Wetherby Skip Services Ltd

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Revision 1

Quarry Works Deposit for Recovery Site

Ground Gas Risk Assessment

HOOPER-SARGENT LIMITED
Environmental Permitting Consultancy

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1 Introduction

1.1 Relevant Regulatory and Guidance Requirements

This Ground Gas Risk Assessment (GGRA) has been prepared by Hooper-Sargent Limited (HSL) on behalf of Wetherby Skip Services Limited (WSSL, the proposed Operator) who have applied for a bespoke Deposit for Recovery Environmental Permit (DfR Permit) for their Quarry Works site (the Site) located on Field Lane in South Elmshall, near Wakefield. The DfR Permit application was selected for Duly Making checks in April 2024 and consequent to that the Environment Agency (Agency) requested more information in their email dated 26 April 2024. This GGRA seeks to address the following questions in the Agency Not Duly Made (NDM) request for additional information (the full list of information requested is detailed in the accompanying HSL cover letter referenced 2405-016/L/001):

2. Please provide an assessment of the gas risk on neighbouring properties of the site.

   Reason: *Whilst the waste material to be accepted at the site is intended to be inert, there remains the potential for gas to be generated through residual / contaminated loads. The development is in very close proximity to an existing housing estate without the benefit of any stated gas protection. Due consideration should be given to potential pathways at all stages of the development.*

This GGRA is based on the information compiled in the accompanying Conceptual Site Model (CSM) Report referenced 2405-016/R/001 and consequent to the revised Environmental Risk Assessment referenced 2405-016/R/002. The outcome of the risk assessments enables the Operator to counter any potentially polluting aspects of the Site by incorporation of mitigation measures.

1.2 GGRA Report Content

This GGRA report incorporates the essential components listed in the Agency's guidance on the preparation of environmental risk assessments[1] as follows:

- Produce an initial CSM based on a desk study, Ground Investigations (GI) and environmental monitoring. This investigative process has informed characterisation of the following:
- Section 2 - Site Pollution Source Term. This will describe the pre-operational setting of the site and how it will develop throughout its operational lifetime. This will reference the type of waste to be used in the DfR activity and acceptance procedures to be employed at the site. In addition to the waste to be used in the DfR activity it will consider sources of gas emissions not associated with the proposed DfR activity on and off site, including pre-operational Ground Investigation (GI) works where relevant.
- Section 3 – Pathways. This section will examine the pathways through which potential emissions from the site could impact sensitive receptors. It will review the current

[1] Risk assessments for your environmental permit - GOV.UK (www.gov.uk)

setting of the site and any changes that may occur in the future as a result of on-site and potential off-site development.

- Section 4 – Receptors. Similar to Section 3, the number, type and vulnerability of current potentially sensitive receptors will be characterised as well as future potential receptors.
- Section 5 – Conceptual Site Model (CSM). The information compiled in Sections 2 to 4 will be used to construct the CSM and highlight aspects which require further consideration as part of a more detailed risk assessment.
- Section 6 – Risk Assessment. This will examine the CSM compiled in the preceding sections and attempt to establish the risk to receptors from any gas generated from the DfR deposits and how the physical presence of that material may influence gas from other sources.

2 Sources of Pollution

2.1 Supporting Information

A comprehensive GI of the Site was carried out on behalf of WSSL in 2018 by ARP Geotechnical Limited (ARP). The objective of the GI was to characterise any existing sources of contamination on site along with the wider site setting, and consider the risks primarily from a Contaminated Land perspective. The factual data collected as part of that GI (as detailed in ARP report referenced WSK/Olr1V2, the ARP Report) will be referenced in the compilation of this CSM as appropriate along with other information sources.

2.2 Historical Development

Appendix C of the ARP Report includes historical maps for the period 1854 to 2018 (1: 10560, 1:10,000 and 1:2500 scale where available). The historical development of the Site based on this information is summarised in Table 1 below and supplemented by observations taken from Google Earth images for the period 1999 to 2023.

Table 1 – Historical Review of Site

Period / Source / Map Scale	On Site (within proposed Permit Boundary)	Off-Site
1854 Yorkshire 1:10,560	Site located within undeveloped agricultural land seemingly called *South Elmsall Field.*	Field Lane runs east to west along southern Site boundary. South Elmsall a small village to southwest. South Elmsall Quarries are present < 250m to the southeast, with Minsthorpe Limestone Quarry ~250 m to the north and another unnamed quarry ~250 m to the west. The Great Northern and Western Railway transits west-northwest to east-southeast ~600 m to the southwest of the current Site. Draw Well is noted at the junction of Hacking Lanem Trough Lane and Crab Tree Lane to the south. Bullsyke Well is noted ~200 m to the southwest of that. A ditch seemingly receiving discharge from Bullsyke Well flows south under the railway and into the Frickley Beck 950 m to the south of Site. Another Draw Well and springs are noted further to the east.
1894 Yorkshire 1:2,500	No significant change.	Limekilns noted across the South Elmsall Quarries site. A large chimney is located in the centre of the South Elmsall Quarries site (labelled in 1932 1:2,500 map). A tramway network extends across the quarry floor with a point of confluence toward the south of the site. This runs through a cutting and into a tunnel beneath Hacking / Trough Lane. The track daylights to the east of Crab Tree Lane and runs parallel to it to the south where it connects via a junction to the railway.
1894 Yorkshire 1:10,560	No significant change.	South Elmsall Quarries occupies the land to up to Field Lane.
1906 Yorkshire 1:2,500	Quarrying activities appear to have commenced in the southern area of the	No significant change.

Period / Source / Map Scale	On Site (within proposed Permit Boundary)	Off-Site
	Site. A trackway now connects the Site to the South Elmsall Quarries site to the south under Field Lane. Based on subsequent maps this is a tramway.	
1907 Yorkshire 1:10,560	No significant change.	Limekilns are noted with Elmshall Quarries. The Wath Branch of the WB & WRJR Railway has been constructed to the east of Site.
1930 Yorkshire 1:10,560	Quarry workings occupy the full Site area. The track connecting the site through the tunnel is no longer shown. What appears to be a raised embankment feature is shown in its place on the quarry floor to the south of the tunnel.	The South Elmsall Quarry has extended further west along Field Lane. A housing estate has been constructed on the immediate west boundary of the Site. A tramway is noted within South Elmsall Quarries, some limekilns noted as disused. Significant expansion observed in South Elmsall to the south west.
1932 Yorkshire 1:2,500	A tunnel is noted to extend underneath Field Lane between the Site and the South Elmsall Quarries site.	No trackway appears to connect to the tunnel under Field Lane to the north.
1938 – 1948 Yorkshire 1:10,560	No significant change.	The Priory housing estate has been constructed 350 m southwest of the Site.
1956 Ordnance Survey Plan 1:10,000	No significant change.	No significant change.
1962 Ordnance Survey Plan 1:2,500	Scrubby vegetation noted within void indicating disuse.	Allotment gardens are noted on the immediate northern boundary of the Site.
1967 Ordnance Survey Plan 1:10,000	No significant change.	South Elmsall Quarries now listed as disused.
1971 Ordnance Survey Plan 1:2,500	Entrance to Site marked with 'Depot'.	A housing estate is being constructed adjacent to the western boundary of the former South Elmsall Quarries, 100 m south west of Site. A depot is located in the base of the mineral workings associated with the South Elmsall Quarries site
1982 Ordnance Survey Plan 1:2,500	No significant change.	The land to the southeast of Site (former South Elmsall Quarries site) is labelled as a refuse tip.
1983 Ordnance Survey Plan 1:10,000	A hair-pin trackway is identified from the site entrance into the quarry. Two buildings are present in the southeastern part of the void.	A depot is identified on the north-eastern boundary of the site. The northern portion of the former South Elmsall Quarries has been shaded to indicate a refuse or slag heap. The backfill extends westwards to align midway along the southern Site boundary. The Wath Branch of the WB & WRJR Railway has been decommissioned.
1986 Ordnance Survey Plan 1:2,500	No significant change.	The land to the southwest of Site (former South Elmsall Quarries site) is labelled as a refuse tip.
1992 Ordnance Survey Plan 1:10,000	No significant change.	Several large warehouses have been built on land 170 m to the north of the Site (Dale Lane Industrial Estate). The extent of the refuse tip to the south is equivalent to the western extent of the Site.
1999 Google Earth aerial photograph	A concrete hardstanding used for carparking is placed over the entrance envelope. Tyre stockpiles occupy most of the area within the Site. 3 Buildings are located within the southeastern	A property has been built on the land immediately to the north of Site. The land to the southeast appears to be restored to farmland. The land to the south appears to be rough ground with some tipping of what appears to be soils or aggregates.

