ENVIRONMENTAL PERMIT VARIATION APPLICATION
HYDROGEOLOGICAL RISK ASSESSMENT

SKELBROOKE QUARRY EXTENSION
STRAIGHT LANE
SKELBROOKE
DONCASTER
SOUTH YORKSHIRE
DN6 8LY

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SKELBROOKE QUARRY EXTENSION, STRAIGHT LANE, SKELBROOKE, DONCASTER

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ENVIRONMENTAL PERMIT (REF.: CP3994ZR) VARIATION APPLICATION

HYDROGEOLOGICAL RISK ASSESSMENT

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1.0 INTRODUCTION

1.1 Scope & Background

1.1.1 Sirius Environmental Limited (Sirius) has been commissioned by Darrington Quarries Limited ('DQL'), part of the FCC group of companies, to prepare an Environmental Permit Variation Application for the Environmental Permit: EPR/CP3994ZR to support a revised scheme of restoration for the former quarry at Skelbrooke Landfill Extension, Skelbrooke, Doncaster. DQL are seeking to commence an alternative restoration scheme for the extension area (primarily in response to safety concerns) which will bring the ground levels within the flooded area to above that of current water levels within the void. This will also aid in surface water management for the wider restored quarry and landfill.

1.1.2 The original Hydrogeological Conceptual Model and Risk Assessment were prepared in April 2000 (SLR, 2000) and consisted of a Hydrogeological (Regulation 15) Risk Assessment. Subsequent to the 2000 Hydrogeological Risk Assessment (HRA), a separate HRA was prepared in June 2003 (SLR, 2003) to support the original PPC application for the adjacent Skelbrooke Landfill facility (Cells 1-6).

1.1.3 Due to the fact that infilling operations never commenced in the Skelbrooke Landfill Site Extension Area, that authorisation to accept material for deposition in the Skelbrooke Extension Area was removed in 2007 and that the Skelbrooke Quarry Extension Area was varied into Closure in 2015 no subsequent Hydrogeological Risk Assessment Reviews (HRARs) have been undertaken. However, periodical reviews of the HRA have also been carried in August 2007 (SLR, 2007), 2013 (FCC, 2013) and September 2019 (TerraConsult, 2019). All periodic HRA reviews were supported by a detailed review of the hydrogeological regime surrounding the Skelbrooke Landfill Site (including the Skelbrooke Extension Area), the assessment of leachate, groundwater and surface water quality, and the derivation of new/revised groundwater compliance points and leachate levels (where appropriate).

1.1.4 This HRAR builds upon the existing conceptual model to incorporate the proposed deposit of selected suitable wastes within the quarry void. The wastes to be deposited within the void will be of a quality in which there is sufficient dilution within the aquifer to prevent the discernible discharge of hazardous substances and limit the discharge of non-hazardous pollutants to prevent pollution. The primary source of material to be deposited will be non-hazardous materials with a low pollution potential, including soils from local greenfield or low-risk brownfield development sites will also be considered. In order protect local ground water quality, site specific waste acceptance criteria (WAC) has been derived for wastes to be placed below the water table and up to 2m form final levels, with acceptance criteria for restoration soils to be deposited within the final 2m based on Soil Screening Values (SSVs) derived using ATRISK Guidance prepare by Atkins.

2.0 UPDATE AND REVIEW OF CONCEPTUAL SITE MODEL

2.1 Source

Site Design and Construction

2.1.1 The Skelbrooke Landfill Extension is located in an area in which extensive mineral extraction has taken place. It is developed within a historic Permian Magnesian Limestone quarry approximately 7.5km northwest of Doncaster and approximately 1km to the west of the A1(T). Extraction operations in the area extend through the Magnesian Limestone and into the Permian Marl with basal void elevations ranging from 16mAOD to 20mAOD.

2.1.2 Planning consent for mineral extraction and restoration of the Skelbrooke Extension Area was originally granted by Doncaster Metropolitan Borough Council in 1998 (Ref.: 96/50/1641/9/MIN). The original scheme of restoration allowed for the landfilling of "controlled wastes, but excluding special wastes", and allowed for 25% settlement.

2.1.3 In 2005, planning consent (Ref.: 03/7149/P) was issued approving a revised scheme of restoration for the extension area. This revised scheme incorporated a low-level restoration profile that would be completed with suitable non-degradable fill materials.

2.1.4 Following the issuing of planning consent in 1998, the Skelbrooke Extension Area obtained authorisation for the disposal of biodegradable wastes in engineered cells under the Waste Management Licensing Regulations 1994 in July 2001 (Licence Ref.: EAWML65052) which was subsequently updated to Environmental Permit EPR/CP3994ZR. However, no cells have been engineered within the Skelbrooke Extension area to date and therefore no wastes have been deposited.

2.1.5 In 2007, the permit/licence was modified to remove conditions allowing the acceptance of waste at the site, with the exception of waste to support landfill restoration activities (where appropriate), subject to prior written agreement with the Environment Agency. No such agreements were requested, and no waste were therefore deposited at the site.

2.1.6 In January 2015, an EA initiated variation to the permit was determined close the facility since when no wastes have been permitted for disposal at the site. A Closure Plan (Doc. Ref.: 1776/R/025/1) dated October 2014 was incorporated into the permit as part of this variation.

2.1.7 Due to the absence of waste deposition activities and the associated development of engineered cells within the Skelbrooke Extension Area, it is considered that the base and sidewall of the Skelbrooke Extension Area consists of exposures of the surrounding country rock which consist of Magnesian Limestone and Permian Marl and that no leachate collection infrastructure or capping system has been installed.

2.1.8 Furthermore, the material for deposition within the Skelbrooke Extension area is to be of a nature that presents a pollution potential that is less than, or equal to, the natural quality of the surrounding geology/groundwater, it is considered that pollution containment engineering (including basal/sidewall lining systems, leachate collection infrastructure and capping systems are not required.

Leachate Management

2.1.9 As previously indicated, no waste deposition activities have been undertaken in the Skelbrooke Quarry Extension Area between the issuing of EAWML65052 (subsequently EPR/CP3994ZR) in 2001 and the definite closure of the landfill operations that were previously permitted at the Skelbrooke Quarry Extension Area in January 2015. Accordingly, there is no leachate to manage within the flooded quarry void or an existing leachate source term to consider against background groundwater quality.

2.1.10 Under the revised development proposals, the infilling of the Skelbrooke Quarry Extension Area will now be achieved by means of disposal of suitable non-biodegradable, non-hazardous wastes which will be tipped directly into the flooded quarry void.

2.1.11 DQL propose to only accept non-hazardous waste that with a low pollution potential, including quarry materials (overburden, fines etc), soils from local greenfield or low-risk brownfield development sites which meet the requirements of site specific Waste Acceptance Criteria (WAC) and other materials, such as construction and demolition waste, with a low risk of contamination. The waste to be accepted at the site will not undergo any significant biological, chemical or physical transformation.

2.1.12 Site specific waste acceptance criteria has been derived for wastes materials to be tipped directly into the flooded quarry and which accounts for the dilution available within the limestone aquifer in order to prevent the discernible discharge of hazardous substances and limit the input of non-hazardous pollutants to prevent pollution, taking into to account baseline groundwater quality of the aquifer. Restoration soils located above the water table within the final 2m of final ground levels accepted against Soil Screening Values (SSVs) derived by Atkins and their ATRISK Guidance.

2.1.13 It is important to highlight that hazardous wastes are excluded from the list of permitted wastes and that infill materials shall consist of a small list of materials that would always qualify as non-hazardous under the Waste Framework Directive. Moreover the waste will also be deemed to be inert in nature on the following criteria:-

- Does not undergo any significant physical, chemical or biological transformations;
- 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
- The 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.

2.1.14 The proposed waste for recovery within the Skelbrooke Quarry Extension Area have been adopted from the list of wastes which the waste producer may not need to test presented in the Environment Agency's Waste Acceptance Procedures for Deposits for Recovery[1]. However, it is appreciated that as the proposed infilling operations involves the deposition of material into the flooded quarry void without the presence of an engineered lining system between the infill materials, a set of WAC stating the upper threshold of materials which can

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

be accepted for use in the proposed recovery operation has been determined accounting for the dilution available in the aquifer and baseline groundwater concentrations of key substances.

2.1.15 The aforementioned review and comparison of existing groundwater quality data recorded as part of ongoing monitoring of the adjacent Skelbrooke Landfill Site (Cells 1-6) and the published regional Upper Magnesian Limestone groundwater geochemistry presented in Bearcock and Smedley (2009) and identified both the key parameters for consideration and appropriate Liquid Equivalent WAC values.

