

Appendix 10C

Ground Investigation Report

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1 Introduction

1.1 Context

Headbolt Lane is an infrastructure project that will extend the Merseyrail network from the existing terminating station at Kirkby to a new station to be constructed at Headbolt Lane.

The project extents (based on the GRIP 3 Option Selection Report) are 29m 57ch to 28m 44ch (29m 1254y to 28.0968y). The engineers line reference (ELR) changes from WJK to WKL2 at the existing head shunt to the east of Kirkby station (~29m 0902y).

The existing rail corridor comprises a single line. The Merseyrail network will be extended east from the existing terminating station at Kirkby, a new turnout will provide access to a new twin-track arrangement with provision for new 3rd rail DC electrification and bi-directional signalling. As part of these works the existing earthwork will be widened and strengthening and / or renewal works will be required to the existing Underbridges 55 and 56 (UB55 and UB56). The existing Northern Rail network will be shortened as a result.

The existing Northern Rail station at Kirkby will be decommissioned and a new station interchange provided at Headbolt Lane. This new station will comprise three platforms, with two platform faces serving Merseyrail and a single platform face serving Northern Rail. Buffer stops will be provided to Merseyrail and Northern Rail to delineate between the two Train Operating Companies. The platforms will be connected by a station access arrangement replicating the operational functionality at the existing Kirkby station.

A new 300 space car park, with passive provision to increase to 500 should demand require, with public transport interchange facilities will be provided at Headbolt Lane.

The scheme has been developed to GRIP stage 3 by Network Rail. Buckingham Group Construction Ltd (BGCL) has been appointed to develop the design to GRIP stage 4, and have appointed Ove Arup and Partners Ltd (Arup) to undertake design services.

Drawings to summarise the anticipated scope of works required for the scheme, prepared to support a recent pre-planning application are presented in Appendix A. It should be noted that GRIP stage 4 design is currently ongoing and as such these may be subject to change as the scheme design develops.

Arup has been commissioned by BGCL to prepare a Ground Investigation Report (GIR) and a Geo-environmental Report to support the GRIP stage 4 design and planning application for the scheme. This report covers both these aspects.

1.2 Objectives

A number of ground related uncertainties were identified in an earlier desk study completed by others [1],[2] and an intrusive ground investigation was recommended.

A ground investigation was designed by Arup to inform GRIP stage 4 design activities and preparation of approval in principle (F001) documents for the scheme.

The purpose of this report is to summarise the findings of this intrusive ground investigation and evaluate the potential impact on the future development by:

- Establishing the general ground profile and ground condition across the site;
- Providing an overview on the groundwater levels below the site;
- Characterising the existing geoenvironmental conditions and providing sufficient information to accompany the planning application to enable conditional planning approval;
- Summarising the existing earthworks within the rail corridor.

The report includes preliminary guidance on the ground-related risks which should be considered within subsequent design and construction phases. Key ground-related risks have also been recorded in the Designers Risk Assessment for the project, with relevant entries presented in Appendix G.

This Ground Investigation Report (GIR) has been prepared in accordance with BS EN 1997 (Eurocode 7 [3]) and NR/L3/CIV/071 [4]. Additionally, it contains the results of geoenvironmental investigations and contamination risk assessment.

The factual data from the ground investigation is provided in the Ground Investigation Factual Report [5].

1.3 Geotechnical category

The scheme has currently been identified to be Geotechnical Category 2 in accordance with BS EN 1997-1:2004, which comprise conventional types of structures, foundations and earthworks design with no exceptional risk or difficult ground or loading conditions.

It is anticipated that a number of design elements within the scheme (primarily bases for ancillary lineside civils structures) will be classed as Category 1 and where appropriate standard Network Rail design details will be used for design.

The Geotechnical Category of the various design elements will be identified in the relevant Form 001.

1.4 Use of report and limitations

This report was prepared by Arup on behalf of BGCL. It takes into account our Client's particular instructions and requirements. This report is not intended for,

and should not be relied on by, any third party and no responsibility is undertaken to any third party in relation to it.

All reasonable skill, care and diligence have been exercised within the timescale available and in accordance with the technical requirements of the brief. Notwithstanding the efforts made by the professional team in preparing the report, it is possible that other ground contamination or ground conditions, as yet undetected, may exist and consequently reliance on this report must be limited accordingly.

2 The Site

2.1 Existing land use

The site location is shown in Figure 1. The majority of the site is currently occupied by the existing Liverpool-Wigan rail corridor between the existing Merseyrail Kirkby station to the proposed Headbolt Lane station site. The alignment of the rail corridor is roughly south-west to north-east. For the majority of its length the existing rail corridor is bounded by residential properties to the north and south. A number of overline and underline structures are present along the length of the project, these are discussed further in sections 2.9 and 2.10.

Figure 1: Site Location



Existing rail levels range from ~23.4 mOD in the vicinity of Kirkby station rising to ~29.7 mOD in the vicinity of the proposed Headbolt Lane Station site.

On the approach to Kirkby Station the existing rail alignment is situated in cutting, transitioning to embankment to the east of Kirkby Station. The rail alignment remains on embankment for the majority of the remainder of the site. Within the vicinity of the proposed Headbolt Lane Station the rail alignment transitions briefly to at-grade, before entering a section of low-height embankment and cutting to the east. The earthworks within the project extents are discussed further in section 2.8.

The proposed station and car park area is in an area of undulating grassland bounded to the south by the Liverpool-Wigan railway line, to the north and east by Headbolt Lane, and to the west by the A506, Back Lane. The ground levels within the proposed car park area slope from the north and south forming a valley centred on Kirkby Brook.

Kirkby Brook bisects the proposed car park area, entering the east of the site from the south via a culvert beneath the railway. The brook flows north west to the centre of the site before diverting to the south west exiting the site in the west beneath the A506.

2.2 Existing desk-based reports

A series of desk-based assessments have been produced by Mott MacDonald which include detailed description of the site and the site history. The assessments cover the site as a whole and are listed below:

- Geoenvironmental Desk Study – Headbolt Lane Station, dated August 2018, 139606-MMD-REP-EGE-000003 (Rev A) [1]
- Existing Track Geoenvironmental Desk Study – Skelmersdale Rail Link, dated March 2020, 139606-MMD-REP-EGE-000001 (Rev A) [2]

Further to the above, reports have been produced for the housing estate to the south of the site on St Kevins Drive and are referenced in the wider context to understand the ground conditions in the local areas. The reports that have been reviewed are listed below:

- ALM Consult, Geoenvironmental Appraisal of land to the west of Bramcote Walk, Kirkby – Interpretive Report, dated April 2016 [6]
- ESG, Knowsley Northern Primary Support Centre, Kirkby – Factual Report on Ground Investigation, dated September 2015 [7]

2.3 Historical land use

A detailed review of on-site and off-site history, based on publicly available sources and historical mapping, is presented in the following reports:

- Existing Track Geo-environmental Desk Study, Skelmersdale Rail Link, Mott MacDonald, 139606-MMD-REP-EGE-000001, March 2020 (NB the site is within study area 1 of this report) [2]
- Geo-environmental Desk Study, Headbolt Lane Station, Mott MacDonald, 139606-MMD-REP-EGE-000003, August 2018 [1]

A brief summary of the on-site history is described below.

The existing railway line is shown in its present day alignment on the earliest mapping reviewed which dates from 1850. The line was initially constructed as a two track railway as part of the Liverpool to Bury line which opened in 1848. Historical mapping indicates the line reduced from a two to a one track railway between 1962 and 1972.

Overbridge 57, Underbridge 56 and the existing western span of Underbridge 55 were constructed when the original railway line was established.

Record drawings indicate that the western span of Underbridge 55 (over County Road), was constructed in 1847. The original superstructure was replaced with the existing deck in 1930. In 1970 the remaining two spans of Underbridge 55 (over

A506), intermediate pier and eastern abutment were built as part of works associated with the construction of the present day A506. Significant strengthening works were undertaken on the intermediate pier in 1990 due to deterioration, thought to be the result of Alkali-Silica Reaction (ASR).

The earliest mapping reviewed, dating from 1850, shows the proposed car park and station site to be occupied by agricultural land with a sandstone quarry identified as Mercer's Delf located within the centre of the site, to the north of Kirkby Brook which is shown flowing through the centre of the site from east to west. A small building identified as Tanpit House is shown to be located in the centre north of the site off Headbolt Lane.

Mapping dating from 1902 shows the quarry to be no longer present and further development of buildings on the northern boundary of the site adjacent to Headbolt Lane. As the quarry is no longer evident it is assumed to have been infilled.

Mapping from 1972 shows the western portion of Kirkby Brook to have been realigned to its present day alignment; presumably as part of works for construction of the A506, and Headbolt Lane which bounds the site in its present day alignment. The footpath which currently crosses the site from east to west is also shown.

Mapping dating from 1990 no longer shows Tanpit House to be present. The crest of the hill on the northern boundary with Headbolt Lane appears to have moved southwards, suggesting a change of ground levels.

2.4 Published geology

Based on the British Geological Survey (BGS) 1:50,000 scale solid geological map [8], the bedrock present beneath the site comprises the Wilmslow Sandstone of the Sherwood Sandstone Group. Immediately to the west of Kirkby Station is a northwest-southeast trending fault with the Chester Formation of the Sherwood Sandstone Group present to the west of the fault line. The Chester Formation is also indicated to subcrop approximately 400m to the south of the proposed Headbolt Lane Station and car park.

Along the rail alignment between Kirkby Station and Underbridge 56 superficial deposits are generally absent in the west with the eastern half of this section underlain by Glacial Till. Alluvium is present in the vicinity of Underbridge 56 associated with Kirkby Brook.

Between Underbridge 56 and the proposed station and car park area superficial deposits are absent, however wind blown sands of the Shirdley Hill Sand Formation are indicated to be present at the eastern site boundary. It is anticipated that the extent of the Shirdley Hill Sand Formation deposits may extend to the west towards Kirkby Brook and may contain some layers of peat.

No made ground is indicated to be present on the site from geological mapping however, given the site's history and current land use, made ground is anticipated to be present along the entire rail alignment associated with the railway

development. Made ground is also anticipated to be present within the following areas of the proposed station and car park site:

- Area of former Tanpit House in the north of the site;
- Area of sandstone quarry (Mercer's Delf);
- Area of railway line and embankment in the west of the site associated with Headbolt Lane; and
- Area of backfilled former stream channel adjacent to the railway line where it crosses the A506.

2.5 Historical ground investigation

Limited historical BGS borehole data [8] is available for the site. There are no records within the site boundary. A BGS borehole record (SD40SW12) is available 270m north of the proposed car park site drilled at land to the east of Ravenscroft Community Primary School. The ground conditions encountered comprised topsoil to 0.46m bgl over sand to 1.86m bgl over clay to 1.83m bgl and weathered sandstone at 3.05m bgl.