Period / Source / Map Scale	On Site (within proposed Permit Boundary)	Off-Site
	portion of the site. The Site perimeter is lined with trees / shrubs.	
2000 Raster Mapping 10k	Additional buildings are visible on site.	The Dale Lane Industrial Estate has been extended to the east (40 m from Site boundary) and north with the addition of more large warehouses. A drain is noted to the east of the warehouse to the east of Site.
2002 Google Earth aerial photograph	Concrete hardstanding clearly visible along length of access track from road and the whole south east area of the Site. It is unclear of the remaining ground is asphalt or unsealed hardstanding.	No significant change.
2009 Google Earth aerial photograph	Tyre depot activities appear to have reduced, with all but one building demolished. Numerous tyre stockpiles are still present along with sporadic soils stockpiles. Stripping of vegetation / soils has exposed what appears to be in-situ minerals deposits or an overburden stockpile on western boundary, north of the access ramp.	Remaining area of former South Elmsall Quarries restored to rough pasture. Activities in depot to west of former quarry appears to have ceased, with only the building remaining.
2013 Google Earth aerial photograph	Tyre depot activity appears to have ceased with all tyres removed. Single building remains with vegetation re-establishing itself on western boundary.	Former depot building has been removed.
2018 Street View 1:10,000	Two buildings noted on Site.	No significant change.
2014 to 2023 Google Earth aerial photographs	Site is derelict, ongoing revegetation.	No significant change.

2.2.1 Historical Summary

On-Site

Quarry excavations at the Site appear to commence between 1894 and 1906 and cease prior to the 1960s. It is assumed the Site was part of the wider South Elmsall Quarries activity due to the physical connection between the two sites by a tunnel and a trackway. After quarrying ceased the Site was subsequently used as a tyre depot or stockyard until 2013 at the latest. Section 5.9 of the ARP Report makes reference to the use of the depot as a transfer station for used industrial tyres. During its peak activity the Site included 3 buildings and a concrete hardstanding that still covers the majority of the Site area. The Site is now disused with two derelict buildings remaining at the Site entrance and base of the quarry, and being progressively reclaimed by vegetation.

Off-Site

The main South Elmsall Quarries site occupied the land to the south of Field Lane. Activities ceased there in the 1960s and the remaining void was restored to fields by landfilling. A small area of void remains on the western extent of that quarry. This was used as an industrial /

commercial depot until the 2000s and is now unoccupied. Another smaller area of void is also present on the eastern boundary and that has been classified as a SSSI of geological interest. A trackway connected the Site to the main quarry, and this extended through another tunnel on the southern boundary of the main quarry where it daylighted on Crab Tree Lane. Wells and springs were noted across the downslope area to the south of Site. Residential properties were developed on the west and north boundary in the 1930s and still remain. The land to the east has been progressively developed for commercial use with an aggregate depot on the immediate eastern boundary and the Dale Lane Industrial Estate which is dominated by large warehouses built in the 1990s onwards.

The physical ground conditions under and around the void resulting from its historical development will be discussed in Section 3 – Pathways. Any contamination associated with the material in the existing ground that could generate gas will be discussed in Section 2.5 – Other Pollution Sources.

2.3 Existing Void

The cessation of quarrying activities left a >60,000 m^3 void at the Site prior to deposit of any imported materials. Access to the Site is currently gained via the site entrance off Field Lane via an engineered concrete hardstanding that previously served as a vehicle parking area. The derelict remains of the former site office are located on the northern extent of this hardstanding. The elevation of the former parking area is approximately 66.5 mAOD.

Access to the former quarry void is via a single lane track sealed with concrete hardstanding that descends northwards by ~ 6 m in elevation via a shallow ramp. At the foot of the ramp (60 mAOD) the concrete surface is extended northwards presumably to assist vehicles in making a 180° turn to the east and into the main depot area. According to the trial pit logs in the ARP Report, the ground to the north of the turning apron and either side of the track leading to the southern area of the void, is unsealed made ground consisting of sand, gravel or cobble-sized aggregates or quarry overburden. The ground level in the northern area of the Site is relatively flat at around 59.5 mAOD to 60 mAOD.

The majority of the southern area of Site was fully sealed with concrete hardstanding. When the tyre depot was active three buildings were located along the eastern face of the former quarry void. The two northern-most buildings were of a Nissan Hut design (semi-circular curved roof) and the southern-most with a pitched roof. During the site inspection carried out by ARP in 2018 they noted the presence of an inspection pit where the now removed Nissan hut was located (Appendix B, Photograph 16 of ARP Report). It is assumed this was used for vehicle maintenance. Heavy oil staining was noted on the concrete slab within the northern-most Nissan Hut and on the concrete surfacing external to it. The Operator has advised that the oil staining has since been removed. It is understood the remaining Nissan hut was damaged by fire and is now derelict. This will be removed prior to commencement of infilling activities. The ARP Report describes the presence of several stockpiles of possible quarry material or demolition material in the southeast area of the southern void. It also describes the presence of used tyres apparently associated with large industrial vehicles.

Section 10.2 of the ARP Report describes walls of the former quarry void as having been cut to a near vertical face on all sides. According to the Oakwood Land Survey topographical survey a 2 m high stockpile of material is present on the eastern boundary of the void and based on Google appears to have been placed there between 2009 and 2023. The topographical survey shows a benched feature on the western boundary just north of the bottom of the access ramp. The embankment leading down from the ramp and former site office / parking area has a shallower ~1v:2h gradient. The ground elevation in the southern-most extent of the void is typically 57.5 mAOD and represents the topographical low point of the site.

The exploratory holes and trial pits installed in the Quarry Works Site as part of the GI described in the ARP Report describes the presence of made ground across the entirety of the site. This includes the ground underneath the hardstanding at the site entrance and the access ramp that extends down into the site. Based on the progression of landfilling works at the much larger South Elmsall Quarries site to the south and the physical connection to it via the tunnel under Field Lane, it is possible similar material was placed in the two sites. Further details about the physical description of the deposited waste material and the tunnel are described in Section 3 - Pathways.