2.1.16 To ensure that the derived Liquid Equivalent WAC values did not result in the degradation of the surrounding groundwater quality, these values were also compared to their corresponding Drinking Water Standard (DWS) and Freshwater Annual Average EQS value (where appropriate).

2.1.17 As discussed within **Section 2.3** of the accompanying ESSD (*Doc. Ref.: WR7640/05*), it is considered that the proposed Liquid Equivalent WAC values represent the worst-case pollution source term for the proposed waste recovery activity. Accordingly, the pollution source term associated with the proposed waste recovery operations is presented in Error! Reference source not found.

Table HRA1: Pollution Source Term Data for Proposed Materials for Deposition within the Skelbrooke Extension Area Quarry Void

Parameter	Proposed Waste Acceptance Criteria (L/S 10:1 mg/kg)	Worst-Case Pollution Concentration (mg/l)	EAL (mg/l)	Risk Factor
Arsenic	1.5	0.15	0.05	30
Cadmium	0.12	0.012	0.0003	33
Chromium	1.5	0.15	0.002	75
Copper	6	0.6	0.015	40
Nickel	1.2	0.12	0.008	15
Lead	0.5	0.05	0.0002	250
Mercury	0.03	0.003	0.00001	300
Nickel	1.2	0.12	0.008	15
Phenol	3	0.3	0.0077	4
Zinc	12	1.2	0.024	50
Chloride	2,400	240	65	3.7
Fluoride	30	3	1	3
Sulphate	3,000	300	1,560	0.2

2.1.18 The WAC listed in **Table HRA1** have been derived from basic dilution factors calculations post-completion of the quarry restoration scheme, taking into account the physical characteristics of the wastes and limestone aquifer, and baseline groundwater quality. These calculations conservatively ignore the initial rinsing/flushing of the wastes upon initial tipping within the flooded quarry, during which the dilution available will be significantly greater prior to settlement, and which will also reduce the source terms below these concentrations upon settlement and consolidation.

2.1.19 The final 2m of the restoration profile will be above the water table and, therefore, it is proposed to use Soil Screening Values (SSVs) derived by Atkins and their ATRISK guidance. The Atkins ATRISK SSVs are calculated by using the appropriate Contaminated Land Exposure Assessment Protocol (CLEA). The proposed 'generic' end-use of the restoration is that of grassland and trees/shrubs which are planted on the restoration area and maintained throughout the aftercare period specified in the planning permission.

2.2 Pathways

2.2.1 A Hydrogeological (Regulation 15) Risk Assessment was prepared and submitted in support of the 1999 Waste Management Licence Application and identified two potential pollution pathways; leakage through the proposed sidewall seals basal leakage through the underlying Permian Marl (Edlington Formation) leakage. The sidewall leakage pathway considered the migration of leachate generated by the then proposed waste inventory (domestic, industrial and commercial) through a substantial thickness of Permian Marl (proven to be approximately 35m thick) prior to reaching the underlying Lower Magnesian Limestone; identified as a possible receptor. The side wall leakage pathway considered the lateral diffusion of generated leachate into the adjacent Upper Magnesian Limestone during the operational and post-operational periods of Skelbrooke Quarry Extension Area. The 1999 Hydrogeological (Regulation 15) Risk Assessment concluded that the risk posed by the fully developed 1999 Skelbrooke Quarry Extension Area proposal to surrounding water resources were negligible.

2.2.2 As previously discussed, the landfill development proposal presented in the 1999 Waste Management Licence Application and discussed in the accompanying Hydrogeological (Regulation 15) Risk Assessment was never developed and the Skelbrooke Landfill Area has remained undeveloped. Accordingly, there has been no requirement to undertake periodic review of the original Hydrogeological Risk Assessment to confirm it validity. However, the development of the adjacent Skelbrooke Landfill Site (Cells 1-6); which was subject to a PPC Permit Application in 2003, has proceeded and as such a contemporary account of the current hydrogeological conceptual site setting is available for review.

2.2.3 The Hydrogeological Risk Assessment Review which accompanied the 2003 PPC Permit Application for the adjacent Skelbrooke Landfill Site (Cells 1-6); subsequently authorised under EPR/BV1470IE, examined the location of the proposed development in relation

2.2.4 As previously discussed, in light of the revised development proposals for the Skelbrooke Quarry Extension Area, and the deposition of selected materials which will be of a quality that will not result in the degradation of the surrounding hydrogeological environment, it was proposed that the Conceptual Site Model (CSM) for the Skelbrooke Quarry Extension Area be revised. It was considered that this revision examined the potential pathways the through which the surrounding hydrogeology and the proposed infill material could interact. In order to visually depict this, a CSM section line transecting previously infilled (and permanently capped) Skelbrooke Landfill Site (Cells 1-6) and the proposed void to be infilled within the Skelbrooke Quarry Extension Area. This CSM Section Line and its corresponding route are both presented in **Drawing No. WR7640/10/HRA1**.

2.2.5 To ensure that a complete picture of the surrounding hydrogeological environment could be obtained and the potential interactions between the

proposed Skelbrooke Quarry Extension Area development and the existing environment could be identified, the current leachate compliance levels within the adjacent Skelbrooke Landfill Site (Cells 1-6) and recorded groundwater range within the adjacent Upper Magnesian Limestone were incorporated into **Drawing No. WR7640/10/HRA1**.

2.2.6 This revised CSM indicated that the same potential pollutant pathways identified in the 1999 Hydrogeological (Regulation 15) Risk Assessment and the subsequent Hydrogeological Risk Assessment; and Risk Assessment Reviews, of the adjacent Skelbrooke Landfill Site still exist for the revised infilling proposals. It was identified that the primary interaction between the proposed infilling material with the surrounding hydrogeological environment is the lateral migration of groundwater through the void sidewall (particularly the Upper Magnesian Limestone). A second potential interaction pathway was also observed and consists of the basal migration of liquid through the low permeability Permian Marl (Edlington Formation), however, due to the proven vertical thickness of this lithological unit (35m) it is considered that the potential of basal leakage from the void area into the underlying Lower Magnesian Limestone is severely limited.

2.2.7 It is further identified that the proposal to infill the proposed quarry void without the installation of an engineered lining system or dewatering of the void means that the infill material will be in direct contact with both the in-situ geology and the groundwater contained within during site operations. However, as indicated in **Section 2.1**, in order to ensure that the infilling operations do not result in the degradation of the surrounding groundwater environment the Waste Acceptance Criteria for the development proposal have been derived to prevent the discernible discharge of hazardous substances and limit the discharge of non-hazardous pollutants to groundwater, taking into account the dilution factors and baseline quality of the limestone aquifer.

2.2.8 Nevertheless, despite the inherent limited/negligible pollution potential of the proposed infill materials, the position of the Skelbrooke Quarry Extension Area void relative to the surrounding geology indicates the potential for lateral interactions between the infill material and the Upper Magnesian Limestone. Accordingly, it is considered prudent to examine the lateral migration of liquid through the sidewalls of the quarry void as a potential pathway.

Geology

2.2.9 The geology of Skelbrooke Landfill Extension is taken from:

- British Geological Survey 1:50,000, Sheet No. 87 Barnsley Solid and Drift (1976);
- British Geological Survey 1:50,000, Sheet No. 78 Wakefield Solid and Drift (1978);
- British Geological Survey 1: 63,360, Sheet No. 88 Doncaster Solid and Drift (1969);
- British Geological Survey 1:63,360, Sheet No. 79 Goole Solid and Drift (1971);
- British Geological Survey 1:50,000, Sheet No. 87 Barnsley (2008);
- Institute of Geological Sciences 1:100,000 Hydrogeological Map of Southern Yorkshire and Adjoining Areas (1982); and
- National Rivers Authority (now the Environment Agency), Policy and Practice for the Protection of Groundwater - Regional Appendix Yorkshire Region. 1991.

2.2.10 These geological maps have been supplemented by site specific information, details of which include:

- Logs of fifteen boreholes advanced in 1991 within the extension area as part of a mineral evaluation exercise; and
- Logs of three boreholes (SB Series) advanced by SECOR (now SLR) in March 1998 to further characterise the nature of the deposits in the extension area and provide permanent groundwater monitoring installations.

2.2.11 Borehole logs from both these investigations are presented in **Appendix ESSD2** and **Appendix ESSD3** of the accompanying ESSD *(Doc. Ref.: WR7640/05).*

2.2.12 The BGS website http://mapapps2.bgs.ac.uk/geoindex/home.html and BGS Map Sheet 87 (1:50 000, Barnsley, 2008) indicates only limited superficial deposits are present in the area. Where present, they are confined to local drainage channels. It was reported in the 2007 HRAR that there were no superficial deposits at the existing Skelbrooke Landfill.

