 GQRA.

3. Hydrogeological risk assessment – Generic quantitative risk assessment (GQRA) (Tier 2)

3.1 Although it is determined in the Tier 1 qualitative risk screening presented in the HRA that there would be no significant risk posed to groundwater and surface water quality from the proposed deposition of inert restoration materials at the site, a Tier 2 generic quantitative risk assessment (GQRA) for the post restoration scenario when groundwater levels recover following the cessation of dewatering at the site has been undertaken. The focus of the GQRA is the potential risk to groundwater from the migration of water which has percolated through the waste deposit into groundwater round the site. It is assumed that the whole mass of restoration materials comprises a potential source of contaminants. The GQRA comprises a simple mass balance equation to demonstrate that there is no significant risk to groundwater quality and surface water quality.

Priority contaminants

3.2 Consistent with EA guidance[4] the modelled substances have been selected by way of a risk screening exercise. The source term assumed for the purpose of the quantitative risk screening exercise is the inert Waste Acceptance Criteria (WAC) leaching limit values which have been screened against appropriate water quality standards. For hazardous substances the relevant screening criterion is the minimum reporting value (MRV) where available or otherwise the limit of quantification provided in the UKTAG Technical report on Groundwater Hazardous Substances[5]. For non hazardous pollutants the screening assessment criterion is the minimum of the UK Drinking Water Standard (DWS), freshwater Environmental Quality Standard (EQS) or the background groundwater concentrations.

3.3 For the purpose of the screening assessment groundwater quality monitoring data for the boreholes BH2/17, BH3/17, WM01, WM02 and BH18/PZA have been reviewed for the period November 2007 to October 2022. The locations of the

4 https://www.gov.uk/guidance/landfill-operators-environmental-permits/what-to-include-in-your-hydrogeological-risk-assessment

5 Hazardous substances to groundwater: minimum reporting values - GOV.UK (www.gov.uk)

boreholes are shown on Figure ESSD 8 and the monitoring data collected at the boreholes is presented at Appendices ESSD H and I.

3.4 As part of the risk screening exercise a risk characterisation ratio (RCR) has been calculated as the assumed source concentration divided by the relevant screening criterion. Based on the results of the risk screening exercise the hazardous substances arsenic, lead and mercury and the non-hazardous pollutants cadmium, copper, nickel and zinc have a RCR greater than 10 and are substances included in the source term for the GQRA and for which Environmental Assessment Levels (EALs) have been set. The hazardous substance chromium has a RCR greater than 10 and is not included in the GQRA as its RCR is lower than that of lead which behaves similarly in the environment and is included in the GQRA. In addition to the above chloride and toluene are included in the GQRA. Chloride is ubiquitous in its presence in groundwater naturally occurring materials and waste materials and toluene is a hazardous substance considered representative of a range of organic compounds.

3.5 As a conservative assumption the source term concentrations used in the GQRA comprise the liquid to solid ratio 10 l/kg leaching limit values presented in the EU Commission document for inert Waste Acceptance Criteria (WAC)[6] expressed in mg/l. The liquid to solid ratio 10 l/kg leaching limit values for inert waste are those with which waste leaching test results are compared prior to acceptance at an inert waste landfill as necessary. The source term concentration for toluene is based on the solid composition WAC for BTEX converted into mg/l. For the purpose of the GQRA it is assumed that the total BTEX concentration comprises toluene. The source term concentrations are specified in Table HRA 2.

Review of Technical precautions

3.6 As set out in the Tier 1 qualitative risk screening, notwithstanding that it is concluded based on the proposed importation of inert waste only that there will be no significant risks to the environment from the proposed development consideration has been given to the residual risk given the sensitivity of the site setting. Site derived low

6 Council decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC. Official Journal of the European Communities. 2003/33/EC

hydraulic conductivity overburden has been and will continue to be placed along the side walls of the excavation forming a low hydraulic conductivity attenuation layer between the quarry void and the saturated sand and gravel deposits surrounding the site in the manner described in Section 2.11. As a precaution and as a minimum, the top 1m of the backfilled site derived overburden will be the subject of Construction Quality Assurance (CQA) to confirm a hydraulic conductivity no greater than 1 x 10^{-7}m/s consistent with the conditions of the permit prior to the placement of imported inert restoration materials.

Modelling approach

GQRA dilution calculation principles

3.7 The Bytham Sand and Gravel Formation is the main groundwater water bearing unit at the site. The sand and gravel deposit is overlain by sandy gravelly clay overburden which generally thickens from approximately 2m to 7m towards the north across Phases 12, 13a and 13c. The base of the sandy gravelly clay overburden/ surface of the mineral deposit at Phases 12, 13a and 13c is between approximately 64mAOD and 66mAOD. Groundwater levels across the site generally fall from approximately 64mAOD to the east and south east of Phases 12, 13a and 13c to approximately 60mAOD to the south west of the site.

3.8 During placement of restoration materials at the site, water accumulating in the void will be managed consistent with the details provided above to facilitate dry placement of restoration materials. It is assumed that during groundwater management operations any substances in the inert waste transported in water percolating through the waste mass will be the subject of significant dilution and be treated within the site surface water management infrastructure prior to re-use within the site operations or permitted discharge to the Rearsby Brook. Following recovery of groundwater levels once groundwater pumping has ceased it is assumed that substances in the inert waste transported in water percolating through the waste mass will migrate to the down hydraulic gradient edge of the attenuation layer and enter groundwater in the Bytham Sand and Gravel Formation aquifer. It is assumed conservatively that the compliance point for hazardous substances and for non-hazardous pollutants is in the groundwater at the edge of the attenuation layer following immediate dilution in the Bytham Sand and Gravel Formation aquifer.

3.9 Based on the conceptual site model presented in the ESSD report the principal receptor for the migration of contaminants is the groundwater in the sand and gravel deposits. The secondary receptors comprise the Rearsby Brook down hydraulic gradient and to the west of the site and groundwater abstractions at distance down hydraulic gradient of the site. The pathway to the Rearsby Brook and groundwater abstractions at distance down hydraulic gradient of the site is via the sand and gravel aquifer. An additional pathway to the Rearsby Brook comprises the discharge from the water management system during placement of restoration materials at the site. A summary of the source-pathway-receptor linkages is presented in Table HRA 1 and the cross section presented on Figure HRA 1. As set out in the ESSD, groundwater flow in the sand and gravel deposits is towards the west generally towards and in the direction of flow of the Rearsby Brook. It is considered that groundwater in the sand and gravel deposits discharges to the Rearsby Brook.

3.10 As set out in the ESSD based on the hydrogeological impact assessment (HIA) report[7] for phases 12, 13a and 13c a minimum hydraulic conductivity for the Bytham Sand and Gravel Formation of 2.31×10^{-4}m/s is considered appropriate for the Bytham Sand and Gravel Formation.