2.4 Proposed Infill Materials

2.4.1 Waste Types

The Quarry Works Site will be classified as a Deposit for Recovery Activity using non-hazardous waste that meets the Waste Acceptance Criteria (WAC) for an inert landfill Site as detailed in 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 Annex to the Landfill Directive (LFD) - Council Decision 1999/31/EC). The type of material to be accepted at the DfR activity will be referenced in this report as meeting the "LFD Inert WAC". It is anticipated that the types of waste to be deposited in the site will consist of Construction and Demolition (C&D) wastes arising from or processed at an off-site permitted facility run by the Operator and excavation wastes arising from mineral extraction activities, commercial or domestic development sites. Further details are included in the revised Waste Acceptance Criteria and List of Waste Document referenced 2405-016/R/005.

The C&D wastes will comprise separate fractions of concrete, brick, tiles and ceramics or mixtures thereof. Materials arising from the physical treatment of aggregates originally arising from mineral wastes will also be imported for deposit. These materials are anticipated to be primarily granular in composition with a range pf particle sizes from sand to large cobbles. This material will contain a negligible organic content and due its source will exclude other materials associated with C&D activities such as plasterboard, wood, metals or plastics.

2.4.2 Gas Generating Component

The excavation wastes from mineral extraction activities will be interburden or overburden only, or waste gravel, sand or clays and crushed rocks. The material excavated from commercial or domestic developments will be limited to sub-soil or stones and exclude peat, topsoil or any other organic material e.g. vegetation that may produce gas under anaerobic conditions. Subsoil or stones should contain a small or negligible organic content when excavated. Material placed in the bulk fill will have negligible potential to produce gas or leachate. Some residual Total Organic Carbon (TOC) is expected but this will tend to comprise of "hard" organic compounds such as resins and lignins which do not give rise to significant landfill gas production and these will be limited to less than 3% in accordance with inert WAC criteria.

TOC analytical technique however does not accurately reflect the organic component of a soil that is readily biodegradable. The method first involves quantification of the proportion of inorganic carbon in the material by acidification. A separate sample of the same material is then subject to high temperature combustion and catalytic oxidation with quantification of the organic carbon by measurement of the liberated carbon dioxide. The inorganic proportion is accounted for in subsequent calculations prior to the TOC value being reported. The TOC testing will not give an indication of the readily biodegradable potential of the material nor can it be used to determine how much gas will be produced. The TOC test is therefore likely to be an over-estimate of the gassing potential of the waste and should not be considered in isolation.

A CL:AIRE research bulletin[2] also discussed TOC in natural soils. It describes the prevalence of large complex organic compounds (stabilised organic matter) such as resins, lignins, waxes or heavy molecular weight hydrocarbons which few microbes can degrade. Other more degradable compounds are bound up in the soil structure and cannot be reached by microbes. These compounds can be exposed during ground disturbance and could explain initial high concentrations of methane recorded from boreholes after they have been recently drilled. These concentrations subsequently reduce to negligible values which are more reflective of the low gas generation potential ground they were installed into.

Any clay or similar components within the subsoils will increase the cohesive properties of the overall DfR matrix and similarly reduce the permeability of it. This may inhibit movement of gas within the pore space of the placed soils and stones.

Where this material is generated from greenfield sites or where there is no suspicion of contamination, they can be accepted without testing to LFD Inert WAC requirements. The likelihood is however that the supplier will normally provide GI testing data for all material proposed for recovery at the site. The absence of GI data or a site description will prompt the Operator to ask for more information or a visit to the source site. If none is provided to the Operator then the material will be refused.

2.5 Other Pollution Sources

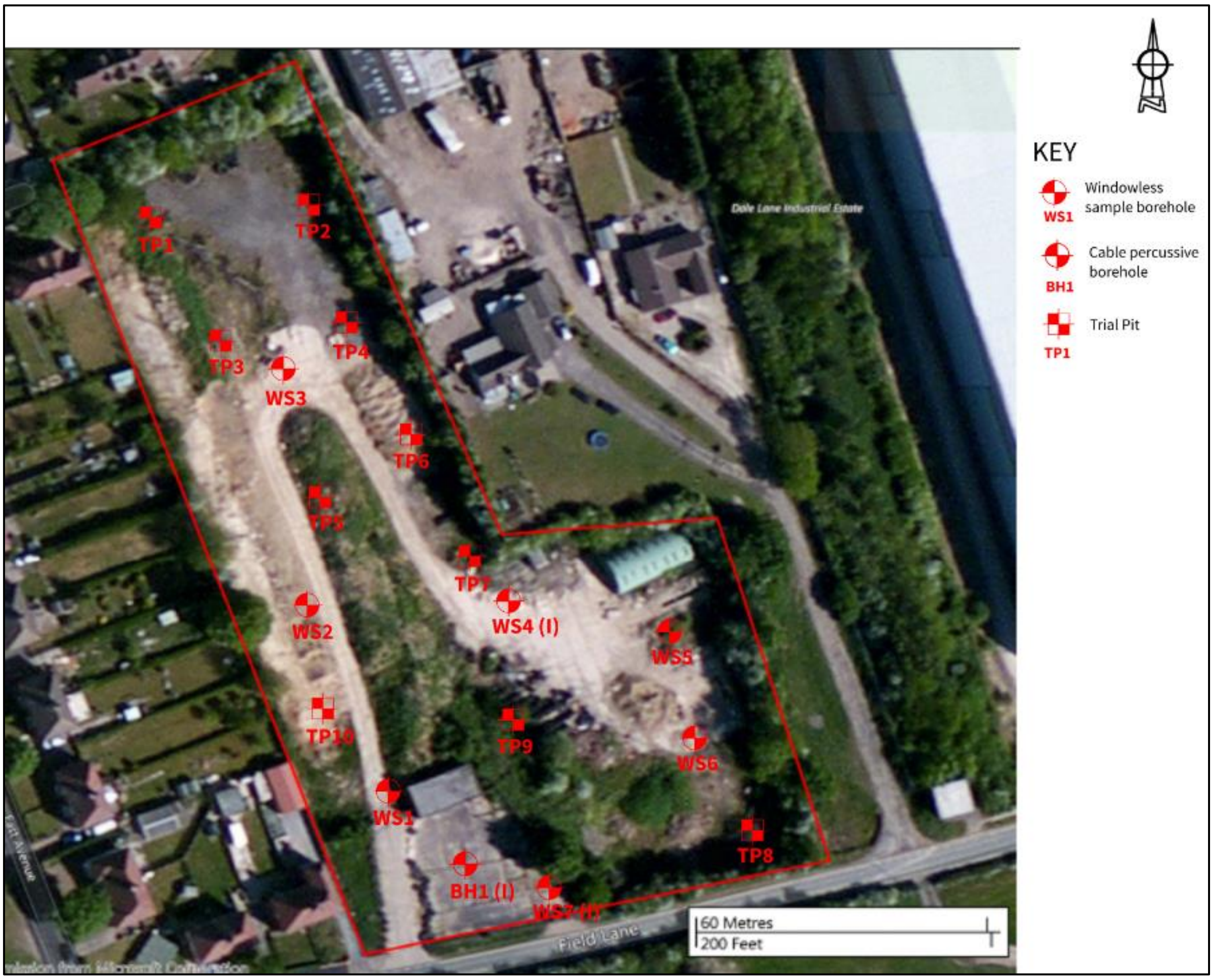
2.5.1 Pre-Operational Site Investigation

The ARP Report includes details of a GI carried out at Site in October 2018. The ARP Report states that scope and extent of the GI was based on the requirements of BS10175 : 2011 + A2 : 2017 "*Investigation of potentially contaminated sites - Code of practice*" and sought to fully characterise the site and provide geotechnical information to aid the design of the site. The site was gridded to 25m intervals and 10 Trial Pits (TP), 7 windowless holes (WS) and 1 hole drilled using Cable Percussive (CP) methods were deployed across that grid or at locations of

[2] CL:AIRE (2012). A Pragmatic Approach to Ground Gas Risk Assessment. CL:AIRE Research Bulletin RB17.
November 2012.

particular interest. The purpose of the CP hole (BH1) was to establish the depth of fill in the southwest area of site near the entrance. None of the trial pits or boreholes progressed into the Cadeby Dolostone bedrock beneath the Site and typically terminated on contact with the Dolostone. The position of the GI locations is detailed on ARP drawing referenced "Exploratory Hole Location Plan" as replicated in Figure 1 below.