2.2.13 From review of British Geological Survey 1:50,000 scale geology maps, publicly available borehole records and borehole logs prepared following site investigations undertaken at and around the Skelbrooke Landfill Site and the installation of monitoring infrastructure, the underlying geological succession in the vicinity of the site can be determined and summarised. A summary of this geological succession (including unit thicknesses) is presented in **Table HRA2**.

Table HRA2: Geological Sequence at Skelbrooke Landfill Complex

Geological Unit	Thickness	Description
Upper Permian Marl (Roxby Formation)	6	Red shaley clays and mudstones with gypsum and anhydrite seams
Upper Magnesian Limestone (Brotherton Formation)	20	Compact and flaggy dolomitic limestone with thin beds of mudstone
Middle Marl (Edlington Formation)	35	Red brown and grey green mudstone with interbedded sulphates (gypsum and, at depth, anhydrite)
Lower Magnesian Limestone (Cadeby Formation)	N/A	Composed of two lithological groups. The upper division contains minutely cellular and highly porous dolomite, characterised at or near surface by solutional features. The lower division comprises regularly bedded dolomitic and oolitic limestones.
Basal Permian Sands and Breccia	N/A	Outcrops as a discontinuous layer of loosely cemented sand succession, resting unconformably on the Carboniferous rocks.

2.2.14 As previously discussed, the base of the Skelbrooke Quarry Extension Area is situated within the Middle Permian Marl. Additionally, a portion of the sidewall exposures of the Skelbrooke Quarry Extension Area comprise of the Middle Permian Marl Formation; covering a vertical distance of approximately 8m. The remaining sidewall exposures consist of the Upper Magnesian Limestone formation which covers a cumulative vertical distance of approximately 22m.

2.2.15 Further review of the geological information available for the Skelbrooke Quarry Extension Area indicates that whilst the sidewall of the flooded void consists of both the Permian Marl Formation and the Upper Magnesian Limestone Formation, the thicknesses of these two units varies. As depicted in the hydrogeological cross-section presented in **Drawing Reference**

WR7640/10/HRA1 the vertical thickness of the Upper Magnesian Limestone sidewall exposure is increased on the western sidewall compared to the eastern sidewall, where a larger exposure of Permian Marl is observed.

Hydrogeology

Physical Characteristics

2.2.16 The Environment Agency classifies the Upper Magnesian Limestone (Brotherton Formation) and Permian Middle Marl (Edlington Formation) as aquifer units with the following paragraphs summarising their assigned aquifer classifications and the physical characteristics of each lithology.

2.2.17 The Upper Magnesian Limestone (Brotherton Formation) is classified by the Environment Agency as a Primary aquifer unit which consists of compact and flaggy dolomitic limestones. This lithological fabric results in a relatively low primary intergranular porosity and permeability; indicated by Allen et al., (1997) to be in the region of $5.5x10^{-4}$m/d, however, the Upper Magnesian Limestone has a the potential for a high secondary permeability due to the presence of macro and micro fractures which have been enhanced by subsequent karstic weathering. The total porosity of this lithological unit is estimated by Allen et al., (1997) be vary between 6 to 30% with an interquartile range of 9.4% to 16%. Groundwater flow through this unit it predominantly achieved through fracture flow, with a permeability range of between ~0.01 and ~165m/d (a mean of ~37m/d was confirmed by SLR (2004) from rising head tests performed in various boreholes installed around the periphery of the main Skelbrooke landfill facility. The lowest permeability value was deemed to be influenced by the proximity of the landfill sidewall which impinged on the cone of depressions. Excluding this permeability value, the mean permeability equates to ~41 m/d. These compare to estimated permeability ranges of between 10 and 100 m/d specified by Allen et al., (1997).

2.2.18 The Permian Middle Marl (Edlington Formation) is classified by the Environment Agency as a as a Secondary B lithology primarily consists of red brown and grey green mudstone with interbedded sulphates (gypsum and, at depth, anhydrite); as indicated in **Table HRA2**. Site specific hydrogeological data for both the engineered and in-situ Permian Marl were identified as part of the 2003 HRA completed for the adjacent Skelbrooke Landfill Site with a permeability range between $1x10^{-10}$m/s (min) and $1x10^{-9}$m/s (max) with a mode of $1x10^{-9m}$/s. These permeability values were derived using CQA testing and characterisation information obtained during the construction of landfill cells (including packer tests in the marl and triaxial permeability test results on remoulded and compacted clay samples).

Groundwater Flow

2.2.19 Groundwater levels have been monitored around the perimeter of the adjacent Skelbrooke Landfill Site since 1996 through a total of 15 monitoring boreholes, all of which monitoring groundwater within the underlying Magnesian Limestone and remain active.

2.2.20 A statistical summary of the recorded groundwater levels in the Magnesian Limestone Lincolnshire between 1996 and 2021 in the vicinity of the Skelbrooke Quarry and landfill complex is presented in **Table HRA3**, whilst groundwater hydrographs are presented in **Appendix HRA1**.

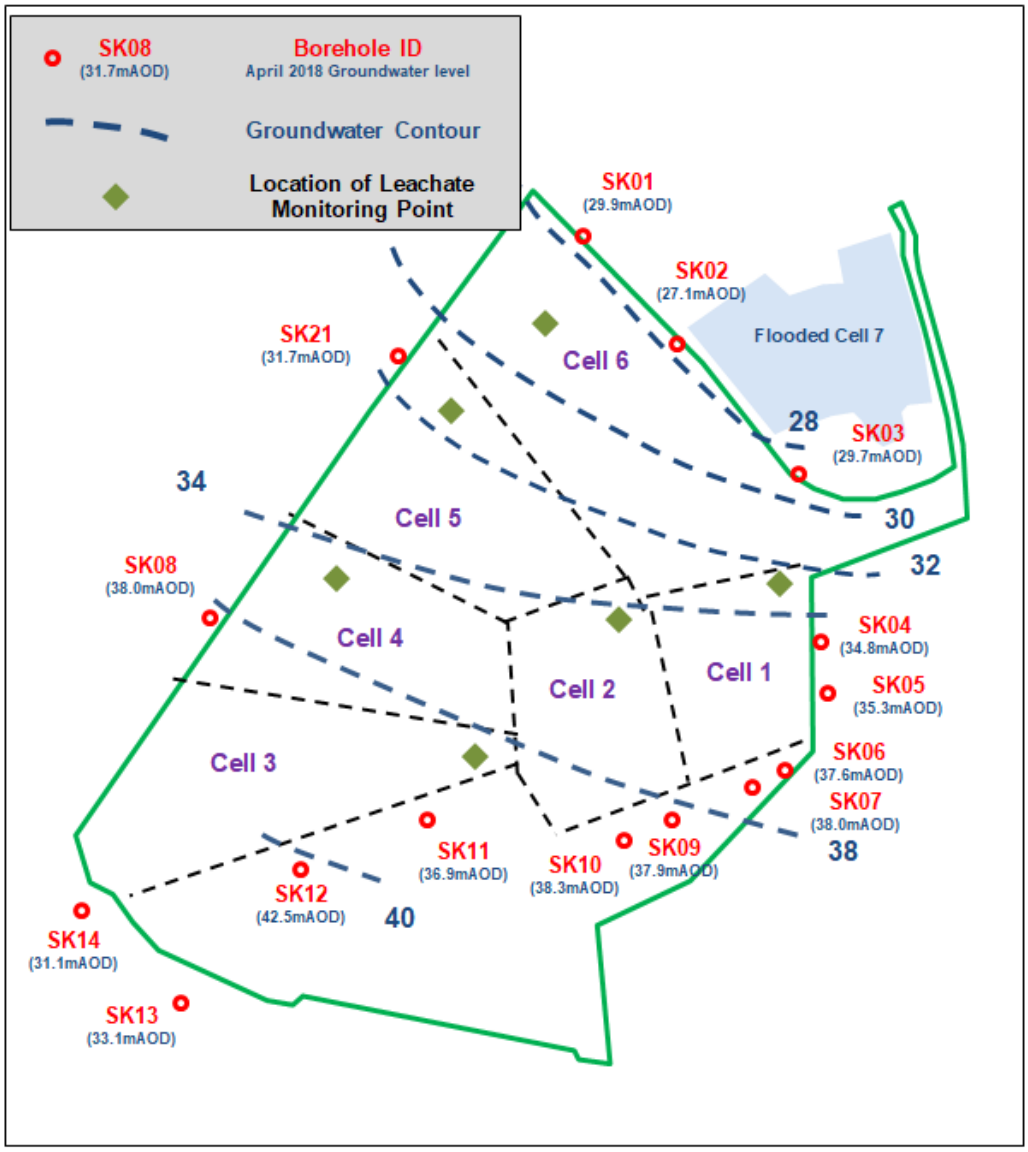
Table HRA3: Statistical summary of monitored groundwater levels in the vicinity of the Skelbrooke quarry and landfill complex

BH ID	1996 – 2021 Groundwater Levels (mAOD)		
	Minimum	Mean	Maximum
Upgradient			
SK06	33.96	36.36	40.64
SK07	32.26	36.75	40.15
SK09	34.82	37.05	38.50
SK10	35.81	37.48	38.70
SK11	34.87	37.18	39.27
SK12	40.51	42.10	42.60
Cross-Gradient			
SK04	30.42	32.97	34.70
SK05	27.74	34.37	37.43
SK08	27.76	32.74	42.59
SK21	27.95	29.56	34.92
Downgradient			
SK01	21.83	24.36	29.98
SK02	23.60	26.39	31.05
SK03	23.12	27.93	29.70

2.2.21 A review of the groundwater timeseries plots presented in **Appendix HRA1** and the statistical analysis presented in **Table HRA3** demonstrate that groundwater levels in the vicinity of the Skelbrooke Quarry Extension Area have remained stable throughout the entire monitoring period. However, it is noted that seasonal fluctuation of groundwater levels (typically between 2 and 4m) are observed in all monitoring boreholes. However, despite these fluctuations, groundwater levels remain within a distinct range throughout the monitoring period.