3.11 For the reasons outlined above dilution in the Bytham Sand and Gravel Formation is considered only in this GQRA. Dilution at the secondary receptors comprising the Rearsby Brook and distant groundwater abstractions is not included. Concentrations of substances in any water pumped from the excavation which may have been in contact with the inert waste are likely to be significantly lower than those in water percolating the waste and migrating to the Bytham Sand and Gravel Formation. Nevertheless the same model is used conservatively to represent both the operational and post operational scenarios.

7 Hafren Water. June 2018. Hydrogeological and hydrological assessment for a proposed extension to Brooksby Quarry. Report Reference 2479/HIA.

3.12 Other than immediate dilution in the Bytham Sand and Gravel Formation aquifer no attenuation of hazardous substances or of non-hazardous pollutants in the attenuation layer or Bytham Sand and Gravel Formation aquifer is considered in the dilution calculations. As dispersion, retardation and degradation processes will reduce the concentrations of hazardous substances or of non-hazardous pollutants in the attenuation layer and the concentrations of non-hazardous pollutants along the groundwater flow path prior to the groundwater reaching the Rearsby Brook, it is considered that this assumption is conservative.

3.13 As a conservative assumption it is assumed that all of the modelled substances are present at the relevant inert WAC concentrations at the outer edge of the attenuation layer site boundary. Accordingly these concentration values are used as model input parameters in a spreadsheet based model which predicts the concentration of contaminants in the sand and gravel aquifer at the compliance point taking into account immediate dilution in the aquifer. For each of the substances environmental assessment limits (EALs) are proposed in the model parameterisation section below. The EALs comprise the concentrations of substances above which it is considered there may be a discernible discharge of hazardous substances to groundwater or pollution of groundwater by non-hazardous pollutants.

Calculation methodology

3.14 To assess the magnitude of the potential impact on groundwater quality of the acceptance of inert waste at the WAC leaching limit values, the predicted concentration of contaminants in the Bytham Sand and Gravel Formation aquifer at the compliance point are compared with the EALs. The predicted concentration of contaminants in the Bytham Sand and Gravel Formation aquifer at the compliance point following immediate dilution is calculated as follows:

$$C_{aq} = \frac{C_{iw} \times Q_{iw} + C_{bq} \times Q_{aq}}{Q_{iw} + Q_{aq}}$$

where:

C_{aq} is the predicted concentration in the aquifer (mg/l)

C_{iw} is the inert WAC liquid to solid ratio 10 l/kg leaching limit value assumed at the edge of the site (expressed as mg/l)

Q_{iw} is the discharge to groundwater from the inert waste fill (m^3/s) which is calculated based on the hydraulic conductivity of the attenuation layer multiplied by the assumed hydraulic gradient across the attenuation layer.

C_{bg} is the background concentration of the contaminant in the Bytham Sand and Gravel Formation aquifer (mg/l)

Q_{aq} is the groundwater flow in the Bytham Sand and Gravel Formation aquifer (m^3/s) down hydraulic gradient of the site which is calculated based on the assumed hydraulic conductivity of the sand and gravel multiplied by the calculated hydraulic gradient in sand and gravel aquifer.

Model parameterisation

3.15 The substances which comprise the source term in respect of the GQRA together with the source concentrations are listed in Table HRA 2. For each of the substances included in the source term the proposed EALs are presented in Table HRA 2. The EAL for the hazardous substance toluene is set at the minimum reporting value (MRV). For the hazardous substances arsenic, lead and mercury in respect of which mean background concentrations are higher than the respective MRV the EAL comprises whichever is lowest out of the maximum recorded background concentration (arsenic) and the mean background concentration plus three standard deviations (lead and mercury). The EALs for non-hazardous pollutants are set based on background groundwater quality and/or relevant water quality standards where available and following EA guidance[8].

3.16 Where possible the input parameters are based on site specific data or other relevant sources. Where no site specific data are available professional judgement has been used to select appropriate parameter values based on relevant scientific literature. The model input parameters are presented in Table HRA 3 and in the spreadsheet

8 https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit#decide-which-environmental-standards-to-use

based model at Appendix HRA B. The following assumptions are made for the input parameters:

- It is assumed conservatively that the hydraulic conductivity of the attenuation layer will be approximately 1 x 10^{-7} m/s.
- The hydraulic gradient assumed for the sand and gravel aquifer pathway is based on the groundwater level data recorded at boreholes BH2/17, BH3/17, WM01, WM02 and BH18/PZA which have been reviewed for the period November 2007 to April 2023.
- It is assumed conservatively that the hydraulic gradient across the attenuation layer will be double the hydraulic gradient assumed for the sand and gravel aquifer.

Model results – Emissions to groundwater or surface water

3.17 The spreadsheet based model which calculates the predicted concentration of contaminants in the sand and gravel aquifer at the compliance point taking into account immediate dilution in the aquifer is presented at Appendix HRA B and in Table HRA 4. An electronic copy of the risk assessment model and results are presented at Appendix HRA C.

Hazardous substances and non-hazardous pollutants

3.18 As an attenuation layer comprising selected site derived overburden will be present between the surrounding aquifer and the inert infill materials there will be no direct discharge of hazardous substances or non-hazardous pollutants from the placement of inert restoration materials at the site. The GQRA model represents the potential indirect discharge of hazardous substances or non-hazardous pollutants from the placement of inert restoration materials at the site.

3.19 The model results show that the inputs of the hazardous substances to the groundwater at the edge of the site following immediate dilution are significantly lower than the respective EALs. It is therefore considered that there will be no discernible discharge of hazardous substances as a result of the permitted operations.

3.20 The model results show that the calculated concentrations of non-hazardous pollutants in the groundwater at the edge of the site following immediate dilution in the Bytham Sand and Gravel Formation aquifer are significantly lower than the respective EALs. Consequently there is no significant risk to down hydraulic gradient receptors such as areas of groundwater discharge to the surface watercourses.

Sensitivity analysis

3.21 Notwithstanding the parameterisation of this GQRA using conservative assumptions, sensitivity analysis has been undertaken to assess the impact of increased flow from the restoration materials into the groundwater at the edge of the site. It is assumed conservatively that the hydraulic gradient across the attenuation layer will be double the hydraulic gradient assumed for the sand and gravel aquifer. Due to the low hydraulic conductivity of the attenuation layer and the inert waste infiltrating rainwater may result in water mounding within the inert waste mass. A sensitivity analysis of the hydraulic gradient across the attenuation layer has been undertaken. The hydraulic gradient has been increased by a factor of two which is 4 times the average hydraulic gradient in the sand and gravel aquifer. The results of the sensitivity analysis are presented at Appendix HRA D and in Table HRA 4 and show that with a doubling of the hydraulic gradient across the attenuation layer the calculated concentrations of the hazardous substances and non-hazardous pollutants in the groundwater at the edge of the site following immediate dilution in the sand and gravel aquifer remain lower than the respective EALs. An electronic copy of the sensitivity analysis models is provided at Appendix HRA C.