Figure 1 – GI Location Plan



A total of 23 solid samples were taken from each of the sample locations with 2 samples taken 5 of the locations. The samples were subject to a range of laboratory tests including metals, hydrocarbons, asbestos, Soil Organic Matter (SOM), pH and sulphate. No water samples were taken for testing due to an absence of standing water in the installations on completion. Made ground consisting of imported waste was encountered at all locations and the physical ground conditions are discussed in Section 3.

2.5.2 Made Ground Gas Generation Potential

BH1 was drilled through the concrete hardstanding of the carpark area to determine the depth of the fill placed there historically to build the access ramp down into the quarry void. The installation log for BH1 indicates made ground is present to a depth of 10.7 m below ground level (mbgl) or from approximately 65.5 mAOD to 57.8 mAOD. This is equivalent to the topographical low point of the former quarry void immediately east of the site entrance (57.5 mAOD). The bottom 3 m of the fill was described as quarry waste or overburden. The material above that was described as clayey, gravelly sand or sandy clay containing dolostone, brick, concrete and wood fragments.

The testing carried out on the made ground material encountered beneath the site indicates it has an organic content higher to that expected of waste suitable for disposal within a Landfill Directive compliant inert landfill site. The SOM ranged from 4.9 % to 19 % with an average SOM concentration of 11.7 %. SOM is not a direct equivalent to Total Organic Carbon (TOC) due to the test method. However application of a conversion factor of 1.72[3] can be applied to SOM and when done so it indicates the average TOC would approximate to 6.8 % and likely above the LFD Inert WAC.

In summary, the material to be imported to Site for use in the DfR activity would likely contain lower a much lower TOC content than the existing non-inert material on Site. This is because it would only be accepted only if it met the more conservative limits imposed by the LFD Inert WAC.

2.5.3 Ground Gas Composition

Pipework was installed into GI locations BH1, WS4 and WS7 which were excavated into the existing made ground deposits at the Site. All other GI locations were backfilled with their arisings after soil samples and logging had been undertaken. The installation logs of all sampling points described the presence of organic material such as coal, with wood fragments noted in BH1 and WS4. Bulk gas concentrations (methane, carbon dioxide and oxygen) and flow rate were measured monthly over the period September to December 2018 and in June 2024 at the three monitoring points.

Over the 4-month period in 2018, up to 1.7 %v/v methane was detected in BH1, 4.5 %v/v methane in WS4 and 0 %v/v in WS7. Carbon dioxide was recorded up to 8.7 %v/v in BH1, 11.2 %v/v in WS4 and 9.4 %v/v in WS7. Only BH1 recorded a flow rate above the instrument limit of detection (positive and negative flows). The highest methane concentrations did not necessarily correspond with the highest carbon dioxide readings. In 2024 a positive gas flow rate was observed in BH1 (1.6 l/hr) with a peak methane concentration of 2.8 % v/v, carbon dioxide of 8 %v/v and no oxygen. No methane or gas flow was observed in WS4 or WS7. Carbon dioxide was recorded at 4.2 %v/v in WS4 with no oxygen, and 5.5 % v/v of carbon dioxide with 11.7 %v/v oxygen was recorded in WS7.

There is no strong relationship between the proximity of the monitoring points to the adjacent landfill site and gas concentrations recorded from them. In 2018 the highest methane reading was from WS4 which was most distant from the landfill, but in 2024 it was BH1 which is much closer. WS7 is the closest monitoring point but did not record any methane in 2018 or 2024. The made ground deposits within the site are as likely to produce landfill gas as the adjacent landfill site, as they are expected to be of a similar age and source. The age of the waste

[3] Total Organic Carbon | Fact Sheets | soilquality.org.au

deposits means that peak gas production probably passed many years ago and positive gas pressures are unlikely as a result.

All boreholes were installed in granular made ground and were sealed into the concrete hardstanding at the surface. Water levels in WS4 were highest although a proportion of the response zone was unsaturated (0.36 m in 2024). The response zones of WS7 and BH1 were largely unsaturated. BH1 was drilled into deep waste deposits used to form a platform and road into the quarry, the steep east-facing outer flank of which is exposed. WS7 was installed at a similar ground elevation as BH1 but closer to this exposed outer face. WS4 by comparison sits in made ground at the base of the quarry and which is locally confined by the quarry walls and concrete hardstanding above it.

In the absence of a sustained gas source the flow of ground gas in the made ground and gas concentrations recorded in it, is likely determined by atmospheric conditions. This where a change in atmospheric pressure can create a pressure gradient between the gas in the ground and ambient conditions. A drop in atmospheric pressure means the air pressure in the ground is higher than at the surface and therefore gas is pulled in that direction if a pathway is present. A rise in atmospheric pressure works in reverse, with lower gas pressure in the ground 'pulling' the air in.

The presence of the concrete slab above all three boreholes will restrict the direct ingress of atmospheric air into the installation. Ambient air will therefore finds another pathway into the ground (and the borehole) and vice versa. WS7s close proximity to the outer flank of the site entrance slab and access road likely reflects less restricted movement of air and gas in and out of that surface via the granular material. No strong positive or negative flows were observed, nor was any methane observed. This suggests equilibrium between ground gas and ambient pressures is reached relatively quickly during pressure changes. The lateral distance of BH1 to the outer flank of the site entrance slab is comparable with WS7, however the installation is twice the depth where gas conditions are more confined. Although WS4 is confined in the base of the quarry, there is open granular ground close by that can allow gas pressures to reach equilibrium.

Ambient air drawn into the ground by a flux in atmospheric pressure is utilised for respiration by microorganisms which produce carbon dioxide as a result. This is detected as elevated carbon dioxide in the ground gases and reduced or absent oxygen observed in all three boreholes. In more stagnant ground gas conditions, methanogenic bacteria can produce methane as they slowly degrade the more recalcitrant carbon present. This could occur after a high pressure event when air and ground pressures reach equilibrium and stabilise. It is unusual then that a positive gas flow was observed in BH1 in June 2024 when high atmospheric pressure conditions were developing at the time i.e. a negative flow would be expected. This could represent a much slower response to an earlier low-pressure event, but without continuous gas monitoring it is not possible to state for certain.