2.2.22 When the groundwater levels presented in **Table HRA3** are transposed onto a site location plan of the adjacent Skelbrooke Landfill Site, the resulting groundwater contour plot confirms an overall north-easterly hydraulic gradient of 0.032 towards the Skelbrooke Quarry Extension Area. Such a hydraulic contour plot was prepared as part of the 2019 HRA undertaken for the adjacent Skelbrooke Landfill Site (Cells 1-6) and is presented in **Figure HRA1**. Please note that the Skelbrooke Quarry Extension Area is represented in this groundwater contour plot and it referred to as “Flooded Cell 7”.

Figure HRA1: Groundwater Contour Plot of Skelbrooke Landfill Site



(Reproduced from 2019 Hydrogeological Risk Assessment Review (Report No. 4485/R/01/01))

2.2.23 However, it was noted in the 2019 HRAR for Skelbrooke Landfill Site that a variance in recorded groundwater levels is observed in SK12, SK13 and SK14. A review of the relevant Ordnance Survey Maps indicate the presence of a topographical divide (~52mAOD) near to southern boundary of Cell 3, this in conjunction with the in-situ (up-thrown Middle Permian Marl) and or presence of quarry fines may be responsible for variance in groundwater levels expressed at SK12 and to the southwest at SK13 and SK14.

2.2.24 Alternatively, the juxtaposed relative positions of the stratigraphically older Cadeby Limestone against the younger Brotherton Formation along the north-westerly facing site boundary (and or presence of the quarry 350m to the southwest) may also explain the lower water table on the southwest corner of Cell 3.

2.2.25 Based on the current understanding of groundwater levels surrounding the site, there is a single aquifer system adjacent to the sidewall of Skelbrooke Quarry Extension Area, the Upper Magnesian Limestone (Brotherton Formation) Aquifer. Groundwater levels within this aquifer unit indicate that they are currently around 29mAOD. Additionally, the geological logs prepared alongside

each monitoring borehole indicate that a substantial unsaturated zone exists beneath the base of the Skelbrooke Quarry Extension Area and that this zone consists of Permian Middle Marl (Edlington Formation).

2.3 Receptor

2.3.1 The Site is not located within a Source Protection Zone, however, the Environment Agency classifies the Upper Magnesian (Brotherton Formation) Limestone Aquifer strata adjacent to the site as a Principal Aquifer; which is capable of supporting water supplies on strategic scale, and the Permian Middle Mark (Edlington Formation) as a Secondary B Aquifer (a lower permeability layer which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering).

2.3.2 Due to the absence of superficial deposits in the vicinity of the proposed Skelbrooke Quarry Extension Area Development, the primary receptor to the proposed infilling activity has been identified to be the Upper Magnesian Limestone.

2.3.3 There are springs and associated fluvial networks associated with The Skell are location ~250m to north/northeast of the application site, to which the limestone aquifer is the source of baseflow to these features. These surface water features are Secondary Receptors to the proposed waste recovery activity.

Compliance Points

2.3.4 The primary receptor to the discharge of pollutants from the landfill relate to groundwaters in the immediately surrounding Upper Magnesian Limestone (Brotherton Formation).

2.3.5 The following compliance points have been identified:

Hazardous Substances

2.3.6 In line with current EA guidance, the point of compliance for Hazardous Substances (formerly List I substances) is the down-gradient boundary of the site relative to the direction of groundwater flow within the limestone aquifer surrounding the site, within the vertical mixing depth.

Non-Hazardous Pollutants

2.3.7 As with previous HRAs examining the adjacent Skelbrooke Landfill Site (Cells 1-6), the compliance point for Non-Hazardous Pollutants remains groundwater in the aquifer horizon at the down-gradient boundary of the site.

Groundwater Quality

2.3.8 Due to absence of infilling activities and subsequent closure of the Skelbrooke Quarry Extension Area in 2015 no dedicated groundwater monitoring schedule has been developed for the Skelbrooke Quarry Extension Area. However, groundwater monitoring schedules specified to the adjacent Skelbrooke Landfill Site (Cells 1-6) have allowed for a review of local groundwater quality.

2.3.9 Groundwater quality in the vicinity of Skelbrooke Landfill Site (Cells 1-6) is currently monitored routinely around the perimeter of the site in a total of 13 perimeter monitoring boreholes (SK01, SK02, SK03, SK04, SK05, SK06, SK07, SK08, SK09, SK10, SK11, SK12, SK21) and two monitoring points, SKSW01 and SKSW03 record the quality of groundwater in the backwall drainage sump

and the backwall drainage discharge point to the surface water lagoon respectively. As discussed previously, each groundwater monitoring borehole monitors the Upper Magnesian Limestone (Brotherton Formation).

2.3.10 These monitoring boreholes provide an indication of downgradient (SK01, SK02 and SK03), cross-gradient (SK04, SK05, SK08 and SK21) and upgradient (SK06, SK07, SK09, SK10, SK11 and SK12) groundwater quality.

2.3.11 Statistical analysis of all the background groundwater quality monitoring data recorded in all monitoring boreholes between 1996 and 2021 has been undertaken as part of this HRA in order to identify the baseline concentrations of the matrix and metallic ions within the surrounding groundwater which have been identified as the main parameters of inert waste 'leachate' quality, which corresponds to the type of materials proposed for deposition within the Skelbrooke Quarry Extension Area. A summary of monitored groundwater quality around the periphery of the existing Skelbrooke Landfill Site for these determinands is presented in both **Table HRA4** and **Table HRA5** with individual datasets and associated timeseries plots presented in **Appendix HRAR2.**

2.3.12 Examination of the timeseries charts and analysed monitoring data (presented in **Table HRA4**) from the upgradient boreholes indicate that background concentrations of all matrix and metallic indicator species do not show any increasing trends since 1996. Furthermore, with concentrations for all determinands remaining stable of improving throughout the monitoring period. This stability in background groundwater quality is depicted in the timeseries plots prepared for all metallic indicator species which visually demonstrate consistent concentrations the monitoring period.

2.3.13 Two additional up-gradient monitoring boreholes have been installed during the operational lifecycle of Skelbrooke Landfill Site (Cells 1-6), namely SK11 and SK12 which commenced monitoring in 2004 and 2007 respectively. Review of the groundwater monitoring records for these more recent up-gradient monitoring boreholes strongly correlate to the pre-existing monitoring boreholes.

2.3.14 Examination of the peripheral boreholes monitoring the cross-gradient groundwater regime also in indicate that the concentrations of groundwater quality indications have has remained at consistently low concentrations throughout the monitoring window. As with upgradient groundwater monitoring records, further statistical analysis demonstrated that apart from rare elevated concentrations (subsequently identified as statistical outliers) concentrations of all determinands have either remained stable or demonstrate a decreasing trend throughout the monitoring period. This stability of groundwater quality depicted for this borehole in the timeseries plots is further represented in the datasets contained within the statistical summary presented in. Review of the analysed datasets indicated that the mean and most frequent recorded values for all parameters strongly correlate to one another, further indicating that concentrations within these boreholes have remained stable throughout the monitoring period.

2.3.15 It is noticed that chloride concentrations recorded in SK08 and the additional cross-gradient monitoring borehole SK21 installed in 2003 are higher relative to SK04 and SK05, with chloride concentrations within SK08 and SK21 recorded at approximately ~60-140mg/l compared to the ~30-60mg/l within SK04 and SK05.