A ground investigation comprising fourteen window sample boreholes and thirty four mechanically excavated trial pits was undertaken for the St Kevins Drive housing estate to the south of the proposed station and car park [6]. The reported ground conditions generally comprised made ground over glacial till over sandstone bedrock. The bedrock was encountered at depths ranging from 3.3-5.2m bgl and is at a level of 24.98-27.9mOD. No significant seepages of groundwater were encountered within the exploratory holes

A request for information (HBL-RFI-034) was submitted for any information held by Network Rail RAM teams (Civil Engineering, Earthworks & Track) within the project extents. No geotechnical information was reported to be held (including historical ground investigation, track bed investigation data and earthwork maintenance records).

2.6 Coal mining risk assessment

The site does not lie within a Coal Authority Coal Mining Reporting Area. A mining risk assessment report was completed by Dunelm Limited in July 2020 [9]. This covered the whole site including the existing rail corridor and proposed car park and station areas. The report states that the site is underlain by sandstone with no known mine workings present and no recorded mine entries within 20m of the site. The mining risk assessment report concludes that the site is not considered to be underlain by shallow workings that would pose a risk to the development of the site and no further action in relation to shallow mine workings is required. A copy of the assessment is presented in Appendix B.

2.7 Hydrogeology and hydrology

The closest surface water features to the site are Kirkby Brook which flows beneath the rail corridor in culvert and through the centre of the proposed car park and Simonswood Brook which flows beneath the rail corridor at Underbridge 56.

The site is not indicated to be at risk of flooding from rivers or sea. Localised flooding associated with Kirkby Brook is indicated to be a risk.

The Environment Agency classifies the Shirdley Hill Sand Formation and Alluvium as Secondary A Aquifers, an aquifer supporting water supplies at a local scale. The Glacial Till deposits are classified as unproductive strata.

The Wilmslow Sandstone Formation and Chester Formation are classified as Principal Aquifers, an aquifer which can provide a high level of water storage and may provide water supply and/or base river flow on a strategic scale.

The site is located within a groundwater Source Protection Zone (SPZ) 3, with several abstractions located to the north and south. The nearest groundwater abstractions are located approximately 2km to the north of the rail alignment.

2.8 Earthworks

Earthwork examination records held by Network Rail within the scheme extents have been reviewed. The earthwork examination database was accessed in July 2020, inspection dates range from January 2013 to March 2020. A high level summary of this information is presented in Table 1.

The earthwork examinations have been undertaken in accordance with the procedure described in NR/L3/CIV/065. It should be noted that for the purpose of identifying earthworks for examination the network is divided into 110 yard (100m) lengths and cuttings or embankments less than 3m high are not classified as earthwork assets and as such are not examined. The earthwork hazard category (EHC) and risk category are both assessed using data obtained from earthwork examination. The EHC is a measure of the statistical likelihood of failure (A is least likely and E most likely). The risk category is an evaluation of the risk posed to the operation of the railway from a variety of failure mechanisms.

Table 1: Summary of data from Earthworks examination records

ELR	Start Mileage	End Mileage	Earthwork Type	Side	EHC	Risk Category	Earthwork Geometry	Summary of Earthwork Characteristics	Movement Indicators
WKL2	28.0770	28.1430	No Earthwork	U		Low Risk	(from topo) 28.1430 at grade, 28.1210 embankment ~2m, <28.1210 embankment ~2m		
WKL2	28.0770	28.1430	No Earthwork	D		Low Risk	(from topo) 28.1430 at grade, 28.1210 embankment ~2m, <28.1210 cutting ~2m		
WKL2	28.1430	29.0440	Soil embankment	U	A	Low Risk	5 to 6m high 32 to 35 degrees	slope vegetated (mature trees and grass/brambles) uniform toe & crest slope to track separation 2 to 3m no earthwork drainage, slope face and toe dry occasional rabbit burrows	29.0108 to 29.0220 local slumping noted
WKL2	28.1430	29.0440	Soil embankment	D	A	Low Risk	3 to 6m high 32 degrees	slope vegetated (mature trees and grass/brambles) uniform toe & crest slope to track separation 2 to 3m no earthwork drainage, slope face and toe dry occasional rabbit burrows	28.1758 to 29.0016 translational failure noted. (NB frequent rabbit burrows present)
WKL2	29.0440	29.0550	No Earthwork	U		Low Risk	(from topo) 29.0440 cutting ~2m, 29.0550 cutting ~2m		
WKL2	29.0440	29.0550	No Earthwork	D		Low Risk	(from topo) 29.0440 at grade, 29.0550 cutting ~2m		
WKL2	29.0550	29.0770	Soil Cutting	U	A	Low Risk	4 to 5m high 30 degree slope	slope vegetated (mature trees and grass/brambles) uniform toe & crest	None noted

ELR	Start Mileage	End Mileage	Earthwork Type	Side	EHC	Risk Category	Earthwork Geometry	Summary of Earthwork Characteristics	Movement Indicators
								slope to track separation 3m no animal activity no cess drainage present, slope face dry	
WKL2	29.0550	29.0880	Soil Cutting	D	A to B	Low Risk	3 to 5m high 30 to 34 degree slope	slope vegetated (mature trees and grass/brambles) uniform toe and crest slope to track separation 3 to 4m no animal activity no cess drainage present, slope face dry	None noted
WKL2	29.0660	29.0770	Rock Cutting	D	B	Low Risk	4m high 90 degree slope	noted as sandstone outcrop midslope distant from track	None noted
WKL2	29.0770	29.0880	No Earthwork	U		Low Risk	(from topo) cutting/retaining wall behind Kirkby station platform		
	29.0880	29.0897	NO DATA	U & D					
WJK	29.0897	29.1210	Soil Cutting	D	B to C	Low to Average Risk	4 to 6m high 28 to 32 degree slope	slope vegetated (mature trees and grass/brambles) slope to track separation 2 to 4m dry slope face (typically) cess drainage present in parts (typically impaired/blocked or unknown condition)	29.0915 to 29.0999 surface issues on lower slope
WJK	29.0897	29.1320	Soil Cutting	U	A	Low Risk	3 to 5m 28 to 36 degrees	slope vegetated (mature trees and grass/brambles) slope to track separation 2 to 4m dry slope face cess drainage present in parts (typically impaired/blocked or unknown condition)	29.1010 to 29.1241 movement indicators noted slope washout, soil creep movement & local slumping at slope face
WJK	29.1210	29.1320	No Earthwork	D		Low Risk	assumed low height cutting		

Notes

Earthworks examination data is reported as Up side (U) and Dn side (D). However only a single line is present within the project extent. Based on topography it is assumed that Up = right cess (back to Liverpool) & Down = left cess.

EHC = Earthwork Hazard Category (where A is least likely, E most likely and N not applicable)

2.9 Services/ Utilities

The desk study reports undertaken previously for the project identified a number of active services/utility crossings within the rail corridor, based on a review of 5-mile plans provided by Network Rail. The services/utilities identified within the project extents are summarised in Table 2.

Table 2: Summary of services/utilities within the project extents

ELR	Miles	Yards	Service/ Utility
WKL2	28	1160	4ft 2" stone arch culvert
WKL2	28	1322	NW 18" stone pipe
WKL2	29	0195	3ft 10" stone arch culvert (Millstream)

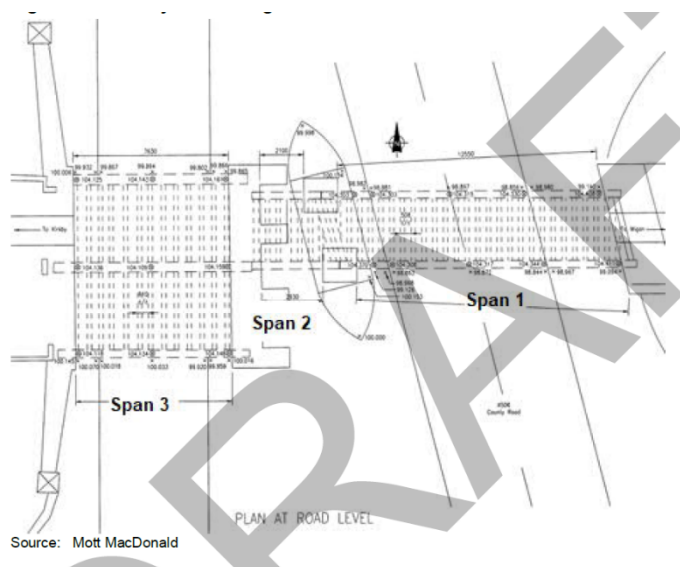
A buried services record search was undertaken by Centara in August 2020 for BGCL to inform the ground investigation works on the site.

2.10 Existing structures

2.10.1 Underbridge 55

Underbridge 55 (located at WKL2, 28m 1590yds) is a three span steel bridge that crosses over the A506 and County Road. Span 3 was constructed in 1847 and spans 1 and 2 added in 1970 to facilitate construction of the A506. The existing pier 2 formed the eastern abutment when the bridge was originally constructed and was modified during the 1970s.

Figure 2: Underbridge 55 layout

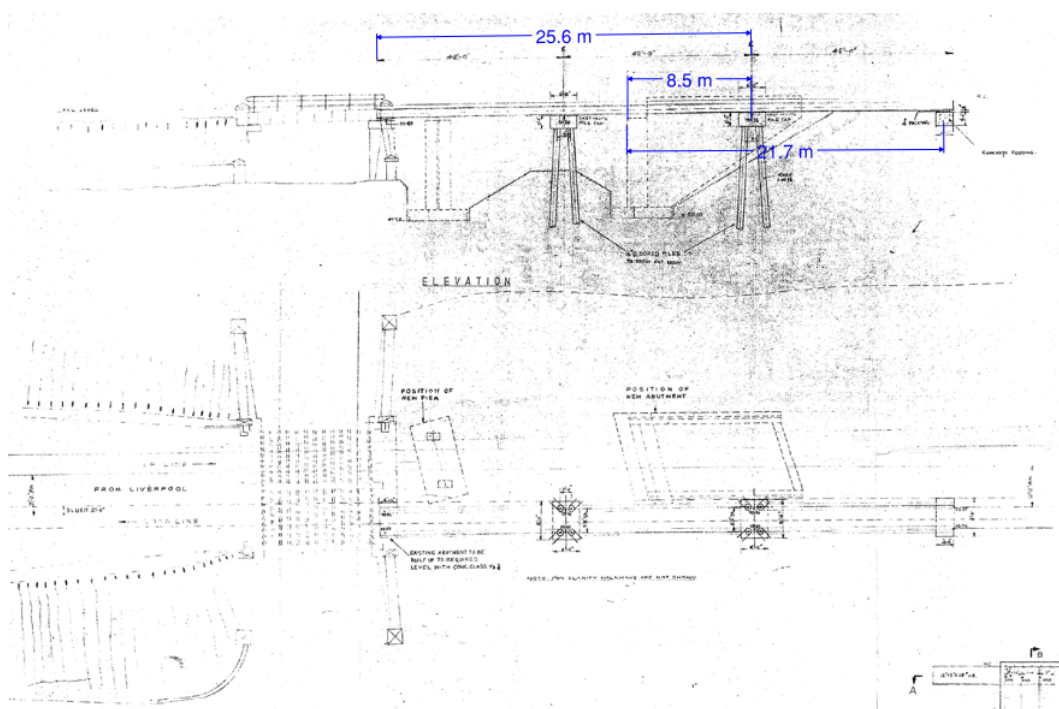


Based on review of published geology, rock is anticipated to be present at shallow depth in the vicinity of UB55. Record drawings held by Network Rail have been reviewed and indicate that all foundations for the existing structure comprise

shallow foundations, which are assumed to bear onto sandstone bedrock. The inferred level of the underside of existing foundations is as follows: pier 2 (21.6mOD), pier 1 (20.3mOD) and east abutment 20.7mOD). Existing road level of A506 is approximately 22mOD.