Methane enrichment can occur in a low permeability waste mass where air and gas movement is continually restricted such as the proposed DfR deposits. During this process methanogens in the soil reduce hydrogen and carbon dioxide to methane. This can result in a net reduction in carbon dioxide and increase in methane. The conversion of carbon dioxide to methane means there is not a significant increase in the quantity of gas produced, just the relative proportion of methane. This is commonly observed in inert landfill sites which report high methane concentrations but negligible gas flows.

In summary the gas conditions recorded at the on-site GI locations may represent the gas generated by the historical waste deposits that they are installed into. The absence of positive or negative gas flows in WS4 and WS7 may represent their shallow depth and proximity to an unsealed surface in granular, gas permeable material. The gas conditions in BH1 also likely represent the fill material and due to its semi-confined position at depth, any may show more influence from atmospheric influences. The gradual infilling of the former quarry void would likely change the gas and flow conditions observed within the existing boreholes.

2.5.4 Off-site Sources of Gas

The primary source of off-site gas is expected to be the landfilled waste located in the former South Elmsall Quarries void immediately south of the Site on the opposite side of Field Lane. The exact engineering specification or environmental pollution controls for this site are unknown, as are the exact waste inputs. Landfilling of the former South Elmsall Quarries site appears to have started at some point between 1971 and 1982 based on the historical mapping. Three BGS registered boreholes are located in the former South Elmsall Quarries Site, approximately 150 m to the southeast[4]. The boreholes appeared to be drilled after the former quarry had been partially landfilled based on the ground elevation which is approximately 10 m lower than current ground levels. The installation logs note the presence of 1.9 to 4.9 m of fill consisting of clayey sand, broken bricks, glass, ash, decayed vegetation and magnesian limestone fragments in varying combinations.

The planning statement submitted in support of an application by Askew Aggregates[5] to excavate and backfill the former brickworks site 515 m south of the Site with inert waste references installation of boreholes in the South Elmsall Quarries landfill to the north of it, between 1980 and 2006. It states the boreholes were 11 m deep, that they penetrated 200 mm into the underlying Dolostone and were all dry. It describes the placement of a 1 m thick clay landfill cap and that no water was encountered during the GI. It was assumed the construction of the landfill reflected the regulatory standards at the time of filling i.e. no requirement for a Landfill Directive compliant attenuation layer or WAC testing for waste inputs. No engineered barrier appeared to be evident underneath the fill based on the BGS-registered logs and the description in the planning statement above. The waste appears to have been placed directly onto the underlying Dolostone or Dolostone overburden. The placement of a 1 m thick capping layer is not a requirement for inert landfills under the LFD.

BGS registered borehole referenced SE41SE/50[6] dated 1976 was located in the northern area of the Site, north of the concrete turning apron. This borehole was drilled down to the underlying

[4] 107249 (bgs.ac.uk)
[5] 09_02426_FUL-0-2076071.pdf (wakefield.gov.uk)
[6] 107244 (bgs.ac.uk)

coal measures which may represent a source of mines gas, it is possible that gas could travel up the former hole if it was not sealed effectively. The log for that borehole does not record the type of fill in the Site, however the datum is comparable to current ground levels suggesting filling may have been completed in that area or the site as a whole. It is possible that both sites may have been filled with material from the same source and possibly by the same Operator. If the waste is similar then it may have a similar gas production potential as the existing Quarry Works Site deposits. The landfilled wastes in the adjacent Elmsall Quarries Site are described as being capped and restored which may direct landfill gas laterally.

The presence of voids to the east (near Valley View / Avenue) and west (the SSSI) of the landfill likely act as a partial barrier to lateral migration through the ground in those directions. The landfilled waste will form a substantial flank against those voids and subject to capping, may represent a pathway for atmospheric air / landfill gas to flux in and out of it. A similar relationship may be occurring through the undisturbed rock or the former under Field Lane, although it is not clear if this is shown by the data from BH1. The placement of low permeability DfR material against the quarry face and historical waste deposits in the Quarry Works Site may act as a barrier to that flux of gas.

2.6 Pollution Source Summary

The 60,849 m^3 void at the Site will be filled with 145,000 tonnes of non-hazardous and inert soil, stones and other aggregate wastes sourced from permitted waste treatment facilities and commercial or domestic development sites. By committing to this range of waste types the proposed Operator is minimising the potential for the generation of significant quantities of biogenic gas within the DfR waste deposits.

The made ground encountered across the site would likely be classified as non-hazardous, non-inert waste for gas generation by contemporary standards. This material evidently produces landfill gas as sampled by existing monitoring points installed within that waste. Due to the age of the waste, movement of gas through the ground is likely determined by atmospheric conditions rather than positive pressures associated with the degradation of a readily available carbon source. The infilling of the former void will likely change the gas concentrations and flow rates recorded from these monitoring points.

The landfill directly south of the Quarry Works Site may have been filled with the same material based on data retrieved from BGS-registered logs drilled in both sites. If it was similar then it also may have a gas generation potential similar to the waste in the Quarry Works Site. The landfilling was carried out before the advent of the Landfill Directive and the restrictions on TOC in the waste may not have been applied.

3 Pathways

3.1 Geological Pathways

The Site is located in a former limestone quarry likely excavated to its fullest extent by the 1930s. The bedrock is described by the British Geological Survey (BGS) 1:50,000 Series

Geology Maps as Dolostone of the Cadeby Formation, formerly described as the Cadeby (Magnesian Limestone) Formation. The BGS[7] describes Dolostone as *"…grey to buff grey, commonly oolitic or granular, with subordinate mudstone, dolomitic siltstone and sandstone."* No faults are present in the Dolostone at the site or the immediate vicinity. A fault between the Dolostone and the adjacent Upper Pennine Cola Measures strata is located 300 m to the south. The BGS does not describe the presence of superficial geology at the site or the local vicinity. The Dolostone is expected to be present beneath the site and laterally so. The three boreholes drilled through the landfill to the southeast (see Section 2.5.5) describe the dolostone beneath the landfill as having small solution cavities lined with dolomite and soft brown clay in the bedding planes.

Medici et al (2019)[8] describe the hydraulic conductivity of the Dolostone in the unfaulted Cadeby Limestone as being within a range of 3.35 x10^{-9} m/s to 1.08 x 10^{-8} m/s. No site-specific data is available to verify what the permeability is in the locality of the Site. The study describes laminar flow of water in un-faulted sections via sub-horizontal, sub-parallel and laterally persistent bedding planes. The intervening rock matrix is described as relatively impermeable reflected by the low hydraulic conductivity values detailed above.

The Dolostone may be more laterally permeable via the bedding planes compared to the main body of the rock itself. The presence of soft clay noted in the bedding planes beneath the adjacent landfill site may represent a constricting factor to that. The permeability of the rock to water could be considered analogous for its potential to conduct gas movement where unsaturated.

3.1.1 Dolostone Groundwater Levels

The absence of boreholes drilled into the Cadeby Dolostone in or close to the site means it is not currently possible to verify what the current groundwater level or flow direction is. The ground level immediately on Field Lane adjacent to the South Elmsall Quarry SSSI is 55 mAOD (based on OS Mapping). A UKRIGS Education Project location briefing note for the site [9] states that the eastern face of the former quarry is "a 7m section through Permian Magnesian Limestones". The site is not described as having standing water in it and therefore is assumed to be dry to at least 48 mAOD.