2.3.16 A review of groundwater quality records for monitoring boreholes located downgradient of Colsterworth Landfill Site indicate that groundwater quality downgradient of the Site strongly correlates to recorded groundwater quality upgradient for the site. This strong correlation is depicted in **Table HRA4** where there is a visible similarity between the mean determinands concentrations including chloride cadmium, copper and zinc with a significant number of detections either at or below corresponding limit of detection values.

2.3.17 Upon review of all groundwater monitoring boreholes, it is noted that sulphate concentrations are noticeably higher than the other determinands discussed above. Due to the presence of relatively elevated sulphate concentrations upgradient, cross-gradient and downgradient of the existing Skelbrooke Landfill Site (Cells 1-6), it is considered that the recorded sulphate concentrations are representative of natural background conditions. Subsequent, review of published information relating to the Upper Magnesian Limestone including Bearcock and Smedley (2009) confirmed that the groundwater contained within the Upper Magnesian Limestone is naturally elevated in sulphate due to the presence of sulphate compounds (e.g. ZnSO4).

2.3.18 Additionally, it was noted that groundwater concentrations for cadmium, chromium, nickel and lead all indicated periods of relatively elevated concentrations during the monitoring periods (i.e. between 1996 and 2021). Upon closer inspection, it was identified that these periods of elevated concentrations were not limited to a single monitoring borehole or direction from the existing Skelbrooke Landfill Site (Cells 1-6). Short-lived elevated concentrations of similar values were recorded in the same rounds of monitoring for all upgradient, cross-gradient and downgradient boreholes for cadmium, nickel and lead. Visual depictions of these events are presented in **Appendix HRA2.** It considered that these events either reflect short lived changes in natural background groundwater chemistry due to changes in Redox conditions or are indicators of subsequent contamination of the samples following abstraction. Whilst it is important that a full groundwater monitoring history is reviewed as part of this Hydrogeological Risk Assessment, it is considered prudent that the Environmental Assessment Levels (and by definition site-specific WACs) are derived from a period of the where such irregularities are not observed. Accordingly, the derivation of conservative Environmental Assessment Levels for these determinands will be undertaken from the point that the monitoring records no longer display these short-lived elevated concentrations (i.e. from July 2011 onwards).

2.3.19 It is appreciated that whilst cadmium, nickel and lead display a number of short-lived (one round of monitoring) elevated concentrations during the monitoring period, the monitoring records for chromium indicate a sustained period of elevated concentrations around the Skelbrooke Landfill Site (Phases 1-6). As observed in the cadmium, nickel and lead monitoring records the elevated concentrations of similar magnitudes were recorded in all monitoring boreholes (upgradient, cross-gradient and downgradient). As depicted in the chromium time-series plot presented in **Appendix HRA2**. However, unlike the short-lived pollution events observed for cadmium, nickel and lead, the elevated chromium concentrations appeared suddenly and persisted for an extended period until January 2016. Due to all perimeter groundwater monitoring boreholes at Skelbrooke Landfill Site recording this elevated chromium concentration it is considered that the recorded chromium concentrations were released from an external source and migrated to the Skelbrooke Landfill (where it was subsequently detected). It is considered that the release of these chromium concentrations continued until approximately January 2016 at which point the source was removed. Subsequently recorded chromium concentrations around

the perimeter of the Skelbrooke Landfill Site immediately responded and reduced to Limit of Detection Levels, where they have remained. To ensure that a conservative EAL (and associated WAC value) is selected for the site, it is considered prudent to derive these values from groundwater chromium concentrations recorded from January 2016 onwards.

2.3.20 To summarise, the recorded concentrations of the key matrix and metallic determinands relating to the proposed material for deposition recording within the groundwater upgradient, cross-gradient and downgradient of the existing Skelbrooke Landfill Site (Cells 1-6) strongly correlate to one another. This indicates that the pollution prevention measures employed at the existing Skelbrooke Landfill Site (Cells 1-6) are operating appropriately and it can be considered that the recorded determinand concentrations are representative of natural baseline conditions.

2.3.21 Further verification that the recorded groundwater concentrations are indicative of natural geochemical baseline conditions is obtained upon comparison of the recorded perimeter groundwater concentrations against published regional groundwater quality data as presented in Bearcock and Smedley (2009) which presented a statistical summary of the key major and minor constituent geochemical species within the Magnesian Limestone of County Durham and North Yorkshire. **Table HRA6** includes a reduced summary table of this this statistical data, focussing on the determinands identified in **Section 2.1**.

2.3.22 Comparison of this published regional dataset against the site-specific geochemical record for Skelbrooke Landfill Site (Cells 1-6) indicates that the recorded upgradient background concentrations (mean + 2σ) recorded at the Skelbrooke Landfill Site correlate favourably to the concentrations of the corresponding parameter presented in **Table HRA6**.

Table HRA4: Summary of Monitored Groundwater Quality in Upgradient and Cross Gradient Monitoring Boreholes around Skelbrooke Landfill Site (Cells 1 – 6) between 1996 – 2021

Parameter	Statistic	Upgradient Monitoring Boreholes						Cross-Gradient Monitoring Boreholes			
		SK06	SK07	SK09	SK10	SK11	SK12	SK04	SK05	SK08	SK21
Cadmium (mg/l)	Minimum	0.00003	<0.00002	<0.00002	<0.0001	0.00003	<0.00002	0.00004	0.00004	<0.00002	<0.00002
	Mean	0.0003	0.0003	0.0003	0.0004	0.0003	0.0002	0.0003	0.0003	0.0003	0.0003
	Maximum	0.001	0.001	0.0013	0.0021	0.0022	0.0014	0.0012	0.0014	0.0018	0.0014
	St Dev	0.0003	0.0002	0.0003	0.0003	0.0003	0.0002	0.0003	0.0003	0.0003	0.0003
	Count	65	79	78	80	73	58	79	79	76	77
Chloride (mg/l)	Minimum	6	2	13	22	25	21	28	19	26	84
	Mean	35.9	33	32.7	50.5	55.4	45	45.9	36.2	91	102
	Maximum	106	87	101	123	80	58	84	77	160	140
	St Dev	27.6	13.6	14	18.1	12.4	8.3	11.8	9.6	19	11.4
	Count	157	195	194	194	156	118	193	192	172	172
Chromium (mg/l)	Minimum	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Mean	0.0035	0.0039	0.0041	0.0044	0.0037	0.0031	0.0041	0.0039	0.0036	0.004
	Maximum	0.0112	0.0241	0.0205	0.0245	0.0214	0.0189	0.0239	0.0162	0.0145	0.0274
	St Dev	0.0025	0.0038	0.004	0.0047	0.0041	0.0035	0.0041	0.0032	0.003	0.0046
	Count	65	80	78	79	73	59	79	79	75	75
Copper (mg/l)	Minimum	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Mean	0.0076	0.007	0.0058	0.0065	0.004	0.0047	0.0049	0.0041	0.0035	0.003
	Maximum	0.03	0.03	0.039	0.02	0.009	0.0231	0.02	0.02	0.013	0.009
	St Dev	0.0056	0.005	0.0056	0.0036	0.002	0.0031	0.0041	0.0038	0.003	0.0019
	Count	66	79	77	77	73	59	80	79	75	75
Lead (mg/l)	Minimum	0.0001	0.0001	0.0001	0.0001	0.000037	0.000032	0.000044	<0.00002	0.000039	0.00005
	Mean	0.003	0.0032	0.0035	0.0027	0.0028	0.002	0.0034	0.0025	0.003	0.003
	Maximum	0.02	0.043	0.0545	0.033	0.03	0.01	0.05	0.013	0.044	0.03
	St Dev	0.0035	0.0056	0.0072	0.0042	0.0041	0.0018	0.007	0.0026	0.006	0.005

Parameter	Statistic	Upgradient Monitoring Boreholes						Cross-Gradient Monitoring Boreholes			
		SK06	SK07	SK09	SK10	SK11	SK12	SK04	SK05	SK08	SK21
	Count	54	67	65	66	68	58	68	67	68	68
Nickel (mg/l)	Minimum	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0009	0.0009	<0.001	<0.001
	Mean	0.0041	0.0044	0.0036	0.0051	0.0044	0.0034	0.0045	0.0038	0.0033	0.0028
	Maximum	0.018	0.038	0.02	0.025	0.021	0.014	0.014	0.0171	0.025	0.02
	St Dev	0.0028	0.0055	0.004	0.0053	0.0036	0.0025	0.0023	0.003	0.0036	0.0032
	Count	56	71	69	70	68	59	70	69	68	68
Sulphate (mg/l)	Minimum	115	96	238	364	379	260	300	165	197	128
	Mean	325	291	356	631	1011	719	473	1120	293	191
	Maximum	857	669	547	1110	1910	1140	940	2040	462	330
	St Dev	162	127	72	158	368	243	114	381	55	42
	Count	54	69	68	68	66	58	68	68	67	67
Zinc (mg/l)	Minimum	<0.002	0.002	<0.002	<0.002	0.0013	<0.002	<0.002	<0.002	<0.002	0.0013
	Mean	0.016	0.016	0.009	0.011	0.0064	0.015	0.008	0.009	0.0058	0.005
	Maximum	0.16	0.08	0.063	0.062	0.043	0.068	0.049	0.068	0.033	0.049
	St Dev	0.023	0.013	0.01	0.012	0.0072	0.012	0.008	0.01	0.0052	0.0062
	Count	65	78	77	78	72	58	79	77	73	73