Record drawings held by Network Rail indicate that temporary works including two groups of four raked bored piles of 16" (~0.4m) diameter were installed as part of the 1970 modification works to UB55 to support a temporary track alignment during construction and are now redundant. The depth of the piles is not clear however it is assumed these extend into underlying rock and that some sub-structure elements remain in place.

Figure 3: Extract from Network Rail drawings showing temporary work (dimensions in m have been added based on scaling from original drawing)



2.10.2 Other structures

Underbridge 56 (located at WKL2, 29m 0145yds) is a two-span masonry arch bridge that crosses over a footpath and the Simonswood Brook.

Overbridge 57 (located at WKL2 29m 0895yds) is a road bridge which carries Glovers Brow over the railway corridor.

A retaining wall (reference WKL2 290820) is located at the back of the Northern platform of Kirkby station, between 29m 0820yds and overbridge 57 (OB57). The latest Network Rail detailed examination (15th April 2010) notes the wall to be predominantly of stonework construction with a blockwork and brickwork section adjacent to OB57. Retained height vary from 2.1m to 0.5m, reducing in height away from OB57. The wall is noted to be secure but sections are identified to be in poor condition with vegetation clearance and repair works recommended to address defects recorded – which include missing mortar, blocks and bulging .

There are no level crossings within the project boundary.

2.11 Unexploded ordnance

A pre-desk study assessment for unexploded ordnance (UXO) was obtained from Zetica as part of the previous desk study work undertaken. This did not identify any UXO risks on or affecting the site and concluded that a detailed desk study was not necessary. As such the site is considered to be situated in an area with a low risk potential from UXO.

3 Ground investigation

3.1 Overview

A ground investigation scope was designed and specified by Arup and implemented by CC Geotechnical Ltd appointed by BGCL. The works were supervised by CC Geotechnical with occasional site visits from Arup.

The fieldwork was split into two categories as outlined below:

- Rail corridor investigation – to provide geotechnical and geoenvironmental data to input to lineside civil, earthwork widening, structures and track bed designs
- Off track investigation – to provide geotechnical and geoenvironmental data to input to off-track civil works primarily the new station and car park design

The factual findings of the investigations were reported in a factual report produced by CC Geotechnical [5].

The as-constructed ground investigation locations are shown in Appendix C.

In-situ testing was undertaken to gain further understanding of soil strength profile and inform classification and parameter selection for geotechnical design. Standard penetration tests (SPT) were undertaken at regular intervals in cable percussive and windowless sampler holes. Tests undertaken in rock were extended from the standard 50 blows to 100 blows. Pocket penetrometer testing was undertaken at regular intervals in suitable fine-grained soil materials in windowless sampler and automatic ballast sampler holes.

Two soakaway tests were undertaken in trial pits within the proposed car park area.

Selected boreholes were fitted with installations to permit gas and groundwater monitoring. Following completion of the fieldwork, four rounds of monitoring were undertaken between 30th September 2020 and 18th November 2020. Monitoring records are presented in the factual report [5] and assessed in subsequent sections of this report.

A programme of laboratory testing was undertaken to establish the geotechnical and geoenvironmental properties of the ground.

3.2 Rail corridor

As part of the ground investigation, selected intrusive locations were undertaken within the rail corridor. These are summarised below:

- 14 automatic ballast sampler holes (ABS1001 to ABS1013) to depths up to 2m below ground level (bgl) within the 4' of existing tracks;
- 10 windowless sample holes (WS1201A-B, WS1202, WS1203, WS1205, WS1207, WS1208, WS1210A-D, WS1212, WS1215) to depths up to 6m bgl within the cess of existing tracks;

- 3 windowless sampler holes (WS1204, WS1206, WS1209, WS1211, WS1214) to depth up to 4.6m bgl at the toe/crest of existing embankment/cut slopes;
- 1 cable percussive borehole (BH1301) adjacent to existing UB55 to depths up to 2.8m bgl.

Exploratory holes with letters after hole reference (e.g. WS1201A) denote repeated attempts due to early refusal.

A groundwater sample was obtained from borehole BH1301. The sample was tested for a range of contaminants including metals, inorganics and hydrocarbons.

3.3 Off track

Further to the above, selected exploratory holes were undertaken to provide geotechnical and geoenvironmental data to input to the design of the proposed new station and car park with associated ancillary roadways and crossings. The intrusive locations undertaken in the off track areas at the site are summarised below:

- 10 mechanically excavated trial pits (TP1401 to TP1410) to depths up to 3.5m bgl;
- 4 cable percussive boreholes (BH1302 to BH1305) to depths up to 2.7 m bgl; and
- 2 mechanically excavated pits (SA1 and SA2) to conduct BRE infiltration/soakaway testing to depths up to 2.2m bgl.

In addition, two surface water samples (SW1601 to SW1602) were obtained from the brook crossing the site. The samples were tested for a range of contaminants including metals, inorganics and hydrocarbons.

4 Ground summary and properties

The ground conditions described in the following sections is predominantly informed by the recent ground investigation, supplemented where appropriate by historical investigation data and desk study sources.

The site has been separated into two main areas, the rail corridor (i.e. within and in close proximity to the Network Rail boundary fence) and the proposed new station and car park. A high level summary of the ground conditions encountered is presented in the following sections, further review and refinement is likely to be required to inform design.

4.1 Rail corridor

4.1.1 Overview

Exploratory holes undertaken within the rail corridor encountered a range of ground conditions influenced by superficial and solid geology and presence of earthworks. As such a series of ground models have been developed, these are detailed in Table 3. It should be noted that the boundaries between the various ground models is indicative and based on a review of both exploratory hole records and topography.

Table 3: Summary of ground models within rail corridor

Project meterage [m]	Network mileage [mm.yyyy]	Earthwork type	Relevant exploratory holes
750 to 1500	29.1283 – 29.463	Cutting	ABS1001 to ABS1007 WS1201B to WS1201A
1500 to 2225	29.463 – 28.1430	Embankment	ABS1008 to ABS1011 WS1202 to WS1209
2225 to 2375	28.1430 – 28.1266	At grade	WS1210
2375 to 2525	28.1266 – 28.1102	Embankment	ABS1012 to ABS1013 WS1211 to WS1212
2525 - 2600	28.1102 – 28.1020	Cutting	ABS1015 WS1215

4.1.2 ~750 to 1500m: existing cutting

Table 4: Ground model 750 to 1500m

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Made Ground Deposits				
Made ground	0 – 0.2	0.3 - 1	Ballast	

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Made ground	0 – 0.8	0.1 – 0.3	Granular track bed material	Not encountered in ABS1001.
Drift Deposits (not encountered in ABS1005, WS1201A and WS1201B)				
Glacial Till deposits	0.85 – 1.2	0.1 – 1.25	Cohesive	Not encountered in ABS1005, ABS1007, WS1201A and WS1201B.
Solid Geology (only encountered between ABS1004 & ABS1007)				
Sandstone	0.25-1.5	0.1 to 0.5 (max proven thickness)	Weathered brown	Not encountered in ABS1001, ABS1002, ABS1003. ABS boreholes report end at shallow depths below ground level. Max thickness proven in WS1201B.

A marked change in ground conditions is evident from the holes in the vicinity of Kirkby Station. To the west of Kirkby Station (ABS1001 to ABS1003) the existing track bed is underlain by Glacial Till whilst rock was encountered at shallow depth in holes within and to the east of the station (including ABS1004 to ABS1006). This is thought to be due to the presence of a fault shown to the west of Kirkby station on published geological mapping.

4.1.3 ~1500 to 2225m: existing embankment

Table 5: Ground model 1500 to 2225m

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Made Ground Deposits				
Made ground	0 – 0.2	0.2 – 0.6	Ballast	
Made ground	0.3 – 0.8	0.35 – 1.2	Granular track bed material	
Made ground	0.75 – 1.6	0.55 – 4.4	Cohesive embankment fill	
Made ground	0.9	4.6	Granular embankment fill	Only present in WS1208
Drift Deposits				
Glacial Till deposits	1.3 – 5.2	0.2 – 1.1	Cohesive	Not encountered in ABS1008, ABS1009, ABS1010,

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
				ABS1011, WS1208.
Glacial Till deposits	4 – 4.7	0.4 – 0.5	Granular	Not encountered in ABS1008, ABS1009, ABS1010, ABS1011, WS1208.
Solid Geology				
Sandstone	2.4 – 5.5	0.25 to 1.5 (max proven thickness)	Weathered brown	Not encountered in ABS1009, ABS1010, ABS1011, WS1207, WS1208. Max thickness proven in WS1202.

4.1.4 ~2225 to 2375m: existing at-grade

Table 6: Ground model 2225 to 2375m

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Made Ground Deposits				
Made ground	0	0.4	Topsoil	
Solid Geology				
Sandstone	0.4	0.6 (max proven)	Weathered brown	Max proven thickness in WS1210.

4.1.5 ~2375 to 2525m: existing embankment

Table 7: Ground model 2375 to 2525m

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Made Ground Deposits				
Made ground	0 – 0.2	0.3 – 0.85	Ballast	
Made ground	0.3 – 1.05	0.3- 1.15	Granular track bed material	
Made ground	1.2	1.5	Cohesive embankment fill	Encountered only in WS1212.
Solid Geology				

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Sandstone	2.7	1 (max proven thickness)	Weathered brown	Encountered only in WS1212, max thickness proven.

4.1.6 ~2525 to 2600m: existing cutting

Table 8: Ground model 2525 to 2600m

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Made Ground Deposits				
Made ground	0 – 0.2	0.3 – 0.65	Ballast	
Made ground	0.3 – 0.85	0.1 – 1.2	Granular track bed material	
Drift Deposits				
Glacial Till deposits	0.95 – 1.5	1.25 - 3	Cohesive	
Solid Geology				
Sandstone	4.5	0.1 (max proven thickness)	Weathered brown	Not encountered in ABS1015. Max thickness proven in WS1215.

4.1.7 Made ground

4.1.7.1 Extent and description

Made ground was encountered in the following holes undertaken within the rail corridor and its proximity: ABS1001 to ABS1011, ABS1013, ABS1015 and WS1201 to WS1203, WS1205, WS1207, WS1208 and WS1212. This comprised a layer of ballast in all cases, typically underlain by granular track bed material and for the majority of the project extent embankment fill.

Ballast

Ballast was encountered in all holes undertaken on or adjacent to the existing tracks. This was typically described as dirty or very dirty ballast, although some holes within the existing 4' reported a thin (up to 150mm thick) layer of clean ballast to be present at ground level.

A layer of pitching stones (described as coarse granite cobbles and typically 150mm thick) were encountered underneath the ballast within the Kirby station area west of OB57. The pitching stones were encountered in ABS1002, ABS1003 and ABS1004 located between ~850 to ~1050. The exact limits of the pitching

stones is not known but they were not encountered in ABS1001 or ABS1005 located at ~ 750m and 1150m respectively.