Water level monitoring in the three boreholes installed through the landfill to the south in 1976 indicate a groundwater level in the Dolostone of 43 mAOD to 45 mAOD. This data is nearly 50 years old and should be treated with caution accordingly, however it is possible the groundwater in the Dolostone is still approximately 10 m below the base of the Site. This suggests there is an unsaturated depth of Dolostone rock beneath the site although the depth is unknown. The waste and upper surface of the South Elmsall landfill was described as being dry

[7] BGS Lexicon of Named Rock Units - Result Details
[8] G. Medici, L.J. West, S.A. Banwart. (2019) 'Groundwater flow velocities in a fractured carbonate aquifer-type: Implications for contaminant transport', *Journal of Contaminant Hydrology,* Volume(222 April 2019), Pages 1-16
[9] SE3_locaccess.pdf (geohubliverpool.org.uk)

in the planning statement that accompanied the application for the Brickworks site further to the south.

The absence of seepages or standing water in the former quarry faces in the Site also suggests the rock is unsaturated laterally and immediately under the site.

3.1.2 Made Ground Water Levels

Water levels were measured monthly over the period September to December 2018 and in June 2024 at the three monitoring points WS4, WS7 and BH1. The response zone of all three installations was limited to the made ground deposits only. The base of BH1 was approximately 0.75 m above the intact Dolostone and WS4 0.07 m above the dolostone. WS7 did not contact the Dolostone during drilling.

BH1 was dry throughout the 2018 period, but a level of 57 mAOD equivalent to 0.84 m head of water above the Dolostone was measured in June 2024. A water level of 56.04 to 56.32 mAOD was recorded in WS4 during 2018 and 56.93 mAOD in June 2024. This is equivalent to a head of 0.79 m to 1.71 m above the top of the Dolostone. The water level in WS7 was 61.45 to 61.63 mAOD in 2018 and absent in 2024.

The water level in WS7 in 2018 was ~ 5m higher in elevation compared to BH1 and WS4. It is assumed this represents a perched water body in the waste deposits at a higher elevation. A standing head of water in BH1 and WS4 in granular made ground, suggests that water does not drain freely into the underlying Dolostone and is reflective of the low hydraulic conductivity values referenced above. It is assumed this water may eventually drain away vertically, but may also find a lateral pathway through the backfilled former tunnel (see below) and into the neighbouring landfill site.

3.2 Anthropogenic Pathways

3.2.1 Quarry Tunnel

Historical OS mapping shows a tunnel that connected the Site under Field Lane to the much larger South Elmsall Quarries to the south. This is expected to be present midway along the southern boundary of the Site. The floor elevation, dimensions and structure of this tunnel is not known. The entrance to the tunnel is not currently visible in the southern face of the quarry wall directly below Field Lane and it is unknown if the tunnel was backfilled and if so, what with. The undisturbed Dolostone beneath Field Lane and any material used to infill the tunnel is possibly the only physical barrier between the two sites.

A trackway is recorded as running through the tunnel and it is therefore assumed the ground would need to be reasonably level on either side. Historical mapping indicates the presence of raised embankments on the southern side of the tunnel after the trackway was removed. This suggests the wider base of excavation to the south was at a lower level. The historical mapping shows the tramway extending from the tunnel and southwards to the central chimney. This is joined by other tramways at a single point of confluence south of the central chimney. The tramway then travels into a cutting and then another tunnel under Hacking Lane. This tunnel daylights immediately west of Crab Tree Lane, south of Hacking Lane. It is therefore assumed that the base of the larger South Elmsall Quarries landfill followed a gentle decline along the trackway from the Field Lane Tunnel at around 55 mAOD to the exit from the Hacking Lane tunnel at around 47 mAOD.

3.2.2 Made Ground

The GI carried out in 2018 established that made ground was present across the entirety of the site, with the most significant deposits associated with the access ramp that extends down into the void from the southwest corner of Site. Where present the concrete slab was 0.08 to 0.23 m thick. Where verified by contact with the underlying Dolostone, the total depth of made ground ranged from 1.3 m to 6 m (excluding BH1). Where present, quarry waste deposits above the dolostone were 0.2 to 1.5 m thick. The quarry waste was typically described as *pale yellow or yellowish brown, silty gravelly sand. Gravel is sub angular fine to medium of dolostone*. The imported made waste deposits are assumed to have been imported to site from sources elsewhere as they differ in description to on-site material assumed to be derived from the Dolostone. This granular material was made up of varying combinations of bricks, concrete, dolostone with occasional / rare fragments of coal, plastic, metal, glass, roots, timber, ceramics or ash.

The existing waste deposits in the access ramp abut the southwest walls of the former quarry. No other material deposits extend to the top of the former quarry faces. The remaining waste has been tipped to a typical depth of 2 m across the entire site. The upper faces of the former quarry void remain exposed, subject to the presence of vegetation and surface soils. The completion of the DfR activity will bring inert waste in contact with the remaining exposed faces of the former quarry.

The granular nature of this material is assumed to have a relatively high permeability as evidenced by the lack of standing water or retained water in most of the exploratory boreholes or trial pits at the Site. Section 10.7 of the ARP Report described some water strikes in the made ground within the base of the quarry, predominantly in the southeast area of site (TP9, WS6 and WS5) with a water level between 54.5 mAOD and 56.2 mAOD. The presence of the concrete slab will act as a barrier to vertical transmission of ground gas. The retention of water in the granular backfill may be due to the underlying lower permeability dolostone beneath the site fill.

3.2.3 Buried Services or voids

Utilities and other services information provided by LinesearchbeforeUdig indicates there are no buried services (electricity, water or sewage) that cross the Site. A vehicle inspection pit was located within the area of a former workshop on the eastern boundary of the quarry. The construction of the pit is unknown. A photograph of the pit (Photograph 16 in the ARP Report) indicates it was lined with concrete and damp silt had accumulated in the base.

3.2.4 Boreholes

BGS registered borehole referenced SE41SE/50[10] dated 1976 was located in the northern area of the former quarry void, north of the concrete turning apron. The purpose of the borehole was apparently to log the much deeper strata in the underlying coal seams approximately 335 m below. The ground level at time of drilling was 59.44 mAOD. This is comparable with the current ground levels in the northern area of Site. It is therefore possible that the backfill noted in the ARP Report was present at that time. The fate of the borehole is unknown but it may potentially have been backfilled on completion of drilling. If filled with granular material it may represent a discrete pathway to lower strata, which being coal measures may have a mines gas generation potential.

BH1 and two of the WS holes (WS4 and WS7) were retained after the 2018 GI to measure liquid levels and ground gas concentrations. None of the boreholes were progressed into the Cadeby Dolostone. The remaining WS holes and TPS were backfilled with arisings. A site visit on 11 June 2024 confirmed that WS4, WS7 and BH1 were still present and serviceable for monitoring.

3.3 Pathway Summary

The waste imported for use in the DfR activity will be placed in a former Dolostone quarry. The Dolostone is expected to have a relatively low permeability with bedding planes forming more permeable pathways if not saturated or filled with soft clay. It is expected that the Dolostone immediately underneath the Site is unsaturated. A layer of imported granular waste overlies a shallower layer of quarry waste across the entire Quarry Works Site, along with the embankment supporting the access ramp and site entrance. This material may be saturated at topographical low points after rainfall events as any water slowly drains into the Dolostone. The imported DfR material will have direct contact with the Dolostone where it is placed against the exposed quarry walls.