[1] - Where concentrations are below the laboratory reporting limit, a value equal to 100% the reporting limit has been used for statistical analysis
[2] - Statistical outliers for period removed

Table HRA5: Summary of Monitored Groundwater Quality in Downgradient Monitoring Boreholes around Skelbrooke Landfill Site (Cells 1 – 6) between 1996 - 2021

Parameter	Statistic	Downgradient Boreholes		
		SK01	SK02	SK03
Cadmium (mg/l)	Minimum	<0.00002	<0.00002	<0.00002
	Mean	0.0002	0.0003	0.0003
	Maximum	0.0011	0.001	0.0029
	St Dev	0.0002	0.0002	0.0004
	Count	49	68	80
Chloride (mg/l)	Minimum	53	51.8	33
	Mean	89.9	115.7	45.4
	Maximum	166	378	72
	St Dev	25	54.2	6.9
	Count	102	160	173
Chromium (mg/l)	Minimum	<0.001	<0.001	<0.001
	Mean	0.003	0.0036	0.0035
	Maximum	0.01	0.0163	0.0208
	St Dev	0.0025	0.0028	0.0032
	Count	48	67	79
Copper (mg/l)	Minimum	<0.001	<0.001	<0.001
	Mean	0.016	0.0044	0.0039
	Maximum	0.138	0.016	0.029
	St Dev	0.00261	0.0026	0.0048
	Count	49	68	79
Lead (mg/l)	Minimum	0.001	0.00036	0.00004
	Mean	0.0022	0.0026	0.003
	Maximum	0.016	0.015	0.03
	St Dev	0.0027	0.002	0.005

Parameter	Statistic	Downgradient Boreholes		
		SK01	SK02	SK03
	Count	47	61	67
Nickel (mg/l)	Minimum	<0.001	<0.0009	<0.0009
	Mean	0.006	0.004	0.005
	Maximum	0.017	0.016	0.023
	St Dev	0.004	0.002	0.004
	Count	47	61	70
Sulphate (mg/l)	Minimum	234	285	1270
	Mean	598	457	1558
	Maximum	1400	902	2180
	St Dev	318	109	175
	Count	45	60	67
Zinc (mg/l)	Minimum	<0.002	<0.002	<0.002
	Mean	0.029	0.01	0.021
	Maximum	0.257	0.08	0.27
	St Dev	0.038	0.0098	0.0418
	Count	89	116	156

[1] - Where concentrations are below the laboratory reporting limit, a value equal to 100% the reporting limit has been used

[2] - Statistical outliers for period removed

Table HRA6: Statistical Summary of Regional Groundwater Quality Data for Magnesian Limestone (County Durham and North Yorkshire) – Adapted from Bearcock and Smedley, 2009.

Parameter	Units	n	n (c)	Min	Mean	Max	0th Percentile Value	5th Percentile Value	25th Percentile Value	50th Percentile Value	75th Percentile Value	90th Percentile Value	95th Percentile Value
Arsenic	µg/l	36	17	<0.05	0.249	2.96	-	-	-	0.05	0.15	0.61	1.46
Cadmium	µg/l	104	87	<0.005	-	0.193	-	-	-	-	-	-	-
Chromium	µg/l	103	51	<0.2	0.044	222	-	-	-	0.2	1.39	2.77	4.9
Copper	µg/l	104	35	<0.5	-	12.5	-	-	-	0.786	1.34	3.6	5.69
Mercury	***No Records Available***												
Nickel	µg/l	104	93	<0.5	-	112	-	-	-	-	-	-	-
Lead	µg/l	104	63	<0.01	0.56	45	0.00165	0.005	0.02	0.059	0.152	0.324	0.48
Zinc	µg/l	104	36	<5	21.7	372	-	1.2	2.6	6.2	19.3	44.6	77.2
Chloride	mg/l	109	1	<2	138	9250	-	14.8	23.1	38.3	53.8	111	235
Fluoride	mg/l	36	0	0.033	0.444	2.09	-	0.271	0.409	0.824	1.39	1.57	1.69
Sulphate	mg/l	107	0	1.18	160	1610	-	21.8	49.5	89.1	153	400	461

Environmental Assessment Levels

2.3.23 The setting of Environmental Assessment Levels (EALs) is necessary in order to determine if the requirements of Schedule 22 to the Environmental Permitting Regulations 2016 will be met.

2.3.24 As previously indicated, the development proposal for the Skelbrooke Quarry Extension Area seeks to infill the existing flooded quarry void with selected non-hazardous materials.

2.3.25 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 shall be employed.

- For Hazardous Substances, the EALs have been derived at the EAs published Minimum Reporting Values (MRV) of Limit of Quantification (LoQ) values as defined in UK Technical Advisory Group on the Water Framework Directive Report "Technical Report on Groundwater Hazardous Substances", 2016. Where higher, EALs have been set at the maximum recorded baseline concentration from site-specific datasets, or where such data is not available the baseline concentration is set at the 50th percentile concentration from (Beacock and Smedley, 2009).
- For Non-Hazardous Pollutants, the EALs have been derived at either:-
  - *Where the baseline concentration is 50% or less than the environmental standards, the EAL is set at ~25% above the maximum recorded baseline concentration*
  - *Where the baseline concentration more than 50% of the environmental standard the EAL is set at the standard value;*
  - *Where the baseline concentration is greater than the EQS or DWS, the EAL is set at the baseline concentration.*

2.3.26 For parameters that are routinely monitored at the site, the baseline concentration is set at the maximum recorded concentration recorded from 2019 onwards to account for the stabilised concentration ranges exhibited in many boreholes since the cessation of groundwater management activities at the adjacent landfill facility. For parameters that are not routinely monitored at the site, the baseline is set at the 50th percentile concentration listed in Beacock and Smedley (2009).

2.3.27 Details of the EALs to be taken forward for consideration are presented in **Table HRA7**.

Table HRA7: Proposed Environmental Assessment Levels (mg/l)

Substance	MRV/LoQ[1]	Laboratory Limits of Detection	EQS / DWS	Baseline Concentration[2]	Proposed EAL
Hazardous Substances					
Arsenic	0.005	(0.001)	-	0.05	0.05
Benzo-a-pyrene	0.00000005	(0.00001)	0.00027 / 0.00001	NS	0.00001
Lead	0.0002	0.001	-	<0.001	0.0002
Mercury	0.00001	(0.00001)	0.00007 / 0.001	NS	0.00001
Non-Hazardous Pollutants					
Cadmium	-	0.0001	0.00025 / 0.005	0.0003	0.0003
Chloride	-	2	250 / 250	50	65[4]
Chromium	-	0.001	0.0047 / 0.005	<0.001	0.002
Copper	-	0.001	(0.001[3]) / 2	0.011	0.015[4]
Fluoride	-	(0.03)	5 / 1.5	0.824	1.5

Substance	MRV/LoQ[1]	Laboratory Limits of Detection	EQS / DWS	Baseline Concentration[2]	Proposed EAL
Nickel	-	0.001	(0.004[3]) / 0.02	0.006	0.008[4]
Phenols	-	(0.0005)	0.0077 / -	NS	0.0077
Sulphate	-	3	400 / 250	1,560	1,560
Zinc	-	0.002	(0.0109[3])	0.024	0.024

[1] - applies to hazardous substances only
[2] - either maximum recorded concentration recorded in upgradient boreholes from 2019 onwards or the 50th percentile concentration published in Beacock and Smedley (2009).
[3] - bioavailable
[4] - 25% above baseline concentration
NS – Not sampled

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 Introduction

3.1.1 The proposed development will involve the restoration of the flooded Skelbrooke Quarry Extension Area by the importation of selected non-hazardous materials which will be of a quality that prevent the discernible discharge of hazardous substances into groundwater and limit the discharge of non-hazardous pollutants to avoid pollution.

3.1.2 In order to achieve this, it is proposed to accept non-hazardous waste which satisfies site specific waste acceptance criteria derived from baseline groundwater quality associated with the Magnesian Limestone and the dilution available within the aquifer. The acceptance and deposition of this these selected materials will ensure that the risk associated with the proposed development will be negligible and as such it is proposed the abstraction of groundwater within the existing quarry void and the installation of basal/sidewall lining systems and a leachate management system are not required.