Granular track bed material

All holes undertaken on or adjacent to existing track alignment (i.e. within the 4' and cess of the existing track alignment) encountered a layer of blanketing material below the ballast. The thickness of this layer ranged from 0.1m to 1.2m but was typically ~0.7m.

Generally, this comprised a layer of ashy fill, described as brown silty sandy gravel, where gravel is fine to coarse angular to sub-angular ash and granite, underlain by a layer of light brown silty gravelly sand, described as loose brown silty fine to medium grained sand. This material is thought to represent a combination of the blanketing material and granular embankment fill used to form the original track bed and seal the cohesive fill used to form the core of the existing embankment.

No visible or olfactory evidence of contamination was reported in any of the locations.

Embankment fill

In on-line holes undertaken where the rail corridor is located on embankment the granular blanketing material overlies embankment fill. In all locations (apart from WS1208) this was reported to be cohesive in nature, typically described as brown sandy gravelly silty clay. The thickness of this layer ranged from 0.55m to 4.4m (typically 2.7m) increasing with embankment height.

At WS1208 the embankment fill was reported to be predominantly granular, typically described as a medium dense brown silty gravelly fine to medium sand to 5m depth, with clay bands present (0.4m as maximum thickness).

A possible relict soil surface was encountered in a number of holes, including WS1207 (3.6 to 4.1m depth) and WS1208 (5 to 5.5m depth). This was reported as a soft brown slightly sandy slightly gravelly silty clay with sand lenses and silty organic sand.

4.1.7.2 Geotechnical in-situ and laboratory testing

A summary of the classification testing for ballast, blanketing material and for both cohesive and granular embankment fill are presented in

Table 9 to 12.

Table 9: Summary of classification tests in ballast material

Laboratory Test	No. of tests	Sample range (mOD) [m bgl]	Typical Range (%)	Mean (%)	Comment
Particle size distribution (wet sieve)	4	22.44 – 29.76 [0.2 to 0.8]	Gravel content: 87 to 100 Sand content: 0 to 10 Clay and silt content: 0 to 3		Consistent with material descriptions on engineer logs (ABS1004, ABS1008, ABS1011, ABS13).

Table 10: Summary of classification tests in granular track bed material

Laboratory Test	No. of tests	Sample range (mOD) [m bgl]	Typical Range (%)	Mean (%)	Comment
Particle size distribution (wet sieve)	8	23.58 – 29.53 [0.5 to 0.9]	Gravel content: 51 to 88 Sand content: 9 to 41 Clay content and silt content: 3 to 11		Consistent with material descriptions on engineer logs.

Table 11: Summary of classification tests in cohesive embankment fill

Laboratory Test	No. of tests	Sample range (mOD) [m bgl]	Typical Range (%)	Mean (%)	Comment
Particle size distribution (wet sieve)	3	24.34 – 26.72 [1 to 2]	Gravel content: 3 to 18 Sand content: 20 to 44 Silt content: 36 to 57 Clay content: 18 to 20		Consistent with material descriptions on engineer logs.
Moisture Content (%)	7	24.09 – 27.35 [1.4 to 2.1]	12 to 20	16.1	
Liquid Limit (%)	6	24.09 – 27.35 [2.1 to 4]	27 to 39	30.8	
Plastic Limit (%)	6	24.09 – 27.35 [2.1 to 4]	13 to 19	15.2	
Plasticity Index (%)	6	24.09 – 27.35 [2.1 to 4]	13 to 20	15.7	

Table 12: Summary of classification tests in granular embankment fill

Laboratory Test	No. of tests	Sample range (mOD) [m bgl]	Typical Range (%)	Mean (%)	Comment
Particle size distribution (wet sieve)	1	25.15 [3]	Gravel content: 4 Sand content: 82 Clay and silt content: 14		Consistent with material descriptions on engineer logs (WS1208).
Moisture Content (%)	2	23.35 – 25.15 [3 to 4.8]	9.6 to 12	10.8	

A summary of SPT N values obtained from made ground materials, specifically in cohesive and granular embankment fill, is presented in Table 13.

Table 13: Summary of SPT N values in made ground

Stratum	No. of SPT N results	Level (mOD)	SPT N range values	SPT N mean value
Cohesive embankment fill	9	22.66 to 28.05	4 to 10	6.7
Granular embankment fill	5	22.85 to 26.85	10 to 18	13.2

Within cohesive materials SPT ‘N’ values can be used to derive undrained shear strength (c_u). Based on $c_u = 5.5 \times N$ (Stroud, 1989 for a typical plasticity index of about 20) [10] this indicates an undrained shear strength (c_u) of 22 to 55kPa.

Pocket penetrometer testing was undertaken on soil samples recovered from windowless sample holes. Within cohesive embankment fill materials reported undrained shear strength values ranged from 30 to 90kPa (from sixteen tests).

There is no clear correlation between measured or derived undrained shear strength with depth, but values are generally consistent with descriptions on engineer logs.

Table 14: Summary of SPT hand vane peak values in embankment fill

Stratum	No. of Hand Vane results	Level (mOD)	Hand Vane peak range values
Cohesive embankment fill	16	22.68 to 27.85	30 to 90

4.1.8 Superficial deposits

4.1.8.1 Extent and description

Glacial Till deposits

Glacial Till, comprising cohesive and granular deposits, was encountered in the majority of exploratory holes undertaken within the rail corridor cutting (from 750

to 1500m and from 2525 to 2600m), and in its proximity, at the crest and toe of embankment (from 1500 to 2225m).

Reported depths ranged from 0.6m to 4.7m with the base of the strata proven in all locations. A variation in composition with depth for both the cohesive and granular deposits has been identified. Material descriptions range from soft to stiff clay for the cohesive deposits, typically described as brown slightly sandy silty clay overlying the bedrock. The granular deposits range from loose to medium dense sand, typically described as brown silty sand.

4.1.8.2 Geotechnical in-situ and laboratory testing

A summary of the classification testing for Glacial Till deposits are presented in Table 15 respectively.

Table 15: Summary of classification tests in Glacial Till deposits

Laboratory Test	No. of tests	Sample range (mOD) [m bgl]	Typical Range (%)	Mean (%)	Comment
Particle size distribution (wet sieve)	2	21.78 – 23.58 [0.8 to 4.5]	Gravel content: 51 Sand content: 41 Clay and silt content: 8		Consistent with granular material descriptions on engineer log ABS1006.
			Gravel content: 1 Sand content: 26 Silt content: 40 Clay content: 33		Consistent with cohesive material descriptions on engineer log WS1203.
Moisture Content (%)	14	21.52 – 29.22 [1.2 to 4.5]	13 to 32	22.5	Cohesive Glacial Till deposits
Liquid Limit (%)	7	21.52 – 29.22 [1.2 to 4.5]	27 to 41	32.6	Cohesive Glacial Till deposits
Plastic Limit (%)	7	21.52 – 29.22 [1.2 to 4.5]	13 to 20	15.7	Cohesive Glacial Till deposits
Plasticity Index (%)	7	21.52 – 29.22 [1.2 to 4.5]	14 to 21	16.9	Cohesive Glacial Till deposits

SPT testing was conducted in the glacial till at a range of depths, totalling 7 tests. SPT 'N' values in the cohesive layer were between 4 and 31, typically increasing with depth. Based on $c_u = 5.5 \times N$ (Stroud, 1989 for a typical plasticity index of about 20) [10], this indicates an undrained shear strength (c_u) of around 22 to 170kPa, indicative of a soft to stiff clay which broadly corresponds to the soil descriptions.

A summary of SPT N values obtained from Glacial Till deposits is presented in Table 16.

Table 16: Summary of SPT N values in Glacial Till deposits

Stratum	No. of SPT N results	Level (mOD)	SPT N range values	SPT N mean value
Cohesive Glacial Till deposits	4	20.98 to 23.84	4 to 31	17.5
Granular Glacial Till deposits	3	21.98 to 22.82	5 to 15	10

Table 17: Summary of Hand Vane peak values in Glacial Till deposits.

Stratum	No. of Hand Vane results	Level (mOD)	Hand Vane peak range values
Cohesive Glacial Till deposits	25	20.81 to 28.52	5 to 110

4.1.9 Bedrock deposits

4.1.9.1 Extent and description

The underlying bedrock was encountered in all the logs undertaken within the rail corridor and its proximity, at the crest and toe of embankment, apart from ABS1001 to ABS1003, ABS1009 to ABS1015 and WS1207.

Locations which reported sandstone at shallow depth (< 1m) were ABS1005, WS1201, ABS1007 (~1150 to 1400) and WS1210 (~2300).

In most locations there is a layer of completely weathered sandstone which was typically recovered as a silty gravelly sand with gravel of sandstone. Depths to the top of the completely weathered sandstone ranged from 0.4m to 2.7m below ground level. The completely weathered sandstone was between 0.2m and 1.6m thick.

Where encountered, the sandstone beneath the completely weathered layer was described as a weathered reddish brown sandstone, recovered as a slightly silty slightly gravelly sand. Depths to the top of sandstone ranged from 0.25m to 4.5m below ground level, typically within the range 0.7m to 2.4m. The base of sandstone was not proven with holes terminating 0.1m to 1.5m below rockhead level.

No visual or olfactory evidence of contamination was reported in any of the locations.

BH1301 was undertaken adjacent to UB55. This reported sandstone bedrock at 2.2m depth (~21.3mOD) with 0.6m penetration achieved. This suggests the original foundations (existing pier 2) are founded at rockhead, potentially within weathered material, and the more recent foundations (existing pier 2) are located ~1m below rockhead, potentially within more competent material.

4.1.9.2 Geotechnical in-situ and laboratory testing

A summary of the classification testing for sandstone within the rail corridor is presented in Table 18.

Table 18: Summary of classification tests in weathered sandstone

Laboratory Test	No. of tests	Sample range (mOD) [m bgl]	Typical Range (%)	Mean (%)	Comment
Particle size distribution (wet sieve)	2	23.52 – 25.3 [0.9 to 1]	Gravel content: 0 to 58 Sand content: 31 to 95 Clay + silt content: 5 to 11		Consistent with material descriptions on engineer logs
Moisture Content (%)	1	28.76 [2.2]	13		ABS1013

SPT 'N' values in the Sandstone were 9 to 750 and a mean value of 219. Lower values were recorded in completely weathered sandstone material. Typical SPT 'N' values ranged from 60 to 375 which corresponds to a very weak to weak rock with a UCS of 0.6 to 3.75MPa

A summary of SPT N values obtained from sandstone is presented in Table 19.