Undisturbed Dolostone is present under Field Lane which separates the Quarry Works Site from the South Elmsall Quarries Landfill immediately to the south. A tunnel that historically linked the two sites is not visible and may have been backfilled / buried by the waste in the Site. Subject to the type of backfill used the tunnel is expected to be a preferential pathway between the two sites. The landfill is understood to have been capped, although the extent and specification has not been confirmed. There was no clear connection between recorded gas concentrations in the Quarry Works Site and the proximity of the directly adjacent landfill site to the south. The exposed quarry face in the Quarry Works Site may be acting as a venting surface to lateral gas emissions however. There are no other buried services that extend outwards from within the Quarry Works Site.

A deep BGS-registered borehole was drilled in the 1970s in the northern area of the Site. This is no longer present and is assumed to have been decommissioned and backfilled. The borehole extended into the underlying coal measures and may represent a source of mines gas. The majority of the 2018 GI boreholes / trial pits were backfilled with arisings. The remaining

[10] 107244 (bgs.ac.uk)

installations extend into the existing waste deposits only. WS4 in the base of the void will be decommissioned prior to commencement of filling operations.

4 Receptors

4.1 Human Receptors

4.1.1 Pre-development

The Site is bounded on its immediately to the west by the gardens of residential housing. The houses themselves are approximately 50 m away, although some have sheds or other outbuildings in their gardens. Toward the north of the Site and on the northern boundary, the houses are significantly closer with one building < 3 m from the Site boundary. On the immediate eastern boundary is the Askew Aggregates compound which appears to include various sheds along with a residential property or office building. Approximately 40 m east of the boundary is the Montessa lodging house. It is also noted a planning application has been submitted for the construction of a bungalow immediately adjacent to the eastern boundary of the Site. The Next Stadium 2 Warehouse is 50 m from the Site at its closest point and is of similar length (north to south) as the Site. There are no residences or occupied buildings within 100 m of the southern boundary of Site. The houses on Valley Avenue are approximately 115 m from the southwest corner of Site.

There is a small area of remaining void associated with the former South Elmsall Quarries site located to the southwest of Site. The houses on Valley Avenue are located on its southern and western boundary and the western flank of the landfill on the eastern boundary. Field Lane abuts the northern boundary. The South Elmsall Quarry geological SSSI located at the eastern extent of the landfill is another remaining area of quarry void. The SSSI and void to the west is situated below ground levels and their sub-surface elevation may be vulnerable to accumulation of gases during temperature inversion events, however the landfill is the more immediate source.

4.1.2 Post-built development

The objective of the DfR activity is to facilitate built development on the site which will likely comprise the construction of residential housing. The construction of the housing will seal the ground surface where foundations are laid, along with the construction of the driveways, roads, footpaths and any surface water management features. The residences will need to be connected to buried utilities which will be excavated into the DfR deposits. The construction of the buildings and associated infrastructure may therefore alter the pathways that any emissions associated with the DfR deposits or the magnitude of impacts on potentially sensitive receptors.

4.2 Sensitive Habitats

According to the Magic Map website[11] The South Elmsall Quary SSSI is located 265 m to the east of the Site. The site is designated as a SSSI because of its status as a geological site of interest, not a sensitive habitat.

4.3 Receptor Summary

The Quarry Works Site is located immediately adjacent to residential housing on its western, northern and eastern boundary. Further east is dominated by commercial activities such as large warehouses. To the immediate south is a landfill site which is not sensitive to landfill gas emissions. There are no habitats in the vicinity that may be susceptible to emissions from the Site. Residential housing will be constructed on the completed platform, the associated services of which will connect to external networks.

[11] Magic Map Application (defra.gov.uk)

5 Conceptual Site Model (CSM)

5.1 Summary

The information provided in the preceding sections details the likely sources of any potential polluting emissions associated with the Site and surrounds, the pathways that those potential emissions may take to move from their source, and, the receptors potentially vulnerable to any such emissions. Using that information a CSM has been compiled and translated into a visual representation of the Site prior to its development and on completion of the DfR activity. Consideration has also been given to the status of the CSM after completion of any built development that will be constructed on the Site.

5.2 CSM Cross Sections

The cross sections in Figures 2a to 2c, and 3a to 3b in the accompanying CSM Report are a visual representation of the information compiled in Sections 2 to 4 above. The sections, chainage and topographical elevations are based on Oakwood Land Surveys drawing referenced FL/CSF/500: *Cross Sections Final Levels* are illustrative only and not to scale. The vertical axis of each section has also been exaggerated by 5 times relative to the horizontal scale in order to include more detail. Where information is missing or unknown, a '?' symbol illustrates that uncertainty or assumption made.

Figures 2a and 3a show the Site in long section (north to south) and short section (west to east) respectively. They show the extent of the existing imported waste and quarry waste fill, including the access ramp that extends down and northwards from the Site entrance in the southwest. They show the position of the GI locations carried out in 2018 and the strata encountered by them, along with the estimated position of the BGS-registered borehole in the northern part of the quarry (Figure 2a). The landfill to the south is shown on the southern side of Field Lane, along with a suggested position of the inter-connecting tunnel (depth, height and length unknown). The height and extent of the adjacent buildings is illustrative only. The green arrows represent potential emissions of gas from the existing waste deposits on Site and the adjacent landfill site. The BGS-registered borehole to the north may also be a pathway for mines gas into the Site.

Figures 2b and 3b show the site at an intermediate stage of filling. The smaller green arrows illustrate the expectation that ground gas movement will be restricted by the placement of a substantial thickness of likely more cohesive, low permeability fill above the existing more permeable waste deposits. The placement of fill over the site may also inhibit any emissions of mines gas from the former BGS-registered borehole should it be occurring.

Figure 2c and 3c depict the Site after deposit of waste has been completed with the DfR activity and show all exposed walls of the former quarry to have been covered by imported fill.

6 Gas Risk Assessment

6.1 Lifecycle Analysis

The potential risk associated with the Site may change from its current partially filled state to the completion of the final landform and likely residential development. An analysis of the risk at each discrete stage has been carried out to establish if the risk increases, decreases or is unchanged.

6.2 Current Status

The Site in its current state consists of a former sub-surface Dolostone quarry that has been partially filled with granular quarry waste (Dolostone) and imported granular non-inert waste. The quarry waste typically has been placed directly on the undisturbed Dolostone bedrock. The quarry waste assumed to have a low pollution potential equitable to the bedrock it sits on. It is in a broken granular state however so will likely have a higher permeability than the bedrock.

The 2018 ARP GI indicates the imported fill has been placed across the entirety of the former quarry floor and forms the structure of the ground level hardstanding at the Site entrance and the 80 m long access ramp into the base of the quarry. The total depth of made ground which consists primarily of imported wastes, ranges between 1.3 m in TP3 (north) to 10.7 m (BH1, Site entrance). Testing of this largely granular material suggests it would likely exceed the LFD Inert WAC for TOC.

The former quarry is entirely below surrounding ground levels with existing waste deposits covering part of the south and western quarry faces. Concrete hardstanding covers approximately one third of the site surfaces. Adjacent to the concrete surfacing is the historical granular waste fill. The granular nature of the quarry waste and imported waste fill above likely has a higher vertical permeability than the Dolostone, which is laterally unsaturated and also likely to be unsaturated immediately beneath the site. This Dolostone is expected to have a low permeability based on literature data and retention of water above it in the made ground.