3.1.3 This assessment will examine not only the theoretical risk posed by the proposed waste deposits to the surrounding hydrogeological environment.

3.2 Proposed Waste Deposits

Nature of the Hydrogeological Risk Assessment

3.2.1 The Hydrogeological Risk Assessment submitted in support of the 1999 Waste Management Licence application consisted of a Hydrogeological (Regulation 15) Risk Assessment which; due to the nature of the wastes proposed for disposal as part of the 1999 Waste Management Licence Application consisted of a quantitative assessment which calculated the potential diffusion flux from the proposed landfill site into the Upper Magnesian Limestone adjacent to the site. This review identified that the magnitude of the potential risk presented by the fully developed Skelbrooke Quarry Extension Area accepting the original waste list containing Hazardous Substances (formerly referred to a List I Substances) and Non-Hazardous Pollutants (formerly referred to as List II substances) was negligible.

3.2.2 Since the Skelbrooke Quarry Extension Area was never developed, with the list of wastes removed from the Environmental Permit in 2007 and the site closed in 2015, no subsequent Hydrogeological Risk Assessment Review has been required/undertaken.

3.2.3 In order to support the restoration of the Skelbrooke Quarry Extension Area using selected materials it is considered prudent to undertake a new Hydrogeological Risk Assessment to confirm the hydrogeological conceptual site model and identify the potential interactions between the proposed non-hazardous materials for deposition and the surrounding hydrogeological receptors, and impacts this might entail.

3.2.4 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."*

3.2.5 The site will accept non-hazardous waste, in which;

- 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.

3.2.6 Based on this definition, the wastes 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.

3.2.7 Additionally, the proposed development is located outside of a designated Source Protection Zone.

3.2.8 Therefore, the proposed waste streams for deposit at the site:-

- Present a limited risk to groundwater and surface water quality; 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.

3.2.9 In light of the proposal to only accept non-hazardous, non-degradable wastes for deposition which satisfies site specific waste acceptance criteria, derived from baseline groundwater quality associated with the Magnesian Limestone and the dilution available within the aquifer, it will ensure that the materials are of a quality that presents a limited pollution potential to groundwater. It is considered that a qualitative modelling approach is appropriate to identify and contextualise the hydrogeological scenario associated with the Skelbrooke Quarry Extension Area restoration proposals. A full justification of this assessment is presented below.

Assessment Scenarios

Previous Assessment Scenarios

3.2.10 Environment Agency guidance requires that Hydrogeological Risk Assessments are carried out for the whole lifecycle of the landfill.

3.2.11 The original Hydrogeological Risk Assessment submitted in support of the 1999 WML application considered the pollution potential of the Skelbrooke Quarry Extension Area during both the operational and post operational period and utilised LandSim modelling software to identify the theoretical diffusion rates from the then proposed wastes (i.e. a combination of biodegradable List I and List II substances) and their predicated impact on adjacent Upper Magnesian Limestone aquifer unit. The 1999 Hydrogeological Risk Assessment also accounted for the impact of the proposed technical precautions for the Skelbrooke Quarry Extension Area.

3.2.12 As the original Skelbrooke Quarry Extension Area (as authorised under EAWML65052) was not developed from the issuing of this Waste Management Licence in 2001 no subsequent Hydrogeological Risk Assessment Reviews have been undertaken.

Revised Assessment Scenarios

3.2.13 Following the review and update of the hydrogeological conceptual site model presented in **Section 2.0** and the proposed alterations to the nature of the wastes to be deposited within the Skelbrooke Quarry Extension Area it is considered appropriate to assess the potential risk to groundwater within the adjacent Upper Magnesian Limestone lithology.

3.2.14 The risk assessment considers the potential for leaching of hazardous substance and non-hazardous substances from the waste deposits into the groundwater. This risk assessment considered the pollution potential associated with the proposed waste deposits during the initial phase of deposition and ongoing interaction with the adjacent groundwater following cessation of deposition activities and full restoration of the Skelbrooke Quarry Extension Area.

3.2.15 It is considered that a risk assessment of lifecycle phases is not required given that there are no technical precautions included within the construction and management of the site that will be subject to long degradation. Additionally, due to the nature of the proposed waste and the absence of any proposed active management processes (i.e. leachate or groundwater management) during the infilling process it is considered that the interaction of the proposed deposition material during the operational and post-operational lifecycle phases will remain the same and as such can be incorporated into a single assessment.

Justification for Hydrogeological Risk Assessment Approach

3.2.16 A semi-quantitative hydrogeological risk assessment has been employed for the proposed waste recovery activity. The assessment adopts simple dilution calculations using site specific values and conservative assumed parameters to calculate the dilution factors available upon completion of the quarry restoration to final levels. These calculations are deemed to represent a conservative assessment of the potential risk posed to groundwater on the following basis:-

- the dilution factors associated with the post-completion phase are significantly lower than during the operational phase when waste will be directly tipped in the flooded quarry void;
- source term reductions by the initial flushing/rising and removal of a proportion of any leachable substances within the wastes is ignored;
- the bulk hydraulic conductivity of the waste deposits is conservatively assumed at $1x10^{-6}$ m/s to account for the limited consolidation of the deposits;
- attenuation processes (i.e. retardation, dispersion and biodegradation) as leachable substances pass through the waste mass are not included;
- the hydraulic gradient within the waste mass assumes doming of the in-waste water levels at the site centre, with typical peak level of 27mAOD and a mean water level at the northern edge of the quarry void of 22mAOD;
- the leachate source term concentrations assume that all deposits comprise the highest potential leachable concentration based on the proposed WAC thresholds. the concentrations of each load will be variable, with the concentration likely to range by several orders of magnitude lower for many loads.

3.2.17 The models have been used to determine the waste acceptance criteria to be adopted, limited to up to 3 times the standard WAC threshold for inert landfills.

Model Parameterisation

3.2.18 Details relating to the parameters used for the dilution calculations are presented in the spreadsheet located in **Appendix HRA3.**

Emissions to Groundwater

Hazardous Substances

3.2.19 A summary of the results of the dilution calculation for hazardous substances are presented in **Table HRA8.**

Table HRA8: Predicted diluted groundwater concentrations of hazardous substances at the edge of the quarry

Substance	EAL (mg/)	Diluted Concentration (mg/l)		
		3x Standard Inert WAC	*1x Standard Inert WAC*	*Proposed WAC*
Arsenic	0.05	0.00049	0.00016	0.0049
Lead	0.0002	***0.00049***	0.00016	0.00016
Mercury	0.00001	<0.00001	<0.00001	<0.00001

3.2.20 The dilution calculations indicate that the elevated baseline concentrations of arsenic will prevent discernible concentrations being detected in the flooded quarry waters and groundwater adjacent to the quarry at the proposed WAC threshold set at an equivalent to 3 times the standard inert landfill WAC. There is also sufficient dilution available within the flooded quarry and limestone aquifer to prevent the discernible discharge of mercury at the proposed WAC threshold set at an equivalent of 3 times standard inert landfill WAC.

3.2.21 Due to the low baseline concentrations and EAL for lead the proposed WAC threshold is set at the standard inert landfill WAC threshold to ensure that sufficient dilution is available to prevent the discernible discharge of this substance to water within the flooded quarry and groundwater in the surrounding limestone aquifer.

3.2.22 Consideration has also been provided to the deposition of a non-compliant load being deposited with elevated PAH concentrations. Using benzo-a-pyrene as a surrogate species, based on it solubility the diluted concentration within the limestone aquifer adjacent to the quarry edge will equate to ~5% of the EAL.

3.2.23 The proposed WAC for the wastes to be deposited within the application site will prevent the discernible input of hazardous substances to groundwater.

Non-Hazardous Pollutants

3.2.24 A summary of the results of the dilution calculation for hazardous substances are presented in **Table HRA9.**

Table HRA9: Predicted diluted groundwater concentrations of non-hazardous pollutants at the edge of the quarry

Substance	EAL (mg/)	Diluted Concentration (mg/l)		
		3x Standard Inert WAC	*1x Standard Inert WAC*	*Proposed WAC*
Cadmium	0.0003	0.00004	0.00001	0.00004
Chloride	65	0.8	0.3	0.8
Chromium	0.002	0.0005	0.0002	0.0005
Copper	0.0154	0.002	0.001	0.002
Fluoride	1.5	0.01	0.003	0.01
Nickel	0.0084	0.0004	0.0001	0.0004
Phenol	0.0077	0.001	0.0003	0.001

Substance	EAL (mg/)	Diluted Concentration (mg/l)		
		3x Standard Inert WAC	*1x Standard Inert WAC*	*Proposed WAC*
Sulphate	1,560	1.0	0.3	1.0

3.2.25 The dilution calculations conservatively show that there is sufficient dilution available within the flooded quarry waters and groundwater within the surrounding limestone aquifer to limit the discharge of non-hazardous pollutants to avoid pollution.