Table 19: Summary of SPT N values in sandstone

Stratum	No. of SPT N results	Level (mOD)	SPT N range values	SPT N mean value
Sandstone	21	19.98 – 28.81	9 - 750	219

4.1.10 Summary of derived parameters

A summary of derived soil parameters for stratum encountered within the railway corridor is presented in Table 20. These values are a preliminary assessment only and should be reviewed before being used for design:

Table 20: Summary of parameters within the railway corridor

Geotechnical Parameter	Derived Value	Basis
Made Ground (granular track bed material)		
Bulk Unit Weight, γ [kN/m ³]	19 to 21	Based on soil descriptions & typical values in BS8002
Angle of shearing resistance, ϕ' [°]	30 (minimum)	Based on soil description
Made Ground (cohesive embankment fill)		
Bulk Unit Weight, γ [kN/m ³]	17 to 19	Based on soil descriptions & typical values in BS8002

Geotechnical Parameter	Derived Value	Basis
Undrained shear strength, c_u , [kN/m ²]	30 to 90	Based on soil descriptions and in-situ testing (SPT & hand shear vane)
Angle of shearing resistance, ϕ' [°]	28 to 32	Based on soil descriptions and correlation with PI
Made Ground (granular embankment fill)		
Bulk Unit Weight, γ [kN/m ³]	20	Based on soil descriptions & typical values in BS8002
Angle of shearing resistance, ϕ' [°]	34 (minimum)	Based on soil descriptions & typical values in BS8002
Glacial Till		
Bulk Unit Weight, γ [kN/m ³]	17 to 19	Based on soil descriptions & typical values in BS8002
Undrained shear strength, c_u , [kN/m ²]	20 to 100	Based on soil descriptions and in-situ testing (SPT & hand shear vane)
Angle of shearing resistance, ϕ' [°]	28 to 34	Based on soil descriptions, correlation with PI and in-situ testing (SPT)
Weathered Sandstone		
Bulk Unit Weight, γ [kN/m ³]	20 to 22	Based on soil descriptions & typical values in BS8002
Angle of shearing resistance, ϕ' [°]	38 (minimum)	Based on soil descriptions and in-situ testing (SPT)
Intact Sandstone		
Bulk Unit Weight, γ [kN/m ³]	20 to 22	Based on soil descriptions & typical values in BS8002
Unconfined Compressive Strength [MN/m ²]	0.8 (minimum)	Based on soil descriptions and in-situ testing (SPT)

4.2 Station and car park

The sequence and type of geological strata identified in the ground investigation are summarised in Table 21. This summary is based on the exploratory holes in the recent ground investigation (TP1401 to TP1410 and BH1302 to BH1305).

Table 21: Stratigraphy summary station and car park

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Made Ground				
Topsoil	0	0.05 - 0.5		Not encountered in BH1303.
Made Ground	0.05 - 1.4	0.5 – 1.6 (proven) 3.1 (unproven)	Granular	Thickness unproven in TP1405.

Stratum	Depth to top (m BGL)	Thickness (m)	Stratum description	Comments
Made Ground	0 – 0.8	0.25 - 1	Cohesive	Encountered in BH1303 and in TP1408.
Solid Geology				
Sandstone	0.5 - 3.5+	2.4 (max proven)	Weathered brown	Boreholes terminated at shallow depths in bedrock. TP1405 excavated to 3.5m and did not encounter bedrock.

4.2.1 Made ground

4.2.1.1 Extent and description

Made ground was encountered in all off-line holes undertaken within the proximity of the proposed station and car park.

Outside the extent of the former quarry reported depths to underside of made ground ranged from 0.5m to 2m bgl, typically 0.5m to 1.5m bgl, with the base of the strata proven in all locations.

Historical mapping shows a quarry within the car park area (north of Kirkby Brook) and former provides an indication of its extent. BH1303 was undertaken close to the centre of the mapped extent and TP1404 some 5 m to the east. Made ground depths of 2 & 3.1 were encountered in BH1303 and TP1404 respectively. The base of made ground was not proven in TP1404 and whilst sandstone was reported for 0.7m below base of made ground in BH1303 it is possible that this may be a sandstone boulder within quarry infill rather than bedrock.

In the majority of locations, the made ground was reported as a predominantly coarse grained material typically described as dark brown silty gravelly fine to medium sand, (brick, ceramic and inclusions of plastic). In a limited number of locations (BH1303 & TP1408) it was reported as a predominantly fine grained material; typically described as sandy slightly gravelly silty clay, gravel is fine to medium subrounded mudstone and red brick, and sand is fine to coarse. The composition of made ground encountered within the former quarry (TP1404 & BH1303) was not significantly different from that reported elsewhere on the site.

No visual signs of contamination were reported in any of the locations, but a strong fuel smell was reported in BH1303 at a depth of 1.4 to 2m bgl.

No relict substructures were encountered within the made ground, including TP1409 & TP1410 which were located within the vicinity of buildings shown on historical mapping.

4.2.1.2 Geotechnical in-situ and laboratory testing

A summary of the classification testing for made ground is presented in Table 22.

Table 22: Summary of classification tests in made ground

Laboratory Test	No. of tests	Sample range (mOD) [m bgl]	Typical Range (%)	Mean (%)	Comment
Particle size distribution (wet sieve)	5	24.09 – 30.01 [0.6 to 1.2]	Gravel content: 3 to 37 Sand content: 52 to 71 Clay and silt content: 8 to 26		Consistent with material descriptions on engineer logs
Moisture Content (%)	14	24.09 – 30.01	24 to 28	26	
Liquid Limit (%)	1	29.24	25		Cohesive made ground in TP1408
Plastic Limit (%)	1	29.24	13		Cohesive made ground in TP1408
Plasticity Index (%)	1	29.24	12		Cohesive made ground in TP1408

A single SPT test was undertaken in the granular made ground at BH1303 at 26.68mOD (1.2 mbgl), returning an SPT 'N' of 4.

Five tests were undertaken on bulk samples obtained from trial pits to establish dry density vs moisture content relationship using light compaction (2.5kg rammer). Sample depths ranged from 0.7 to 2.0m. Reported maximum dry densities ranged from 1.84 to 1.89 with optimum moisture content of 15 to 13% respectively, on average 95% maximum dry density achieved for a moisture content range of 10.7 to 17.7%. Moisture content testing indicates the soils to be wet of optimum, meaning that at natural moisture content achievable compaction will be less than 95% maximum dry density.

4.2.2 Bedrock deposits

4.2.2.1 Extent and description

The underlying bedrock was encountered in all the locations undertaken within the proximity of the proposed station and car park, apart from TP1405 located within the proximity of the former quarry and excavated to a depth of 3.5m.

Depths to top of sandstone ranged from 0.2m to 3.2m below ground level, typically within the range 0.8m to 3m. The base of sandstone was not proven with holes terminating 0.6m to 2.4m below rockhead level.

In most locations, it was typically described as weathered reddish brown sandstone, in BH1302, 1303, 1305 and TP1404 it was recovered as silty gravelly sand.

No visual or olfactory evidence of contamination was reported in any of the locations.

4.2.2.2 Geotechnical in-situ and laboratory testing

A summary of the classification testing for sandstone within car park and station is presented in Table 23.

Table 23: Summary of classification tests in sandstone

Laboratory Test	No. of tests	Sample Level range (mOD)	Typical Range (%)	Mean (%)	Comment
Particle size distribution (wet sieve)	5	24.51 – 29.54	Sand content: 21 to 97 Gravel content: 12 to 60		
Moisture Content (%)	7	23.29 – 29.54	6 - 18	12.4	

SPT testing was conducted in the sandstone at depths of 0.2-1.3 below the rock surface and vary from 68 to 429. This corresponds to an extremely weak to very weak rock with a UCS of 0.7-4.3MPa.

Table 24: Summary of SPT N values in sandstone

Stratum	No. of SPT N results	Level range (mOD)	SPT N range values	SPT N mean value
Sandstone	10	24.42 – 28.11	68 - 429	160

Two soakaway tests were undertaken in SA1 and SA2 in accordance with the methodology outlined in BRE 365 to assess the infiltration rate within the weathered and competent sandstone strata. The logs and calculation sheets are presented in the CCG Factual Report [5]. The infiltrations rates obtained were 1.41×10^{-5} m/s (SA1) and 1.35×10^{-5} m/s (SA2).

4.2.3 Summary of derived parameters

A summary of derived soil parameters for stratum encountered within the proposed station and car park area is presented in Table 25. These values are a preliminary assessment only and should be reviewed before being used for design:

Table 25: Summary of parameters within the station and car park

Geotechnical Parameter	Derived Characteristic Value	Basis
Made Ground		
Bulk Unit Weight, γ [kN/m ³]	17 to 19	Based on soil descriptions & typical values in BS8002
Angle of shearing resistance, ϕ' [°]	32 (minimum)	Based on soil descriptions and in-situ testing (SPT)
Weathered Sandstone		
Bulk Unit Weight, γ [kN/m ³]	20 to 22	Based on soil descriptions & typical values in BS8002
Angle of shearing resistance, ϕ' [°]	38 (minimum)	Based on soil descriptions and in-situ testing (SPT)
Intact Sandstone		
Bulk Unit Weight, γ [kN/m ³]	20 to 22	Based on soil descriptions & typical values in BS8002
Unconfined Compressive Strength [MN/m ²]	0.8 (minimum)	Based on soil descriptions and in-situ testing (SPT)

4.3 Groundwater

4.3.1 Groundwater encountered during fieldworks

Groundwater strikes was encountered during the fieldworks as summarised below in Table 26.

Table 26: Summary of groundwater strikes

Location	Strata	Groundwater strike depth (m bgl)	Comments
WS1207	Made ground (embankment – cohesive)	3.0	Described as a slight seepage
WS1214	Superficial deposits (granular)	2.3	Described as groundwater strike
WS1215	Made ground (granular)	0.8	Described as surface water

Groundwater were not encountered at any of the other intrusive locations during the field works.

4.3.2 Groundwater monitoring

Twelve window sample boreholes and five cable percussive boreholes were installed with a single 50mm combined gas and groundwater monitoring standpipe. The standpipes in the window sample boreholes have been monitored on four occasions between 30th September 2020 and 18th November 2020. The standpipes in the cable percussive boreholes have been monitored on three occasions between 7th October 2020 and 18th November 2020.

The installation details and the range of depths to groundwater recorded during monitoring undertaken to date are summarised in Table 27.

Table 27: Summary of groundwater monitoring

Location	Response zone (m bgl)	Response zone stratum	Groundwater depth during monitoring visits (m bgl)	Site area
WS1202	1 – 2.4	Superficial Deposits	1.43 to 1.8	Railway embankment crest
WS1203	1 - 4	Made Ground	Dry	Railway embankment crest
WS1204	0.5 – 2.3	Sandstone	Dry	Railway embankment toe
WS1205	1 - 5	Made Ground	Dry	Railway embankment crest
WS1206	0.5 – 3.1	Sandstone	2.37 to 2.52	Railway embankment toe
WS1207	3 – 6	Made Ground	Dry	Railway embankment crest
WS1208	1 – 4	Made Ground	Dry	Railway embankment crest
WS1209	0.5 – 1.7	Sandstone	0.34 to 1	Railway embankment toe
WS1211	0.5 – 2.2	Sandstone	1.44	Railway embankment toe
WS1212	2.7 – 3.7	Sandstone	Dry	Railway embankment toe
WS1214	0.5 – 4.6	Superficial Deposits	1.31 to 2.4	Railway embankment toe

Location	Response zone (m bgl)	Response zone stratum	Groundwater depth during monitoring visits (m bgl)	Site area
WS1215	0.5 – 1.4	Made Ground	0.27 to 0.6	Railway embankment crest
BH1301	1 – 2.8	Sandstone	1.62 to 2.07	Bridge 55
BH1302	0.5 – 1.8	Sandstone	1.35 to 1.65	Station
BH1303	1.4 – 2.7	Sandstone	Dry	Car park
BH1304	1.0 – 1.3	Sandstone	Dry	Central culvert crossing
BH1305	1.4 – 2	Sandstone	1.57	Eastern culvert crossing

5 Geoenvironmental screening assessment

5.1 Conceptual site model

5.1.1 Introduction

A conceptual model describes the scenario in which the risks to human health and the environment posed by contaminated land are assessed. It describes the ground and surface conditions, the proposed ground works and the final form of the development. In particular, the model identifies and describes the sources of the potential contamination, the behaviour of the contamination in environmental media such as soil and groundwater, surface water and air. It also identifies and characterises potential human health and environmental receptors, and plausible pathways.