The former tunnel expected to be present on the southern quarry face connected the Quarry Works Site to the former South Elmsall Quarries site, now a restored landfill. The tunnel is no longer visible and it is assumed it has been backfilled. The landfill was filled with waste described as inert, however it was not subject to the constraints of the Landfill Directive and may be similar in composition as the waste in the Quarry Works Site, the two being filled at around the same time. It is understood that the landfill was capped with 1 m of clay and restoration soils.

The waste imported to the Site in the 1970s has the potential to produce biogenic gas, although this potential has likely reduced after 50 years. Methane and carbon dioxide gas was detected in the GI boreholes and this is likely associated with the fill in the Quarry Works Site. The influence of the emissions from the adjacent landfill is difficult to discern however. The current void is fully open to atmosphere and if any gas is present it will be readily dispersed. That includes any gas that may be migrating under pressure from the adjacent landfill through the intervening rock under Field Lane or the former tunnel. The likelihood of substantial volumes of gas being produced by the landfill is however low due to its age and assumed low organic content.

The quarry face / tunnel could be acting as a pathway for atmospheric air to pass into the adjacent landfill during high atmospheric pressure events and landfill gas to be drawn out under low pressure events, particularly when the pressure change is rapid. The presence of a low permeability cap on the landfill could create a pressure gradient with gas / air following any discrete pathways in or out of the landfill. This in addition to the landfill flanks which slope down into the SSSI site to the east and the former depot to the west may relieve the pressure on other discrete pathways from the landfill.

The risk to sensitive receptors from gas emissions from the existing waste deposits in the site is low, as any gas is able to freely vent away.

6.3 Progression of Deposit

The Operator does not propose to remove any of the existing fill material from the Site prior to commencement of infilling under the proposed DfR permit. The concrete slab will be left in place as this will form a robust running surface for visiting HGVs and be easier to clean of mud and debris. All vegetation or organic-rich soils that have accumulated within the void will however be removed prior to infilling activities.

Infilling activities will commence in the southern area of the void first. This area of Site is understood to be largely sealed with the concrete hardstanding, with the exception of the east-facing slope of the embankment up to the hardstanding and ramp at the Site entrance. The level ground immediately east of the access ramp and the concrete site road is also unsealed. Placement of lower permeability fill against the southern quarry face under Field Lane will significantly disrupt the flow of any air into, or gas out of, the rock or tunnel caused by a higher or lower ground gas pressure in the landfill. Gas or air may find an indirect pathway via the granular wastes under the access road / site entrance, or the wastes either side of the concrete hardstanding, but this will also be sealed off as the DfR deposits progress. The absence of any other open subsurface voids in the immediate vicinity means there will be limited external drivers that can draw gas from the DfR deposits toward other receptors.

The DfR deposits will be a mixture of granular and cohesive fill, the latter of which will reduce the overall porosity of the waste mass. The absence of a freely venting surface extending as a continuous body into the waste mass should restrict the movement of gas within the structure of it. The placement and tracking-in of inert waste against the quarry walls will also restrict air and gas movement in and out of the waste. The Operator will endeavour to place the more cohesive material against the rock face to form a consistent interface with it. There are no other open voids in the vicinity of the Site which can form a point of ingress and egress for air or gas, similar to the mechanism that may have occurred historically between the landfill and the Quarry Works Site. The placement of the DfR deposits should reduce the influence of atmospheric conditions on ground gas movement by effectively sealing off the walls and base of Quarry Works Site. If present, this would also restrict and air ingress or gas egress from the BGS-registered borehole drilled into the underlying coal measures.

The waste to be placed under the DfR Permit will have a low gas generation potential by virtue of strict waste acceptance controls applied to it. Ground gas concentrations of methane and carbon dioxide above 1 %v/v and 1.5 %v/v area expected to develop in the DfR deposits, however the quantity as represented by a positive gas flow rate is expected to be low. The overall lower permeability of the DfR structure and its placement against the relatively low permeability Dolostone should restrict ground gas movement through the two types of strata. It will also restrict any movement of gas in the existing waste deposits on Site and via the Dolostone / tunnel on the shared boundary with the landfill site to the south. The flux of any atmospheric air into that site and gas out of it may change by sealing off any pathway however.

6.4 Completion of Deposit and Development

On completion of the infilling activity all formerly exposed quarry faces will be sealed off by a combination of cohesive and granular fill material, with emphasis put on placing more cohesive material against the walls and existing waste deposits. The potential for ground gas movement to be influenced by this somewhat substantial venting surface will likely be diminished. Any gas generated by the DfR deposits will likely be retained in the pore space of the deposited material and at low to negligible pressure. The ability for it to migrate laterally will be restricted by its low gas pressure, overall low permeability of the DfR structure, the low permeability of the surrounding Dolostone and a diminished influence of atmospheric conditions.

It is not the Operators intention to rely on surface venting of any gas in the DfR deposits to reduce the risk of lateral migration, nor is it expected that intrusive measures such as venting points will need to be installed to encourage venting of the gas. The partial sealing of the platform surface by construction of a residential development and associated infrastructure i.e. foundation slabs, roads, footpaths and surface water management scheme, should therefore not increase the diversion of gas laterally.

The risk of potentially harmful emissions of gas generated from the DfR deposits is considered to be low during the construction of the platform and on its completion. This assumption will however be verified by imposition of an appropriate monitoring regime which will:

- Confirm the wastes deposited at the Site meet the waste acceptance criteria;
- demonstrate the quantity of any gas produced by the material is not under pressure or influenced by atmospheric conditions;
- can support an eventual surrender application for the DfR Permit; and,
- be used by the developer to inform the specification of any gas protection measures required for the houses.

6.5 Requisite Surveillance

The existing gas monitoring points will be retained on Site for as long as practicably possible to track any influence of constructing the DfR structure on the ground gas regime. These are:

- WS4 – installed through the concrete slab in the south-central area of the Site.
- WS7 – installed thought the concrete slab on the eastern edge of the Site entrance hardstanding.

- BH1 – installed through the concrete slab in the centre of the Site entrance hardstanding.

It is likely that WS7 and BH1 will be retained for the duration of the infilling of the DfR activity and during any aftercare phase prior to permit surrender. The position of WS4 means it will need to be decommissioned once deposit activities reach that part of Site, although all effort will be made to retain it for as long as possible. These gas monitoring points will provide an indication of how the ground gas regime has changed on the southern boundary which is likely to be influenced the most by atmospheric conditions and the adjacent landfill.

As soon as practicable on completion of the DfR activities four boreholes will be drilled into the DfR deposits at their deepest point i.e. along the centre of the Site. The number of points is based on a Site area of 1.2 Ha and the previous Agency Guidance of 2 No boreholes per hectare or a minimum 4 No. holes per Site. BH1 and WS7 already effectively act as in-waste gas monitoring points. The response zone of the new installations will extend from at least 1 m from the surface down to the base of the Site i.e. the concrete slab where present. They will be fitted with a screw-cap and valve assembly and secured within lockable borehole covers. They and the retained boreholes WS7 and BH1 will be sampled for bulk gas concentrations (methane, carbon dioxide, oxygen and balance gas), relative pressure and gas flow. The atmospheric and ground conditions at the time of sampling will also be recorded. The Operator may choose to install continuous gas sampling instruments in these points to expedite the aftercare period and surrender of the DfR Permit.

This monitoring regime will be detailed further in the accompanying Environmental Setting and Site Design report referenced 2405-016/R/006.