3.22 A sensitivity analysis is undertaken to assess the impact of reduced flow in the sand and gravel aquifer by reducing the hydraulic conductivity of the Bytham Sand and Gravel Formation by a factor of 2.5 from 20m/day to 8m/day. The results show that the calculated concentrations of the hazardous substances and non-hazardous pollutants in the groundwater at the edge of the site following immediate dilution in the sand and gravel aquifer remain significantly lower than the respective EALs.

3.23 As stated in the model parameterisation section above, where possible the input parameters used in the GQRA are based on site specific data or other relevant sources. Where no site specific data are available professional judgement has been used to select appropriate parameter values. Sensitivity analyses have been carried out and are presented above to assess the sensitivity of the model to the assumptions made in the input parameters. It is proposed that groundwater level and quality monitoring is carried out during the operational and post operational phases of the site as set out in Table ESSD 2. The proposed groundwater quality compliance limits are set out in Table 5 of this HRA.

Accidents and their consequences

3.24 Whilst it is considered that using the WAC liquid to solid ratio 10 l/kg leaching limit values is a conservative approach as this assumes that all substances are at the maximum allowable limit, a further sensitivity analysis has been undertaken with respect to the source term concentration used in the model. In effect the sensitivity analysis allows for the unlikely situation where a significant portion of waste loads are accepted above the WAC. The source term has been increased to double the WAC liquid to solid ratio 10 l/kg leaching limit values. The results of the sensitivity analysis are presented at Appendix HRA D and Table HRA 4 and show that with an increase in source term concentrations the calculated concentrations of the hazardous substances and non-hazardous pollutants in the groundwater at the edge of the site following immediate dilution in the sand and gravel aquifer remain lower than the respective EALs. An electronic copy of the model including the source term at double the WAC is provided at Appendix HRA C.

3.25 Notwithstanding the above detailed consideration has been given to the possibility that non compliant waste will be accepted at the site. In summary:

- Robust Waste Acceptance Procedures (WAP) will be in place to minimise the risk that unacceptable waste materials will be accepted at the site and procedures will be in place for the rejection of non-conforming loads.

- No wastes will be accepted from contaminated sites.

- Because robust WAP will be implemented the uncertainty with regard to the presence of contaminants above inert WAC in the waste deposited will be low.

- Tarmac has been operating its WAP at numerous inert landfills and deposit for recovery sites including at Brooksby Quarry complex by agreement with the EA.

- The source term used in the modelling presented in this report conservatively assumes all waste is at the inert WAC limits and includes significant concentrations of toluene even though there is no expectation that toluene would be present in the waste.

Conclusions of Tier 2 GQRA

3.26 Based on the results of this Tier 2 GQRA it is considered that there is no significant risk from the proposed deposition of inert restoration materials at the site to groundwater quality in the superficial Secondary A aquifers, the surface water quality in the Rearsby Brook or groundwater abstractions at distance down hydraulic gradient of the site.

4. Hydrogeological risk assessment – Verification monitoring

Hydrogeological leachate completion criteria

4.1 No biodegradable waste materials will be deposited at the site which could result in the generation of leachate. Only inert wastes will be deposited at the site which have a limited potential for leaching of contaminants. As such, the specification of leachate completion criteria and in waste leachate monitoring are not necessary for the deposit of waste at the site as a recovery activity.

Monitoring

4.2 Notwithstanding that it is concluded based on the proposed use of inert waste only that there will be no significant risks to the environment from the proposed development and based on the site design and there being no direct pathway to groundwater or surface water receptors a programme of confirmatory groundwater and surface water monitoring is proposed. A programme of groundwater and surface water monitoring is presented in Table ESSD 2. The monitoring will be carried out during the operation of the site and for a limited period following restoration of the site. The monitoring locations are shown on Figure ESSD 8.

Groundwater monitoring and compliance limits

4.3 The proposed groundwater monitoring locations and determinands for which groundwater quality compliance and assessment limits will be set are presented in Table HRA 5. Consistent with Table HRA 5 groundwater quality compliance and assessment limits for groundwater at boreholes WM01 and BH18/PzA down hydraulic gradient of Phases 12, 13a and 13c. The down hydraulic gradient locations for Phase 12, 13a and 13c have been selected based on pre-extraction groundwater elevations and flow directions. It is proposed that the compliance limits are reviewed and updated as necessary following the collection of additional groundwater quality data. It is proposed that the review and updating as necessary of groundwater quality compliance limits will be secured through the use of appropriate improvement conditions.

4.4 No compliance or assessment limits are provided for surface water quality as based on the assessments carried out there is no direct pathway to surface water receptors following restoration of the site. During the operational phase of the site imported inert restoration materials will be placed against the excavation side walls and there will be no requirement to manage groundwater by discharging directly to surface watercourses during the placement of the inert restoration materials. It is therefore considered that the environmental performance of the proposed operations can be assessed through the monitoring of groundwater quality.

5. Conclusions

5.1 The proposed development comprises the deposition of inert waste as a recovery activity hence is not the subject of paragraphs 3.1 to 3.4 of Annex I of the Directive 1999/31/EC on the landfill of waste, as read with Council Decision 2003/33/EC establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of, and Annex II to, Directive 1999/31/EC (the Landfill Directive). Irrespective of the fact that the proposed development is not the subject of the Landfill Directive, waste acceptance procedures will be implemented to minimise the probability that non-inert wastes will be deposited at the site.

5.2 Based on the results of the Tier 1 qualitative and Tier 2 quantitative risk assessments presented in this HRA it is concluded that the site will be compliant with Schedule 22 of The Environmental Permitting (England and Wales) Regulations 2016 with regard to the implementation of the Directive 2006/118/EC of the European Parliament and of the Council on the protection of groundwater against pollution and deterioration (the Groundwater Directive).

5.3 Based on the HRA presented in this report it is concluded that there will be no discernible impact or pollution of groundwater in the Bytham Sand and Gravel Formation Secondary A Aquifer from Phases 12, 13a and 13c receiving waste in accordance with the proposed WAP. It is concluded that there is no significant risk from the proposed deposition of inert waste as a recovery activity to groundwater and surface water quality in the vicinity of the site over the whole life cycle of the site.

5.4 Groundwater quality compliance and assessment limits for groundwater at the down hydraulic gradient boreholes are presented in Table HRA 5. It is proposed that the compliance limits are updated following the collection of additional groundwater quality data and prior to commencement of recovery activities at the site.

5.5 Based on the environmental setting and the nature of the waste materials that will be deposited active long term site management will not be necessary in order to prevent groundwater pollution.