The potential risks to human health and the environment have been considered in the context of a conceptual source-pathway-receptor model of the site, identifying:

- The principal pollutant hazards associated with the site (the sources);
- The principal receptors at risk from the identified hazards; and
- The existence, or absence, of plausible pathways which may exist between the identified hazards and receptor.

For risks to be present at the site, all three elements (source-pathway-receptor) of a plausible pollutant linkage must be present. Potential source-pathway-receptor linkages are described below based on the assumption that the site will be redeveloped for commercial use in the form of a new station building and car park with associated works along the existing rail corridor to provide the new twin-track arrangement.

5.1.2 Potential sources

The existing rail alignment has been present since the mid-1800s. The proposed station and car park area was historically agricultural land and later a quarry with associated out houses before its current use as public open space. The site has a history of earthworks in the form of level changes associated with land reprofiling and surface water and utility diversions. The historical activity on site will contribute to the potential sources of contamination that may be present. A summary of potential contaminants that could be associated with historical activity on site are provided in Table 28.

Table 28: Summary of potential contaminants

Potential source	Potentially contaminative materials	Comments
Made ground (demolition material/ infilled quarry/ railway)	Asbestos Heavy metals Petroleum hydrocarbons Polycyclic aromatic hydrocarbons (PAH) Ground gases (methane, carbon dioxide)	Made ground deriving from building demolition of historical buildings on site (Tanpit House) could contain asbestos. Potential contamination also associated with railway line, quarry and infilling The generation of ground gas will depend on the thickness and organic content of made ground.

5.1.3 Potential receptors

Receptors that may be present during construction and after completion of the development include:

- Construction workers, site workers/visitors and site neighbours during construction;
- Site workers/visitors post-construction;
- Groundwater within the Sherwood Sandstone (Principal Aquifer) and Shirdley Hill Sand Formation (Secondary A Aquifer); and
- Kirkby Brook.

5.1.4 Potential pathways

Potential pathways that may be present during redevelopment and operation include:

- Human health - ingestion of soils or dust;
- Human health - inhalation of dust, vapour or ground gas;
- Human health - dermal contact with soils;
- Controlled waters - migration of dissolved phase contamination within groundwater;
- Controlled waters (and human health by vapours) – transport of non-aqueous phase contaminants;
- Ground gas - ingress of ground gas into buildings.

5.1.5 Summary of potential pollutant linkages

A summary of the potential pollutant linkages identified based on the findings of the ground investigation in relation to the site is presented in Table 29. Overall a low risk from site contamination was identified at the site.

Table 29: Summary of potential pollutant linkages

Sources	Pathways	Receptors	Comments
Potentially impacted made ground soils	Dermal contact with soils Inhalation of dust or vapour Ingestion of dust, soil	Construction workers	No significant contamination identified in soils beneath the site which is considered to pose a risk to future site users. Standard good health and safety practices to be applied
Ground gases	Accumulation of gases in confined spaces producing asphyxiation and explosion risk	Future site users of Headbolt Station	No significant sources of ground gas expected on site. Ground gas monitoring undertaken to date indicates that the risk from ground gas to site end users is negligible
Leachable contaminants in the made ground	Vertical infiltration of leachate Lateral movement along service pipe/trenches	Groundwater	No significant contamination identified in soils beneath the site. Limited localised pockets of perched groundwater were recorded during the ground investigation. Hardstanding/ building slab will limit infiltration and leachate production.

5.2 Data screening

The laboratory analytical results and field data collected during the ground investigation have been screened against current published or internal guideline values in order to provide an initial assessment of the potential contamination status of the site. The data for soil, water and ground gas have been assessed separately, as presented in the sections below.

5.3 Soil screening assessment

5.3.1 Methodology

To simplify the assessment of ground contamination risks, the statutory guidance suggests that generic soil quality guideline values may be used for the initial screening of soil contamination testing results. Generic assessment criteria (GAC) and site-specific assessment criteria (SSAC) can be calculated using the software version of the Contaminated Land Exposure Assessment (CLEA) model. The model estimates human exposure (children and adults) to soil contaminants for those potentially living, working and/or playing on contaminated sites over long time periods (chronic exposure). The CLEA model does not consider short-term (acute) risks to humans, such as those which may arise during construction activities, or the risks posed by contaminated groundwater.

Soil guideline values (SGVs) generated using the CLEA software and accompanying toxicological reports have been issued by the Environment Agency

(EA) for eleven contaminants. Arup has produced GAC using risk assessment software (CLEA v1.06) in accordance with the CLEA assessment framework for the four standard CLEA end uses (residential with plant uptake, residential without plant uptake, allotments, and commercial) and for soil organic matter (SOM) values of 1%, 2.5% and 6%.

5.3.2 Soil assessment criteria – commercial end use

The soil results have been compared against screening criteria for a commercial end use. The key input parameters are summarised in Table 30. Full details on the input parameters and background research can be provided upon request. The GACs have been developed using a Soil Organic Matter (SOM) value of 6%, which has been selected based on the average SOM content of the soils sampled on site.

Table 30: Summary of key input parameters

Parameter	Unit	Value (commercial end use)
Age Range (critical receptor)	Years	16-65 (Female)
Exposure Frequency	days/yr	230
Exposure duration outdoor	hr/day	1
Soil to skin adherence factor	mg cm ⁻² day ⁻¹	0.14
Maximum exposed skin fraction	m ² /m ²	0.08
Soil and dust ingestion rate	mg/day	50
Inhalation rate	m ³ /day	13.4

5.3.3 Soil screening results

The results of the human health screening assessment are presented in Appendix E1. A total of 62 soil samples were screened for a variety of contaminants.

All contaminants have been reported below their respective screening criteria for a commercial end use and are considered unlikely to pose a significant risk to future site users.

There is a potential risk to construction workers who may come into direct contact with contaminated soils, particularly during earthworks. However, exposure periods are generally shorter than those experienced by long term site users and can usually be reduced to an acceptable level through adoption of adequate health and safety procedures.

Asbestos was not identified in any of the soil samples tested. However, asbestos may be present (as yet undetected) and it would be prudent to proceed assuming a potential risk during earthworks and construction works where soils are disturbed, as this may allow fibres to be released into ambient air. Appropriate mitigation measures should be applied to protect construction workers and site neighbours and should be designed and implemented by a competent contractor. Mitigation measures should include as a minimum dust suppression and appropriate PPE.

The results indicate that the existing soils within the site are likely to be chemically suitable for reuse as part of the development and that no specific remediation is likely to be required with respect to the protection of human health.

5.4 Controlled waters screening assessment

5.4.1 Controlled waters assessment criteria

Groundwater and surface water test results have been screened against criteria based on the lowest published value of freshwater Environmental Quality Standards (EQS) and UK drinking water standards (DWS) to identify potential contaminants of concern. Where no EQS values are available the results have been compared to EU drinking water standards (EUDWS) or World Health Organisation standards (WHO).

5.4.2 Controlled water screening results

Two surface water samples (SW01 and SW02) from Kirkby Brook upstream and downstream of the station and car park area and one sample of groundwater (BH1301) were obtained during the ground investigation. The contaminants which exceed the screening criteria are summarised in Table 31. This assessment is also presented as Appendix E2.

Table 31: Exceedances of water screening criteria

Determinand	Screening criteria	Exceedances
Manganese	30 µg/l	BH1301 (917 µg/l)
Selenium	10 µg/l	BH1301 (44 µg/l)
Anthracene	0.1 µg/l	BH1301 (0.34 µg/l)
Fluoranthene	0.0063 µg/l	BH1301 (3.69 µg/l) SW01 (0.09 µg/l) SW02 (0.14 µg/l)
Benzo(a)pyrene	0.00017 µg/l	BH1301 (3.37 µg/l) SW01 (0.06 µg/l) SW02 (0.1 µg/l)

In general, the groundwater and surface water testing indicates that the majority of contaminants tested are recorded below the screening criteria.

Elevated concentrations of manganese and selenium were recorded in the groundwater in BH1301. Manganese and selenium are known to be naturally present within groundwater in the Sherwood Sandstone in this region of the UK. Due to the lack of significant contamination identified in the made ground it is considered unlikely that the site is the source of elevated manganese and selenium groundwater concentrations.

Elevated concentrations of PAHs were recorded in the groundwater (anthracene, fluoranthene and benzo(a)pyrene) and both surface water samples (fluoranthene and benzo(a)pyrene) and it is possible that the made ground may be a contributory

source, however no significant hydrocarbon contamination was recorded within the soils.

Due to the limited of groundwater encountered during the investigation and the lack of significant contamination identified in the made ground any risk posed from soil contamination is considered to be negligible.

5.5 Gas monitoring

Made ground can be a source of ground gases, however at the site significant organic material that could be considered a potential source of ground gases has not been identified. A plausible pollutant linkage between site users and any ground gases accumulating in the station buildings to asphyxiating or explosive concentrations was identified in the conceptual site model. Ground gas monitoring was undertaken upon completion of the recent ground investigation and a generic risk assessment has been undertaken following the guidance outlined in CIRIA C665 [12] the results of which are described below. V low risk

5.5.1 Methodology

The risk posed to buildings by hazardous ground gases has been assessed in accordance with CIRIA C665 [12] and British Standard guidance [13] and follows the source-pathway-receptor model.

5.5.2 Gas monitoring results

To date, a total of four rounds and three rounds of gas monitoring have been completed for twelve standpipes and five standpipes respectively installed within the site as part of the recent ground investigation. The cable percussive borehole installations have only been monitored three times as they were not drilled at the time of the first monitoring round. Atmospheric pressures during the monitoring to date have ranged from 989 to 1006 mb.

The results of the gas monitoring are summarised in Table 32.