Review of Technical Precautions

Leachate Management

3.2.26 Due to the proposed infilling strategy and the non-hazardous, non-biodegradable nature of the proposed materials for deposition, it is considered that the potential for leachate generation is absent. Accordingly, it is proposed that active leachate abstraction or monitoring activities are not required.

Groundwater Management

3.2.27 As discussed earlier within this section, the adjacent engineered Skelbrooke Landfill Site (Cells 1-6); which operates under the principle of hydraulic containment, and the restored Doncaster Metropolitan Borough "dilute and attenuate" landfill are located immediately west and east of the Skelbrooke Quarry Extension Area respectively.

3.2.28 In order to ensure that the hydraulic containment conditions under which the main Skelbrooke Landfill Site (Cells 1-6) operates and to prevent the ingress of contaminated groundwaters from the neighbouring Doncaster MBC landfill it is proposed that no groundwater management infrastructure be installed at to facilitate the restoration of the Skelbrooke Extension Area.

3.2.29 Accordingly, due to the pollution potential of the proposed materials for deposition being less than, or equal to, the natural quality of the surrounding geology/groundwater it is proposed that groundwater within the Upper Magnesian Limestone will be allowed to remain at natural levels and that the regional groundwater flow direction (to the northeast) will be uninterrupted.

Surface Water Management

3.2.30 Due to the nature of proposed site operations which involve the tipping of material which satisfies the site-specific Waste Acceptance Criteria and Procedures into the flooded landfill void it is proposed that surface water management will not be required.

3.2.31 During the infilling of the Skelbrooke Quarry Extension Area, surface water from the adjacent Skelbrooke Landfill Site will continue to be discharged into Skelbrooke Extension Area Void, further enhancing the dilution available during active tipping phase of the activity.

3.2.32 Upon restoration of the Skelbrooke Quarry Extension Area, a wetland area will be established within the footprint of the Skelbrooke Quarry Extension Area void to act as an attenuation lagoon for the wider Skelbrooke Quarry and Landfill complex (**Drawing No. WR7640/10/ESSD5**). Surface water contained within this quarry area will subsequently discharge via the existing discharge point (SKSW04) to the River Skell, as shown in **Drawing No. WR7640/10/HRA2**.

Accidents and their Consequences

3.2.33 Details of accidental occurrences at the site that could present a potential risk to groundwater adjacent to the site are provided in **Table HRA10**.

Table HRA10: Qualitative Accident Risk Assessment

Hazard	Risk to Groundwater	Likelihood	Mitigation and Corrective Measures
Deposition of biodegradable and non-degradable, non-hazardous and hazardous wastes	Generation of landfill gas and leachate containing Hazardous Substances and 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 into 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.

3.2.34 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.

3.2.35 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 wastes within the landfill.

3.2.36 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 **Section 2.2** of the accompanying Supporting Statement (**Doc. Ref.: WR7640/04**).

4.1.2 Due to the non-hazardous, non-biodegradable nature of the proposed wastes for deposition; the quality of which will be such that the materials will not degrade the natural groundwater geochemistry, and the absence of engineered basal and sidewall lining systems, it is considered that no in-waste water quality or level monitoring is undertaken following the cessation of infilling operations.

4.2 Groundwater Monitoring

4.2.1 The groundwater monitoring schedule during the operational phase of the infilling activities of the Skelbrooke Quarry Extension Area it presented in **Table HRA11**. The location of the proposed groundwater monitoring points for the Skelbrooke Quarry Extension Area are presented in **Drawing No. WR7640/10/HRA2**.

4.2.2 It is noted that the proposed Skelbrooke Quarry Extension Area and the adjacent Skelbrooke Landfill Site (Cells 1-6) will share three groundwater monitoring boreholes (SK01, SK02 and SK03). In order to streamline the monitoring process and reduce the costs associated with monitoring the same borehole twice, it is proposed to synchronise the monitoring schedules of the existing Skelbrooke Landfill Site and the proposed Skelbrooke Quarry Extension Area so that all common monitoring requirements can be undertaken in a single site visit.

4.2.3 Additionally, it is important to highlight that although the proposed groundwater monitoring points of SK15, SK16, SK17, SK18 and SK19 are currently identified as unmonitored landfill gas monitoring boreholes, however, the basal elevations of these boreholes place the within the Upper Magnesian Limestone and DQL has confirmed that they screen the Magnesian Limestone and can be converted to combined gas/groundwater monitoring boreholes.

Table HRA11: Groundwater Monitoring Schedule

Monitoring Point Reference	Parameter	Monitoring Frequency	Monitoring Standard or Method
Upgradient (SK01, SK02, SK03 & any replacement monitoring boreholes)	Water Level, arsenic, cadmium, chloride, chromium, copper, Electrical Conductivity, lead, nickel, sulphate, pH, zinc	Quarterly	As specified in Environment Agency Guidance LFTGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk) or such other subsequent guidance as may be agrees in writing with the Environment Agency
	Calcium, iron, magnesium, manganese, potassium, sodium, total alkalinity, PAHs	Annually	
Cross-Gradient (SK17, SK18, SK19 & any replacement monitoring boreholes) Or Downgradient (SK15, SK16 & any replacement monitoring boreholes)	Water Level, arsenic, cadmium, chloride, chromium, copper, Electrical Conductivity, lead, nickel, sulphate, pH, zinc.	Quarterly	
	Calcium, iron, magnesium, manganese, potassium, sodium, total alkalinity, PAHs	Annually	
All Monitoring Points	Base of Monitoring Point (mAOD)	Annually	

4.2.4 Groundwater compliance levels will be derived for downgradient monitoring boreholes SK15 and SK16 following the collection of at least 6 months of background data.

4.2.5 Details of the post-closure groundwater monitoring requirements are presented in **Section 7.0** of the accompanying Support Statement (**Doc. Ref.: WR7640/04**).

4.3 Surface Water Monitoring

4.3.1 During the operational phase of the infilling activities, surface water monitoring will be undertaken on both the water contained within the Skelbrooke Quarry Extension Area void. This monitoring will entail monthly chemical analysis of selected parameters and visual inspections for hydrocarbon contamination.

4.3.2 In addition to monitoring the water contained within the Skelbrooke Quarry Extension Area void, the monitoring point SKSW04; which is also included within the monitoring schedule for the adjacent Skelbrooke Landfill Site (EPR/BV1470IE) will be incorporated into the surface water monitoring schedule for the extension area. As the waters being discharged will come into contact with the waste deposits being used to restore the extension area the range of parameters will be adapt for the extension area permit to include those linked to the waste characteristics.

4.3.3 The proposed surface water monitoring schedule for the extension area is present in **Table HRA12.**

Table HRA12: Surface Water Monitoring Schedule

Monitoring Point Reference	Parameter	Reference Period	Monitoring Frequency	Monitoring Standard or Method
SKSW04 & SKLAGOON	Arsenic	Spot Sample	Monthly	In accordance with Environment Agency document LFTGN02 (February 2003) 'Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water'
	Cadmium			
	Chloride			
	Chromium			
	Electrical Conductivity			
	pH			
	Suspended Solids			
	Visual Oil and Grease			

4.3.8 Compliance limits are also proposed at 'SKLAGOON' (see **Table HRA13**) to ensure that the quality of any waters that need to be discharge from the site during the active tipping phase do not present a significant risk to surface water quality in The Skell river. Compliance limits are largely derived at the EALs and wastes acceptance criteria derived under this assessment or the freshwater EQS value where lower.

Table HRA13: Proposed surface water compliance limits

Monitoring Point Reference	Parameter	Source	Limit (incl. unit)	Reference Period	Monitoring Frequency	Monitoring Standard or Method
SKLAGOON	Arsenic[1]	Surface Water Management System	5 µg/l	Spot Sample	Quarterly	In accordance with Environment Agency document LFTGN02
	Cadmium[1]		0.25 µg/l			
	Chromium (III)[1]		4.7 µg/l			
	Sulphate		400 mg/l			

Monitoring Point Reference	Parameter	Source	Limit (incl. unit)	Reference Period	Monitoring Frequency	Monitoring Standard or Method
	Visible Oil and Grease		None visible			(February 2003) 'Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water'

[1] – dissolved concentrations

5.0 CONCLUSIONS

5.1 Compliance with the Schedule 22 of the EPR2016

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

- The restoration of the quarry with wastes pose 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 prevent the discernible 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 monitored schedules will be used in accordance with the requisite surveillance requirements of Schedule 22 to the EPR2016.

6.0 REFERENCES

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