TABLES

Table HRA 1

Source - pathway - receptor linkages throughout the lifecycle of the site

Phase of landfill	Source	Pathway	Receptor
Operational and post operational/ Completion	***Water percolating through the inert restoration materials*** Given the inert nature of the waste that will be deposited at the site the potential for the presence of discernible concentrations of hazardous substances or significant concentrations of non-hazardous pollutants is considered highly unlikely. During quarrying and restoration the groundwater table is depressed by groundwater pumping. The inert wastes will be placed above the depressed groundwater level.	Attenuation layer Water management system Unsaturated superficial deposits. Groundwater in the superficial deposits.	Water management system thence re-use within the wash plant within the quarry complex or Rearsby Brook both following significant dilution within the quarry void, settlement lagoon, clean water lagoon and discharge polishing lake. Groundwater in the superficial deposits. Surface water reaches at and in the vicinity of the site.
Post operational/ completion	***Water percolating through the inert restoration materials*** Given the inert nature of the waste that will be deposited in the site the potential for the presence of discernible concentrations of hazardous substances or significant concentrations of non-hazardous pollutants is considered highly unlikely. The groundwater level will recover following cessation of groundwater pumping upon completion of infilling.	Attenuation layer Groundwater in the superficial deposits.	Groundwater in the superficial deposits. Surface water features at and in the vicinity of the site.

Table HRA 2

Source term concentrations assumed in the generic quantitative hydrogeological risk assessment calculations

Determinand	Environmental assessment limit (EAL) (mg/l)	EAL source [a]	Source term concentration (mg/l)	Mean background concentrations (mg/l)
Hazardous substances				
Arsenic	0.006	Maximum BGC	0.05 [b]	0.0016
Lead	0.00193	Mean BGC plus 3 standard deviations	0.05 [b]	0.00065
Mercury	0.00010	Mean BGC plus 3 standard deviations	0.001 [b]	0.00004
Toluene	0.004	MRV	0.8695 [c]	0.002 [d]
Non hazardous pollutants				
Cadmium	0.00026	Mean BGC plus 3 standard deviations	0.004 [b]	0.00005
Chloride	93.7	Mean BGC plus 3 standard deviations	80 [b]	39.4
Copper	0.0316	Mean BGC plus 3 standard deviations	0.2 [b]	0.0027
Nickel	0.0044	Mean BGC plus 3 standard deviations	0.04 [b]	0.0017
Zinc	0.0656	Mean BGC plus 3 standard deviations	0.4 [b]	0.0088

Notes:

MRV Minimum reporting value;

BGC Groundwater background concentration based on the available water quality monitoring data presented at Appendix HRA B

[a] The MRVs specified are consistent with MRVs specified at https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values or the MRV is consistent with the UKTAG limit of quantification specified at https://www.wfduk.org/sites/default/files/Media/UKTAG_Technical%20report_GW_Haz-Subs_ForWebfinal.pdf

[b] Based on the inert waste liquid to solid ratio 10 l/kg leaching limit values (reference 1) expressed in mg/l.

[c] The source term concentration for toluene is based on the solid composition WAC for BTEX converted into mg/l. It is conservatively assumed that the total BTEX concentration comprises toluene.

[d] For toluene where no background concentrations are available the background concentration is assumed conservatively to comprise half of the EAL (see Appendix HRA C (*Toluene source term)*)

Table HRA 3

Physical input parameters

Parameter	Units	Parameter value	Input worksheet title	Reference/Justification
Assumed hydraulic conductivity of the attenuation layer (m/s), K_{AL}	m/s	1.0×10^{-7}	*GQRA*	It is conservatively assumed that the hydraulic conductivity of the attenuation layer is consistent with the requirements of the Landfill Directive (1999/31/EC) for inert landfills. As the attenuation layer will comprise generally glacial till the hydraulic conductivity is likely to be considerably lower than the assumed value.
Hydraulic conductivity of the sand and gravel aquifer K_{aq}	m/s	2.31×10^{-4}	*GQRA*	Minimum assumed in 2018 HIA of 20m/d for Bytham Sand and Gravel Formation.
Hydraulic gradient of the sand and gravel aquifer, i_{aq}	m/m	0.00474	*GQRA*	Pre-extraction hydraulic gradient across the Brooksby Quarry complex between groundwater monitoring boreholes WM1 and WM2.
Hydraulic gradient across the artificial geological barrier (m/m), i_{AL}	m/m	0.00948	*GQRA*	To account for the possibility that the hydraulic gradient in the waste mass will be greater than in the aquifer, conservatively a hydraulic gradient of twice that in the aquifer has been used.
Width of the waste, w	m	390	*GQRA*	Based on Figure ESSD 2 (drawing reference TAR/BRO/12-21/22914). Confirmed by aerial photography images.

Parameter	Units	Parameter value	Input worksheet title	Reference/Justification
Thickness of the waste below the rest groundwater level, thickness _waste	m	3	*GQRA*	Approximate saturated thickness of waste based on Figure ESSD 7 (drawing reference TAR/BRO/06-22/23185) and Figure ESSD 6 (drawing reference TAR/BRO/08-21/2274

Table HRA 4

Results of the GQRA and sensitivity analyses

Determinand	**Environmental assessment limit (EAL)** (mg/l)	**Predicted substance concentration within Bytham Sand and Gravel Formation GQRA results** (Appendix HRA C ***GQRA*** worksheet)	**Predicted substance concentration within Bytham Sand and Gravel Formation Sensitivity analysis** (Appendix HRA C ***Sens_i AL x 2*** worksheet)	**Predicted substance concentration within Bytham Sand and Gravel Formation Sensitivity analysis** (Appendix HRA C ***Sens_k Aq reduced*** worksheet)	**Predicted substance concentration within Bytham Sand and Gravel Formation Sensitivity analysis** (Appendix HRA C ***Sens_source term x 2*** worksheet)
Hazardous substances					
Arsenic	0.006	0.00164	0.00168	0.00170	0.00169
Lead	0.00193	0.00069	0.00074	0.00076	0.00074
Mercury	0.00010	0.00004	0.00004	0.00004	0.00004
Toluene	0.004	0.00275	0.00350	0.00387	0.00350
Non hazardous substances					
Cadmium	0.00026	0.00005	0.00006	0.00006	0.00006
Chloride	93.7	39.4	39.5	39.5	39.5
Copper	0.0316	0.00287	0.00304	0.00313	0.00304
Nickel	0.0044	0.00168	0.00172	0.00173	0.00172
Zinc	0.0656	0.0091	0.0095	0.0096	0.0095