Table 32: Summary of gas monitoring data

Monitoring well	No. visits	Methane		Carbon dioxide		Peak gas flow (l/hr)	Site area
		Range % v/v	No. >1%v/v	Range % v/v	No. >5%v/v		
Response zone in made ground							
WS1202	4	<0.1	0	<0.1 – 3.1	0	<0.1	Railway embankment crest
WS1203	4	<0.1	0	1.3 – 11.1	1	<0.1	Railway embankment crest
WS1205	4	<0.1	0	0.2 – 7.1	1	<0.1	Railway embankment crest

Monitoring	No.	Methane		Carbon dioxide		Peak gas flow	Site area
WS1207	4	<0.1	0	2.7 – 9.5	2	<0.1	Railway embankment crest
WS1208	4	<0.1	0	3.7 – 5.5	1	<0.1	Railway embankment crest
WS1214	4	<0.1	0	1.1 – 2.4	0	<0.1	Railway embankment toe
WS1215	4	<0.1	0	<0.1 – 0.4	0	<0.1	Railway embankment crest
BH1303	3	<0.1	0	8.5 – 13.2	3	<0.1	Car park
Response zone in sandstone							
WS1204	4	<0.1	0	1 – 2.2	0	<0.1	Railway embankment toe
WS1206	4	<0.1	0	2.1 – 2.8	0	<0.1	Railway embankment toe
WS1209	4	<0.1	0	0.4 – 1.8	0	<0.1	Railway embankment toe
WS1211	4	<0.1	0	0.6 – 1.0	0	<0.1	Railway embankment toe
WS1212	4	<0.1	0	0.4 – 4.6	0	<0.1	Railway embankment toe
BH1301	3	<0.1	0	1.5 – 1.6	0	<0.1	Bridge 55
BH1302	3	<0.1	0	0.9 – 2.3	0	<0.1	Station
BH1304	3	<0.1	0	1.9 – 2.3	0	<0.1	Central culvert crossing
BH1305	3	<0.1	0	1.7 – 2.3	0	<0.1	Eastern culvert crossing

No methane was recorded in any of the boreholes (<0.1%). Carbon dioxide levels within the made ground recorded elevated concentrations in some wells with a maximum concentration of 13.2% recorded in BH1301.

The gas flow rates recorded were negligible (<0.1 l/hr) in all boreholes suggesting that ground gases are not being generated in significant quantities.

Gas Screening Values (GSV) have been calculated for methane and carbon dioxide, in line with current CIRIA guidance. The GSVs indicate that the gassing regime within the site conforms to Characteristic Situation 1 and presents a very

low risk to the future development. For this situation gas protection measures are not required within new buildings.

5.6 Preliminary waste assessment

An indicative waste classification exercise was undertaken to provide information for the management of materials at the site. Made ground samples were tested for a range of inorganic and organic contaminants during the recent ground investigation and the online waste classification service HazWasteOnline was used to screen the results to identify those samples that may be classified as hazardous if offsite disposal is required. The online service classified material in line with current waste guidance, WM3. Once data is uploaded the service generates detailed reports containing the hazardous properties identified for each sample. These reports are presented in Appendix F.

5.6.1 Automatic Ballast Sampling assessment

Automatic Ballast Sampling (ABS) was carried out to investigate the construction and condition of existing track bed. The procedure for assessing the re-usability of the ballast is defined in NR/L3/ENV/044 [16].

15 ABS samples were analysed for the Network Rail ballast analytical suite which includes a limited metal suite, TPH, asbestos and other analytes that have been identified by risk assessment as potential contaminants – in this case PAH. HazWasteOnline was used to screen the results to identify those samples that may be classified as hazardous waste.

HazWasteOnline classification identified all of the ballast samples tested would be classified as non-hazardous waste.

5.6.2 Car park and station assessment

An indicative waste classification has not been undertaken for samples obtained from the proposed car park and station site as the earthworks strategy is still being developed and the volume of material which may require off-site disposal as waste is currently unknown. On the basis of initial earthworks assessments to inform pre-planning a net deficit of fill materials is anticipated and the volumes of material requiring off-site disposal are likely to be small. Once the earthworks strategy for the site has been developed it is recommended that the requirement for waste classification assessment on materials from the proposed car park and station site be revisited.

5.7 Concrete aggressivity

Contaminants such as sulphate and acidic conditions generally present a low risk to human health but can result in degradation of buried concrete. The chemical environment for concrete has been assessed following the guidance outlined in BRE Special Digest 1 [14].

The design sulphate (DS) and aggressive chemical environment for concrete (ACEC) classes were assessed assuming that the site was classified as non-pyritic brownfield with mobile groundwater. A summary of the assessment results is provided in Table 33.

Table 33: Summary of concrete aggressivity assessment

Strata	Characteristic pH	Characteristic sulphate (mg/l)	Design sulphate class	ACEC class
Made ground	6.3	20	DS-1	AC-1
Superficial Deposits	6.4	20	DS-1	AC-1
Bedrock	6.2	60	DS-1	AC-1

6 Geoenvironmental risk assessment

6.1 Introduction

The screening assessments for the receptors identified in the conceptual site model have identified residual risks at the proposed site. Based on the proposed redevelopment and the plausible pollutant linkages identified in the conceptual site model, these residual risks have been assessed. The risk classifications of Very Low, Low, Moderate or High risk have been based on the CIRIA guidance C552 [17]. A brief description of each is provided below:

- High Risk - There is a high probability that severe harm could arise or is occurring to a designated receptor from an identified hazard. Urgent investigation (if not undertaken already) is required and remedial works may be necessary;
- Moderate Risk - It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Investigation (if not already undertaken) is normally required to clarify the risk. Some remedial works may be required in the longer term;
- Low Risk - It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild;
- Very Low Risk - There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be significant.

In addition to the risk classifications within the CIRIA guidance, a Negligible risk rating has also been used within the assessment where no plausible pollutant linkage exists.

6.2 Human health

6.2.1 Construction phase

There is a potential risk to construction workers who may come into direct contact with contaminated soils, particularly during earthworks. However, exposure periods are generally shorter than those experienced by long term site users and can usually be reduced to an acceptable level through adoption of adequate health and safety procedures.

Asbestos was not identified in any of the soil samples tested. However, asbestos may be present (as yet undetected) and it would be prudent to proceed assuming it still poses a potential risk during earthworks and construction works where soils are disturbed, as this may allow fibres to be released into ambient air. Appropriate good practice measures should be applied to protect construction workers and site neighbours and should be designed and implemented by a competent contractor.

Mitigation measures should include as a minimum dust suppression and appropriate PPE.

If the mitigation procedures described above are implemented during construction it is assessed that the risk of harm to construction workers and neighbours will be **Very Low**.

6.2.2 Operational phase

The concentrations of all contaminants measured during the ground investigation in soil were below values that might be regarded as posing a risk to future users of the proposed station and car park.

The proposed site use means that there is little potential that site users will come into contact with the soils on site. The results indicate that the existing soils within the site are chemically suitable for reuse as part of the development. If soft landscaping areas are proposed then a validated clean topsoil and subsoil will be required, it is possible that some of this material could be site-won.

Consequently, the risks from dermal contact with made ground soils, ingestion of site made ground and inhalation of made ground soil or dust vapour to future site users is **Very Low** and that no specific remediation is likely to be required with respect to the protection of human health.

6.3 Controlled waters

Limited groundwater was encountered during the ground investigation. The lack of superficial deposits between the made ground deposits and sandstone within the proposed station and car park site may permit migration of leachable contaminants into the underlying principal aquifer. However, no significant contamination which could be considered to pose a risk to groundwater was recorded within the made ground soils beneath the site. The proposed station and car park development will predominantly comprise buildings and hardstanding which will minimise infiltration.

Consequently the risks to controlled waters from the proposed development are considered to be **Very Low**.

It is understood that new buildings and structures will be constructed using shallow foundations. If piled foundations into the sandstone are proposed for any new structures a pathway between the made ground and the principal aquifer may be established through piling operations. However, due to the limited presence of significant contamination and absence of a low permeability layer above the principal aquifer, the risk of piling operations creating a pollutant pathway is deemed to be low.

Infiltration drainage may be incorporated into the drainage scheme for the development. This will be confirmed as part of the next design stage where further assessment will be undertaken to confirm the design. The drainage system will incorporate control measures (e.g. petrol interceptor) to prevent migration of any pollutants into the sandstone bedrock which will be assessed as part of the design.

6.4 Ground gas

A potential pollutant linkage exists between ground gas generating soils and future users of the proposed station building, if gas can flow or permeate through building envelopes and accumulate within enclosed spaces. None of the soils encountered have potential to generate significant flows of hazardous gases. Gas monitoring undertaken at the site to date indicates that the gas regime would be classified as Characteristic Situation 1 and therefore ground gas protection measures in new buildings on the site will not be required. The risk from ground gases based on the monitoring results is therefore assessed to be **Very Low**.

6.5 Construction materials

The BRE assessment did not identify any elevated sulphate concentrations within made ground on site which could pose a potential risk to buried concrete. It is considered that all buried concrete at the development site should be designed in accordance with DS-1 and AC-1.

7 Outline remediation strategy

This section presents an outline remediation strategy for the proposed works. Detailed contractor's method statements will need to be prepared prior to commencing works on site. An options appraisal has not been undertaken as the mitigation measures are intrinsic to the development design or relate to site management, as described below.

7.1 Excavated materials management

The scheme includes significant earthworks cut and fill in the car park area. The most sustainable approach is to reuse materials onsite during the development and minimise offsite disposal. This includes materials resulting from the demolition of the existing buildings and excavated soils.

The risk assessments indicate excavated soils are chemically suitable for reuse where needed in the development. A Materials Management Plan (MMP) prepared in accordance with the CL:AIRE Definition of Waste Code of Practice (CL:AIRE DoWCoP) would enable excavated materials to be reused within the development and avoid the material being considered as waste.

The CL:AIRE DoWCoP requires a validation report is produced confirming the location, quantity and suitability of material reused. No visibly contaminated or odorous material should be reused.

If excavated material cannot be reused on site (for example geotechnically unsuitable or surplus to requirements) it may be possible to treat the soil to make it suitable for reuse, reuse the material on another project (with consideration of waste regulatory requirements) or as a least preferred option, offsite disposal to soil treatment facility or landfill.

7.2 Imported material

If any import of soils is proposed the material must be confirmed as geotechnically and chemically suitable. If the imported material is potentially a waste the regulatory mechanism for the material import must be clearly defined (e.g. CL:AIRE DoWCoP).

The testing regime for imported material must be defined. Typically imported materials from brownfield sites should be tested at a frequency of 1 sample in 50m³. If the source desk study confirms a greenfield source, and no environmental incidents on the site of origin, then it is considered that the testing frequency for imported material can be reduced (e.g. 1 per 500m³).

7.3 Unforeseen contamination

Grossly contaminated materials are not expected to be encountered at the site. However, on any brownfield site there is the possibility that unforeseen contaminated material may be encountered during excavation works. Care should

be taken during ground works and excavations should be supervised to ensure any previously unforeseen contamination is appropriately managed.

Any material which is identified as potentially contaminated (for example by visual appearance or odour) should be delineated and samples taken for chemical analysis by an Environmental Scientist. The samples should be compared to the soil assessment criteria to determine the suitability of this material for use within the development.

7.4 Buried structural concrete

It is recommended that buried concrete is specified to meet design sulphate class DS-1 and ACEC AC-1.

7.5 Liaison with regulatory authorities

A contaminated land planning condition may be applied to the planning consent, typically requiring investigation, risk assessment and remediation strategy to be approved prior to the commencement of development. This report has been produced in anticipation of such a condition. The planning consent may also include a condition requiring the works be implemented in accordance with the remediation strategy and a validation report be approved prior to occupation of the development.