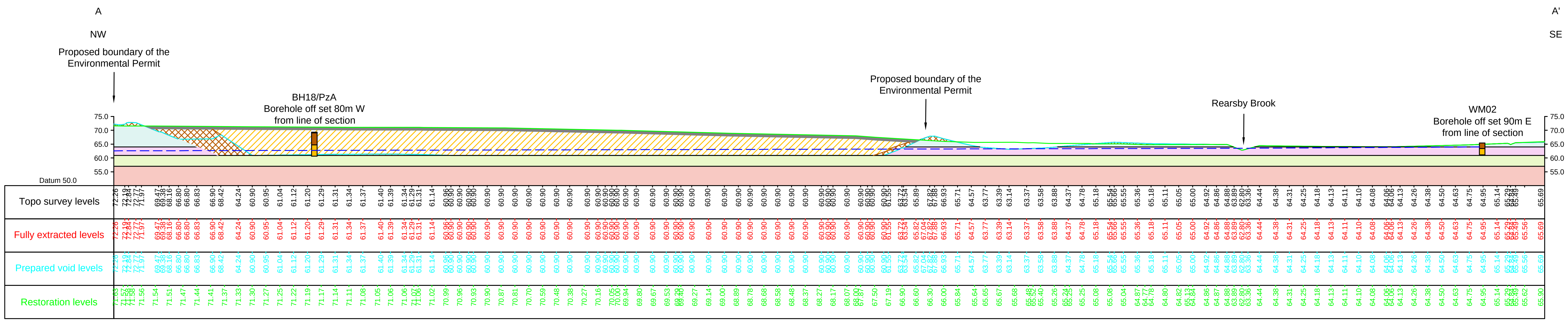
Table HRA 5
Groundwater quality compliance limits and assessment levels

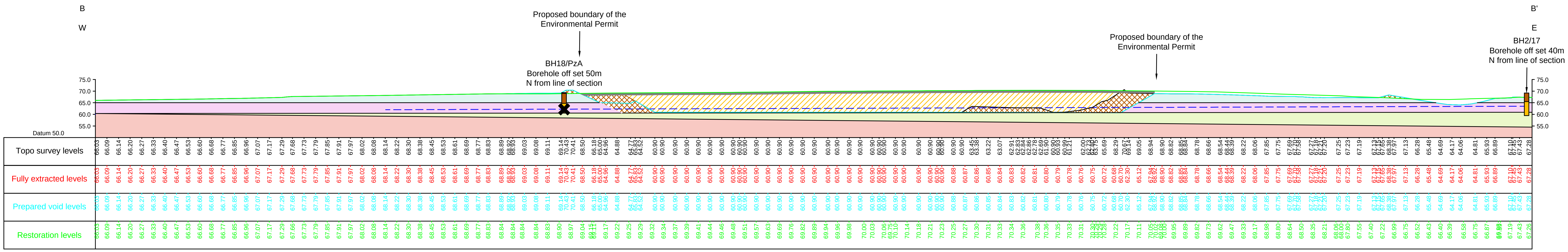
Criterion Objective To confirm that the deposition of inert waste at the site has no adverse effect on groundwater quality	
Measurement	Arsenic, cadmium, chloride, copper, lead, mercury, nickel, toluene and zinc
Frequency	Monthly for one year then quarterly. To be reviewed annually. Compliance limits and assessment levels will be reviewed one year after the collection of additional groundwater quality monitoring data for the boreholes detailed below round the three areas of the site.
Monitoring points the subject of compliance	Groundwater monitoring boreholes WM01 and BH18/PzA down hydraulic gradient of Phases 12, 13a and 13c.
Compliance limits[1] for down hydraulic gradient groundwater monitoring boreholes	**HAZARDOUS SUBSTANCES** The concentration of arsenic shall not exceed 0.006mg/l The concentration of lead shall not exceed 0.00193mg/l The concentration of mercury shall not exceed 0.00010mg/l The concentration of toluene shall not exceed 0.004mg/l
	NON-HAZARDOUS POLLUTANTS The concentration of cadmium shall not exceed: • 0.00026mg/l in boreholes WM01 and BH18/PzA The concentration of chloride shall not exceed: • 93.7mg/l in boreholes WM01 and BH18/PzA The concentration of copper shall not exceed: • 0.0316g/l in boreholes WM01 and BH18/PzA The concentration of nickel shall not exceed: • 0.0044mg/l in boreholes WM01 and BH18/PzA The concentration of zinc shall not exceed: • 0.0656mg/l in boreholes WM01 and BH18/PzA
Assessment levels[2] for down hydraulic gradient groundwater monitoring boreholes	**HAZARDOUS SUBSTANCES** The concentration of arsenic shall not exceed • 0.0041mg/l in boreholes WM01 and BH18/PzA The concentration of lead shall not exceed • 0.00150mg/l in boreholes WM01 and BH18/PzA The concentration of mercury shall not exceed • 0.00008mg/l in boreholes WM01 and BH18/PzA The concentration of toluene shall not exceed • 0.004mg/l in boreholes WM01 and BH18/PzA
	NON-HAZARDOUS POLLUTANTS The concentration of cadmium shall not exceed: • 0.00019mg/l in boreholes WM01 and BH18/PzA The concentration of chloride shall not exceed: • 75.6mg/l in boreholes WM01 and BH18/PzA The concentration of copper shall not exceed: • 0.022mg/l in boreholes WM01 and BH18/PzA The concentration of nickel shall not exceed: 0.0035mg/l in boreholes WM01 and BH18/PzA The concentration of zinc shall not exceed: • 0.047mg/l in boreholes WM01 and BH18/PzA
Assessment test	Concentrations exceed the assessment level on three consecutive occasions.

Contingency action	**Response Time**
Advise the Environment Agency.	1 month
Increase the survey frequency to monthly.	1 month
Undertake investigation work to identify the source of the contaminants.	6 months

Report to the Environment Agency on the re-appraisal of risks and options for corrective measures.	12 months
If the risks are acceptable re-evaluate the assessment criteria. If the risks are unacceptable implement agreed corrective measures.	18 months 18 months
Notes: [1] The compliance limit for the hazardous substances arsenic is set at the maximum recorded background concentration. The compliance limit for the hazardous substances lead and mercury are set at the mean recorded background concentrations plus three standard deviations. The compliance limit for the hazardous substance toluene is set at the MRV. For groundwater monitoring boreholes WM01 and BH18/PzA down hydraulic gradient of Phases 12, 13a and 13c the compliance limits for the non-hazardous pollutants cadmium, nickel and zinc are set at the mean background concentration recorded at boreholes BH2/17, BH3/17, WM01 and WM02 and BH18/PzA plus three standard deviations. The compliance limit for the non-hazardous pollutant chloride is set at the maximum background concentration recorded at boreholes BH2/17, BH3/17, WM01 and WM02. [2] The assessment levels for the hazardous substances arsenic, lead and mercury and non-hazardous pollutants cadmium, chloride, copper, nickel and zinc are set at the mean background concentration recorded at the relevant boreholes as described above plus two standard deviations. The assessment level for the hazardous substance toluene is set at the MRV.	

FIGURES





Key / Notes

Soils

- Sand and gravel
- Silt and clay
- Interpolated groundwater levels recorded in May 2006 (pre-extraction groundwater levels)
- Restoration soils
- Inert waste (or onsite materials)
- Backfilled onsite material
- Compliance point for hazardous substances and non hazardous pollutants
- Thrussington Till Member of the Wolston Glaciogenic Formation
- Bytham Sand and Gravel Formation
- Blue Anchor Formation
- Branscombe Mudstone Formation

Notes:
Based on model references B355 BROOKSBY 2021-06-30 QU B.LSS, TOTAL VOID AVAILABLE.LSS and 02. PREPARED VOID TO PERMIT BOUNDARY.LSS

Location of cross sections shown on drawing reference TAR/BRO/03-23/23638

Rev	Status	Drn	App	Chk	Date
	Final	KR	JAD	CJG	04/08/23

Site: BROOKSBY QUARRY

Client: TARMAC A CRH COMPANY

Title: Schematic cross sections through the proposed restored site

Figure HRA 1

Scale: 1:1,250@A2

Drawing Ref: TAR/BRO/06-23/23769

MJCA
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APPENDICES

APPENDIX HRA A

GENERIC QUANTITATIVE RISK ASSESSMENT – RISK SCREENING EXERCISE

			Inert waste leaching limit values [A]			Freshwater Environmental Quality Standard (EQS) [I, J]					Brooksby Quarry Phases 12, 13a and 13c			
Parameter	Symbol and notes	Category [B, C]	L/S = 10l/kg	L/S = 10l/kg eluate concentratation	UK Drinking Water Standard [H]	AA-EQS	MAC-EQS	Minimum reporting value (MRV) [F, G]	Minimum of MRV, DWS and EQS	Risk characterisation ratio (ignoring background groundwater quality)	Mean background concentration	Screening assessment criterion	Risk characterisation ratio (RCR)	Risk characterisation ratio (RCR) BG GW
Units			mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mg/l			
Antimony	Sb	Non hazardous	0.06	0.006	0.005				0.005	1.2		Minimum quality standard	1.2	
Arsenic	As	Hazardous	0.5	0.05	0.01	0.05		0.005	0.005	10.0	0.0016	Mean background	30.8	30.8
Barium	Ba	Non hazardous	20	2										
Cadmium	Cd [K]	Non hazardous	0.04	0.004	0.005	0.00015	0.0009		0.00015	26.7	0.00005	Mean background	88.4	88.4
Chromium	Cr	Hazardous [D]	0.5	0.05	0.05	0.0034	0.032	0.001	0.001	50.0	0.00104	MRV	50.0	48.1
Copper	Cu [L]	Non hazardous	2	0.2	2	0.001			0.001	200.0	0.0027	Minimum quality standard	200.0	75.4
Lead	Pb [L]	Hazardous	0.5	0.05	0.01	0.0012	0.014	0.0002	0.0002	250.0	0.00065	MRV	250.0	77.3
Mercury	Hg	Hazardous [E]	0.01	0.001	0.001		0.00007	0.00001	0.00001	100.0	0.00004	MRV	100.0	24.4
Molybdenum	Mo	Non hazardous	0.5	0.05										
Nickel	Ni [L]	Non hazardous	0.4	0.04	0.02	0.004	0.034		0.004	10.0	0.0017	Mean background	24.0	24.0
Selenium	Se	Non hazardous	0.1	0.01	0.01				0.01	1.0		Minimum quality standard	1.0	
Zinc	Zn [L, N]	Non hazardous	4	0.4		0.0123			0.0123	32.5	0.0088	Mean background	45.4	45.4
Chloride	Cl^-	Non hazardous	800	80	250	250			250	0.3	39.4	Mean background	2.0	2.0
Fluoride	F^- [M]	Non hazardous	10	1	1.5	1	3		1	1.0		Minimum quality standard	1.0	
Sulphate	SO_4^{2-}	Non hazardous	1000	100	250	400			250	0.4	129.1	Mean background	0.8	0.8
Phenol index		Non hazardous	1	0.1		0.0077	0.046		0.0077	13.0		Minimum quality standard	13.0	
Dissolved organic carbon		Non hazardous	500	50										toluene
Total dissolved solids		Non hazardous	4000	400										

Selection of screening assessment criterion:

Hazardous substances — Screening criterion is the MRV.

Non hazardous substance — Screening criterion is the minimum of the UK DWS or EQS unless the mean background concentration is lower in which case the mean background concentration is used.

Risk characterisation ratio — The risk characterisation ratio (RCR) is the assumed source concentration divided by the relevant screening criterion.

Key

(shaded) Substance that it is proposed is modelled.

Notes

[A] Council decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC. Official Journal of the European Communities. 2003/33/EC.

[B] "2018 01 31 Confirmed hazardous substances list" http://www.wfduk.org/sites/default/files/Media/JAGDAG/2018%2001%2031%20Confirmed%20hazardous%20substances%20list_0.pdf accessed 18 May 2023

[C] Where a substance has not been determined as a hazardous substance or non hazardous pollutant it is assumed that it is a non hazardous pollutant.

[D] Conservatively it is assumed that all of the chromium is chromium VI which is designated as a hazardous substance.

[E] Conservatively it is assumed that all of the mercury is mercury II which is designated as a hazardous substance.

[F] https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values accessed 18 May 2023

[G] MRV for arsenic, chromium and lead based on http://wfduk.org/sites/default/files/Media/UKTAG_Technical%20report_GW_Haz-Subs_ForWebfinal.pdf

[H] The Water Supply (Water Quality) Regulations 2016 (England) (with 2018 amendments consolidated) https://www.legislation.gov.uk/uksi/2016/614/schedule/1 accessed 18 May 2023

[I] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1010041/Freshwaters_specific_pollutants_and_operational_environmental_quality_standards.ods accessed 18 May 2023

[J] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1010036/Freshwaters_priority_hazardous_substances__priority_substances_and_other_pollutants_environmental_quality_standards.ods accessed 18 May 2023

[K] The EQS values reported are for a water hardness between 100mg/l and 200mg/l.

[L] EQS is for the bioavailable concentration. It is assumed that all is of the dissolved concentrations will be bioavailable.

[M] The EQS values reported are for less than 50 milligrams of calcium carbonate per litre of water (mg/l)

[N] Dissolved plus ambient background concentration.

Substances for which there is no MRV or relevant environmental quality standards are not considered in detail.

APPENDIX HRA B

GENERIC QUANTITATIVE RISK ASSESSMENT MODEL

GENERIC QUANTITATIVE RISK ASSESSMENT CALCULATIONS

Determinand	Compliance limit or environmental assessment limit (EAL) (mg/l)	Mean background concentrations (mg/l)	Concentration at the outside edge of the attenuation layer (WAC LS ratio 10l/kg expressed as mg/l)	Concentration predicted in the aquifer (mg/l)	Ratio of predicted discharge concentration after immediate dilution to MRV (Hazardous substances) or predicted concentrations to EAL (Non-hazardous pollutants)
Arsenic	0.006	0.0016	0.05	0.00164	0.27
Lead	0.00193	0.00065	0.05	0.00069	0.36
Mercury	0.00010	0.00004	0.001	0.00004	0.4
Toluene	0.004	0.002	0.8695	0.00275	0.69
Cadmium	0.00026	0.00005	0.004	0.00005	0.21
Chloride	93.7	39.4	80	39.4	0.42
Copper	0.0316	0.0027	0.2	0.00287	0.09
Nickel	0.0044	0.0017	0.04	0.00168	0.38
Zinc	0.0656	0.0088	0.4	0.0091	0.14

The source term for toluene is based on the solid composition WAC for BTEX converted into mg/l
It is conservatively assumed that the total BTEX concentration comprises toluene
Substances for which no background concentrations are available. Background concentrations conservatively assumed to comprise half of the EAL.

$$C_{aq} = \frac{C_{iw} \times Q_{iw} + C_{bg} \times Q_{aq}}{Q_{iw} + Q_{aq}}$$

Where C_aq is the calculated concentration in the aquifer (mg/l)
Where Qiw = K_{AL} x i_{AL} x (w_waste x thickness_waste) 1.11E-06
Where Qaq = K_aq x i_aq x (w_waste x thickness_waste) 1.28E-03

K_{AL} is the assumed hydraulic conductivity of the attenuation layer (m/s)	1.00E-07	m/s	It is conservatively assumed that the hydraulic conductivity of the attenuation layer is consistent with the requirements of the Landfill Directive (1999/31/EC) for inert landfills. As the attenuation layer will comprise generally glacial till the hydraulic conductivity is likely to be considerably lower than the assumed value.
K_aq is the hydraulic conductivity of the sand and gravel aquifer (m/s)	2.31E-04	m/s	Minimum assumed in 2018 HIA of 20m/d for Bytham Sand and Gravel Formation
i_aq is the hydraulic gradient within the sand and gravel aquifer (m/m)	0.00474		Pre-extraction hydraulic gradient across the Brooksby Quarry complex between groundwater monitoring boreholes WM1 and WM2
i_{AL} is the hydraulic gradient across the artificial geological barrier (m/m)	0.00948		To account for the possibility that the hydraulic gradient in the waste mass will be greater than in the aquifer, conservatively a hydraulic gradient of twice that in the aquifer has been used.
w_waste is the width of the waste (m)	390	m	Based on Figure ESSD 2 (drawing reference TAR/BRO/12-21/22914). Confirmed by aerial photography images.
thickness_waste is the thickness of the waste below the rest groundwater level (m)	3	m	Approximate saturated thickness of waste based on Figure ESSD 7 (drawing reference TAR/BRO/06-22/23185) and Figure ESSD 6 (drawing reference TAR/BRO/08-21/22740)

C_bg is the background concentration in the sand and gravel aquifer (mg/l)
C_iw is the concentration at the outside edge of the attenuation layer

APPENDIX HRA C

ELECTRONIC COPY OF THE GENERIC QUANTITATIVE RISK ASSESSMENT MODEL AND SENSITIVITY ANALYSIS

APPENDIX HRA D

GENERIC QUANTITATIVE RISK ASSESSMENT SENSITIVITY ANALYSIS

GENERIC QUANTITATIVE RISK ASSESSMENT CALCULATIONS - SENSITIVITY ANYALYSIS FOR HYDRAULIC GRADIENT ACROSS ARTIFICAL GEOLOGICAL BARRIER DOUBLED

Determinand	Compliance limit or environmental assessment limit (EAL) (mg/l)	Mean background concentrations (mg/l)	Concentration at the outside edge of the attenuation layer (WAC LS ratio 10l/kg expressed as mg/l)	Concentration predicted in the aquifer (mg/l)	Ratio of predicted discharge concentration after immediate dilution to MRV (Hazardous substances) or predicted concentrations to EAL (Non-hazardous pollutants)
Arsenic	0.006	0.0016	0.05	0.00168	0.28
Lead	0.00193	0.00065	0.05	0.00074	0.38
Mercury	0.00010	0.00004	0.001	0.00004	0.4
Toluene	0.004	0.002	0.8695	0.00350	0.87
Cadmium	0.00026	0.00005	0.004	0.00006	0.22
Chloride	93.7	39.4	80	39.5	0.42
Copper	0.0316	0.0027	0.2	0.00304	0.10
Nickel	0.0044	0.0017	0.04	0.00172	0.39
Zinc	0.0656	0.0088	0.4	0.0095	0.14

The source term for toluene is based on the solid composition WAC for BTEX converted into mg/l
It is conservatively assumed that the total BTEX concentration comprises toluene
Substances for which no background concentrations are available. Background concentrations conservatively assumed to comprise half of the EAL.

$$C_{aq} = \frac{C_{iw} \times Q_{iw} + C_{bg} \times Q_{aq}}{Q_{iw} + Q_{aq}}$$

Where C_aq is the calculated concentration in the aquifer (mg/l)
Where Qiw = K_{AL} x i_{AL} x (w_waste x thickness_waste) 2.22E-06
Where Qaq = K_aq x i_aq x (w_waste x thickness_waste) 1.28E-03

K_{AL} is the assumed hydraulic conductivity of the attenuation layer (m/s)	1.00E-07	m/s	It is conservatively assumed that the hydraulic conductivity of the attenuation layer is consistent with the requirements of the Landfill Directive (1999/31/EC) for inert landfills. As the attenuation layer will comprise generally glacial till the hydraulic conductivity is likely to be considerably lower than the assumed value.
K_aq is the hydraulic conductivity of the sand and gravel aquifer (m/s)	2.31E-04	m/s	Minimum assumed in 2018 HIA of 20m/d for Bytham Sand and Gravel Formation
i_aq is the hydraulic gradient within the sand and gravel aquifer (m/m)	0.00474		Pre-extraction hydraulic gradient across the Brooksby Quarry complex between groundwater monitoring boreholes WM1 and WM2
i_{AL} is the hydraulic gradient across the artificial geological barrier (m/m)	0.01896		Varied as part of the sensitivity analyis to double the hydraulic gradient assumed as part of the GQRA and four times the hydraulic gradient in the aquifer.
w_waste is the width of the waste (m)	390	m	Based on Figure ESSD 2 (drawing reference TAR/BRO/12-21/22914). Confirmed by aerial photography images.
thickness_waste is the thickness of the waste below the rest groundwater level (m)	3	m	Approximate saturated thickness of waste based on Figure ESSD 7 (drawing reference TAR/BRO/06-22/23185) and Figure ESSD 6 (drawing reference TAR/BRO/08-21/22740)

C_bg is the background concentration in the sand and gravel aquifer (mg/l)
C_iw is the concentration at the outside edge of the attenuation layer

GENERIC QUANTITATIVE RISK ASSESSMENT CALCULATIONS - SENSITIVITY ANYALYSIS FOR HYDRAULIC CONDUCTIVITY OF AQUIFER REDUCED BY A FACTOR OF 2.5

Determinand	Compliance limit or environmental assessment limit (EAL) (mg/l)	Mean background concentrations (mg/l)	Concentration at the outside edge of the attenuation layer (WAC LS ratio 10l/kg expressed as mg/l)	Concentration predicted in the aquifer (mg/l)	Ratio of predicted discharge concentration after immediate dilution to MRV (Hazardous substances) or predicted concentrations to EAL (Non-hazardous pollutants)
Arsenic	0.006	0.0016	0.05	0.00170	0.28
Lead	0.00193	0.00065	0.05	0.00076	0.39
Mercury	0.00010	0.00004	0.001	0.00004	0.4
Toluene	0.004	0.002	0.8695	0.00387	0.97
Cadmium	0.00026	0.00005	0.004	0.00006	0.23
Chloride	93.7	39.4	80	39.5	0.42
Copper	0.0316	0.0027	0.2	0.00313	0.10
Nickel	0.0044	0.0017	0.04	0.00173	0.39
Zinc	0.0656	0.0088	0.4	0.0096	0.15

The source term for toluene is based on the solid composition WAC for BTEX converted into mg/l
It is conservatively assumed that the total BTEX concentration comprises toluene
Substances for which no background concentrations are available. Background concentrations conservatively assumed to comprise half of the EAL.

$$C_{aq} = \frac{C_{iw} \times Q_{iw} + C_{bg} \times Q_{aq}}{Q_{iw} + Q_{aq}}$$

Where C_aq is the calculated concentration in the aquifer (mg/l)
Where Qiw = K_{AL} x $i_{\_AL}$ x (w_waste x thickness_waste) 1.11E-06
Where Qaq = K_aq x i_aq x (w_waste x thickness_waste) 5.12E-04

K_{AL} is the assumed hydraulic conductivity of the attenuation layer (m/s)	1.00E-07	m/s	It is conservatively assumed that the hydraulic conductivity of the attenuation layer is consistent with the requirements of the Landfill Directive (1999/31/EC) for inert landfills. As the attenuation layer will comprise generally glacial till the hydraulic conductivity is likely to be considerably lower than the assumed value.
K_aq is the hydraulic conductivity of the sand and gravel aquifer (m/s)	9.24E-05	m/s	Minimum assumed in 2018 HIA of 20m/d for Bytham Sand and Gravel Formation reduced by a factor of 2.5 for the purpose of undertaking the sensitivity analysis.
i_aq is the hydraulic gradient within the sand and gravel aquifer (m/m)	0.00474		Pre-extraction hydraulic gradient across the Brooksby Quarry complex between groundwater monitoring boreholes WM1 and WM2
$i_{\_AL}$ is the hydraulic gradient across the artificial geological barrier (m/m)	0.00948		To account for the possibility that the hydraulic gradient in the waste mass will be greater than in the aquifer, conservatively a hydraulic gradient of twice that in the aquifer has been used.
w_waste is the width of the waste (m)	390	m	Based on Figure ESSD 2 (drawing reference TAR/BRO/12-21/22914). Confirmed by aerial photography images.
thickness_waste is the thickness of the waste below the rest groundwater level (m)	3	m	Approximate saturated thickness of waste based on Figure ESSD 7 (drawing reference TAR/BRO/06-22/23185) and Figure ESSD 6 (drawing reference TAR/BRO/08-21/22740)

C_bg is the background concentration in the sand and gravel aquifer (mg/l)
C_iw is the concentration at the outside edge of the attenuation layer

GENERIC QUANTITATIVE RISK ASSESSMENT CALCULATIONS - SENSITIVITY ANYALYSIS FOR SOURCE TERM CONCENTRATIONS DOUBLED

Determinand	Compliance limit or environmental assessment limit (EAL) (mg/l)	Mean background concentrations (mg/l)	Concentration at the outside edge of the attenuation layer (WAC LS ratio 10l/kg expressed as mg/l)	Concentration predicted in the aquifer (mg/l)	Ratio of predicted discharge concentration after immediate dilution to MRV (Hazardous substances) or predicted concentrations to EAL (Non-hazardous pollutants)
Arsenic	0.006	0.0016	0.1	0.00169	0.28
Lead	0.00193	0.00065	0.1	0.00074	0.38
Mercury	0.00010	0.00004	0.002	0.00004	0.4
Toluene	0.004	0.002	1.739	0.00350	0.88
Cadmium	0.00026	0.00005	0.008	0.00006	0.22
Chloride	93.7	39.4	160	39.5	0.42
Copper	0.0316	0.0027	0.4	0.00304	0.10
Nickel	0.0044	0.0017	0.08	0.00172	0.39
Zinc	0.0656	0.0088	0.8	0.0095	0.14

The source term for toluene is based on the solid composition WAC for BTEX converted into mg/l
It is conservatively assumed that the total BTEX concentration comprises toluene
Substances for which no background concentrations are available. Background concentrations conservatively assumed to comprise half of the EAL.

$$C_{aq} = \frac{C_{iw} \times Q_{iw} + C_{bg} \times Q_{aq}}{Q_{iw} + Q_{aq}}$$

Where C_aq is the calculated concentration in the aquifer (mg/l)
Where Qiw = K_{AL} x i_{AL} x (w_waste x thickness_waste) 1.11E-06
Where Qaq = K_aq x i_aq x (w_waste x thickness_waste) 1.28E-03

K_{AL} is the assumed hydraulic conductivity of the attenuation layer (m/s)	1.00E-07	m/s	It is conservatively assumed that the hydraulic conductivity of the attenuation layer is consistent with the requirements of the Landfill Directive (1999/31/EC) for inert landfills. As the attenuation layer will comprise generally glacial till the hydraulic conductivity is likely to be considerably lower than the assumed value.
K_aq is the hydraulic conductivity of the sand and gravel aquifer (m/s)	2.31E-04	m/s	Minimum assumed in 2018 HIA of 20m/d for Bytham Sand and Gravel Formation
i_aq is the hydraulic gradient within the sand and gravel aquifer (m/m)	0.00474		Pre-extraction hydraulic gradient across the Brooksby Quarry complex between groundwater monitoring boreholes WM1 and WM2
i_{AL} is the hydraulic gradient across the artificial geological barrier (m/m)	0.00948		To account for the possibility that the hydraulic gradient in the waste mass will be greater than in the aquifer, conservatively a hydraulic gradient of twice that in the aquifer has been used.
w_waste is the width of the waste (m)	390	m	Based on Figure ESSD 2 (drawing reference TAR/BRO/12-21/22914). Confirmed by aerial photography images.
thickness_waste is the thickness of the waste below the rest groundwater level (m)	3	m	Approximate saturated thickness of waste based on Figure ESSD 7 (drawing reference TAR/BRO/06-22/23185) and Figure ESSD 6 (drawing reference TAR/BRO/08-21/22740)

C_bg is the background concentration in the sand and gravel aquifer (mg/l)
C_iw is the concentration at the outside edge of the attenuation layer