The need for regulator consultation and decision should be considered in the programme and sufficient time allowed.

7.6 Remediation implementation

Detailed contractor's method statements should be prepared prior to commencing works on site in accordance with this Remediation Strategy and including the following content:

- Environmental protection measures (including water management and dust suppression)
- Health and safety management
- Stockpile management
- Material reuse proposals (if required, with reference to CL:AIRE DoWCoP)
- Confirm material reuse validation criteria and testing frequency (if required)
- Waste management proposals (off site soil disposal, if required)
- Imported soil proposals (if required)
- Proposals for addressing unforeseen contamination
- Buried concrete classification
- Potable water supply pipe requirements
- Validation plan (see below).

7.7 Validation and reporting

Evidence that the works have been undertaken in accordance with this Remediation Strategy and the method statements should be collected by the contractor during the works. A validation report should be prepared including the following, as a minimum:

- Photographic records and details of any below ground infrastructure removed
- Records of environmental protection measures implemented
- Results of validation testing compared to validation criteria
- Records of earthworks including photographs
- Details of any unexpected contamination encountered
- Material reuse records
- Offsite surplus soil disposal records
- Environmental regulator communications

This information should be compiled into a validation report by a suitably qualified environmental scientist at the end of the works.

8 Key development considerations

This section outlines the main areas of geotechnical design associated with the project and provides a description of the relevant geotechnical risk and recommended approach for the management of these. It is intended to assist with the development of specific solutions to address these risks in latter design stages and support the preparation of the Approval in Principle documents at GRIP stage 4.

8.1 Rail corridor

8.1.1 General ground and groundwater conditions

Made ground deposits present along the rail corridor typically comprise a layer of ballast, underlain by granular track bed material and for the majority of the project extent embankment fill.

The ballast encountered was described as dirty or very dirty ballast. The granular track bed material was on average 0.7m thick and comprised a layer of ashy fill (sandy gravel) over a gravelly sand layer. In most locations the embankment fill comprises cohesive material (sandy gravelly silty clay).

Glacial Till, comprising cohesive and granular deposits, was encountered in the majority of exploratory holes undertaken within the rail corridor cutting (from 750 to 1500m and from 2525 to 2600m), and in its proximity, at the crest and toe of embankment (from 1500 to 2225m). Reported depths ranged from 0.6m to 4.7m with the base of the strata proven in all locations.

Sandstone bedrock was encountered at depths ranging from 0.25m to 4.5m below ground level and typically described as weathered reddish brown sandstone. Sandstone was generally encountered at a depth greater than 2m, however in exploratory holes between 1150 to 1400 and 2300m it was reported at shallow depth (<1m).

Pitching stones were encountered at shallow depth underneath the ballast within the Kirby station area west of OB57 (~850 to ~1050). The exact limits of the pitching stones has not been defined but they were not encountered in holes undertaken at ~750m and 1150m.

Very limited perched groundwater was encountered with the exploratory holes undertaken during the ground investigation. Where encountered groundwater monitoring in the sandstone recorded water levels at approximately 1.4 – 2.5m depth. It is anticipated that the main groundwater body lies at a considerable depth below ground level.

8.1.2 Impact on existing earthworks

Some embankment widening to accommodate the proposed track alignment will be required. The extent will be assessed during design development in GRIP stage

4 and will be a function of the rail corridor width required to accommodate access routes, position of safety, cabling in addition to the tracks.

It is anticipated that cess retention will be required to facilitate embankment widening in some areas as widening by earthworks will not be practical for large sections of the site, due to vegetation cover on existing earthwork slopes and/or proximity of the Network Rail boundary to embankment toe.

Network Rail standard details for cess retention, utilising a king post retaining structure, are likely to be suitable for retained heights of up to 1m (subject to design). Retained heights greater than 1m may require anchoring (for example by soil nails) or the use of an alternative retaining structure (for example reinforced concrete stem wall) if widening by earthworks is not practical.

Where the proposed rail corridor is situated in areas of cutting it is anticipated that it will be possible to accommodate this within the existing cutting width without impacting on existing cut slopes. Some local regrading or low height retention may be required to accommodate lineside equipment, this will require further review during design development when lineside equipment locations are confirmed.

8.1.3 UB 55 (Bridge 55)

In order to accommodate the proposed track alignment works to UB55 are required. New foundations will need to be constructed to support the new eastern abutment and intermediate pier. Based on the ground conditions encountered the anticipated foundation solution is shallow pads bearing onto intact sandstone bedrock.

The interface between the new foundations and the existing substructure elements will require careful consideration (in particular for pier 2) to manage issues associated with differential settlement and to develop construction sequencing.

Further ground investigation will be required to inform detailed design. The ground investigation is required to investigate temporary works installed for the construction of UB55 adjacent to the east abutment and prove the depth of the underside of the existing foundation of the abutment. Further investigation is also recommended to provide rotary coring into the intact sandstone to understand rock strength for the bridge widening foundations.

8.1.4 Ancillary civils

Details of the specific locations of individual lineside infrastructure elements of the projects are to be confirmed. It is anticipated that these will include lineside equipment foundations (location cases, REB, etc) within the vicinity of Kirkby station. A limited number of signal structures will be required however the location of these is not currently known.

Based upon ground investigation information it is expected that the majority of locations will be suitable for application of standard detail foundations utilising shallow foundations bearing onto embankment fill or natural ground. However further assessment will be required during design development to confirm this.

For structures with significant lateral loading (for example signal structures) piled foundations may be more efficient particularly if located on areas of existing embankment or in areas where widening to accommodate the existing rail corridor is required to minimise loading on the widening solution.

8.1.5 Track bed and ballast re-use assessment

Automatic Ballast Sampling (ABS) was carried out to investigate the construction and condition of existing track bed. Waste classification identified all ballast samples tested (15No.) would be classified as non-hazardous waste. Which indicates that the ballast should be managed as non-hazardous ballast in accordance with the requirements of NR/L3/ENV/044 [16].

The suitability of existing track bed materials for use in the track bed for the proposed track alignment will be reviewed as part of the track design.

8.1.6 Geoenvironmental issues

The ground investigation did not identify any evidence of significant contamination within the soils in the rail corridor.

There is a potential risk to construction workers who may come into direct contact with contaminated soils, particularly during earthworks. However, these risks can be mitigated to an acceptable level through the adoption of adequate health and safety procedures and appropriate good practice measures including dust suppression and PPE.

The soil assessment indicates that soils are suitable for reuse within the site. A Materials Management Plan (MMP) prepared in accordance with the CL:AIRE Definition of Waste Code of Practice would enable excavated materials to be reused within the development and avoid the material being considered as waste.

It is considered that all buried concrete at the development site should be designed in accordance with DS-1 and AC-1.

8.2 Car park and station

8.2.1 General ground and groundwater conditions

Made ground was encountered in all off-line holes undertaken within the proximity of the proposed station and car park. Outside the extent of the former quarry reported depths to underside of made ground ranged from 0.5m to 2m bgl, typically 0.5m to 1.5m bgl, with the base of the strata proven in all locations.

Historical mapping shows a quarry within the car park area (north of Kirkby Brook). Ground investigation locations within the mapped extent of the former quarry reported made ground depths between 2m and 3.1m bgl, however the base of made ground was not proven in one location.

The underlying bedrock was encountered in all the locations undertaken within the proximity of the proposed station and car park. Depths to top of sandstone

ranged from 0.2m to 3.2m below ground level, typically within the range 0.8m to 3m. The base of sandstone was not proven with holes terminating 0.6m to 2.4m below rockhead level.

Limited perched groundwater was encountered with the exploratory holes undertaken across this area of the site during the ground investigation. Groundwater monitoring in the sandstone shows the water level to be similar to that seen during the fieldwork. It is anticipated that the main groundwater body lies at a considerable depth below ground level. There is a risk of encountering localised perched groundwater during construction activities.

Soakaway testing indicates the sandstone permeability (1.3 to 1.4×10^{-05} m/s) is likely to be suitable to enable infiltration drainage to be incorporated into the drainage scheme, although further assessment is required to confirm this and size any soakaways. Given the site end usage, control measures (for example a petrol interceptor) will be required to prevent migration of any pollutants into the sandstone bedrock and should be assessed as part of design development.

8.2.2 General earthworks

In order to form the proposed car park levels earthworks will be required. An earthworks volume assessment has not yet been undertaken however it is anticipated that the volume of cut will be greater than the volume of fill and as such there will be an earthworks deficit requiring net import of earthwork fill. It is recommended that any imported earthworks fill is granular in nature.

Based on the ground investigation trial pits (undertaken using a 5T excavator to depths up to 2.5m below rockhead and 0.5m below intact rockhead) it is anticipated that excavations for proposed car park level (up to 2m below existing ground level) should be possible with conventional plant.

Site won made ground and sandstone materials are both considered geotechnically suitable for re-use as general earthworks fill. Based on grading the made ground is anticipated to be suitable as a class 2 materials (general cohesive fill) and sandstone a class material (general granular fill).

Given the nature of site won materials earthwork gradients of 1 in 3 (vertical to horizontal) are considered appropriate. Steeper gradients may be achievable with selected site-won soils or imported granular fill.

Changes in proposed ground levels are proposed to be accommodated through earthwork slopes. As such retaining walls are not currently anticipated to be required, should this change during design development gravity or reinforced concrete stem walls, founded on weathered sandstone or competent made ground are likely to be suitable.

8.2.3 Station building and platforms

Given the anticipated loading of the station building and the relatively shallow bedrock, shallow pad foundations are likely to be the preferred foundation option to support the main structural loads. These would be founded on competent underlying sandstone bedrock.

Due to the variable nature of the made ground it is not recommended that ground bearing floor slabs are founded directly on to this material. However, if the existing made ground is removed to confirm the top of the underlying competent bedrock and replaced with compacted and validated engineered granular fill, the use of a ground bearing slab should be suitable.

The proposed station platforms will be relatively lightly loaded and as such shallow foundations based upon Network Rail standard details are considered to be appropriate. Dependent upon local ground conditions it is anticipated that it will be possible to found the majority of these on weathered sandstone bedrock. In areas where this is not practical bearing onto competent made ground or embankment fill materials should be appropriate.

8.2.4 Brook crossings

The proposed scheme includes a road bridge and two footbridge crossings over Kirkby Brook. The span and structural form for these is subject to design development. It is anticipated that wingwall structures will be required to accommodate the approach earthworks to the road crossing.

Shallow foundations on sandstone bedrock are likely to be the preferred foundation solution for the bridges over the brook. Dependent upon loadings and settlement criteria shallow foundations on competent made ground may be possible for the footbridge crossings. The northern abutment of the road bridge is close to the former quarry extents from historical mapping and as such rockhead may be locally deeper requiring a greater foundation depth.

Shallow foundations, founded on sandstone bedrock, are also considered suitable for the wingwalls associated with the approach earthworks for the road crossing. The form of construction for the wingwalls requires review but reinforced concrete stem walls or reinforced earth structures are considered to be suitable at this stage.

8.2.5 Headbolt Substation

An earthworks platform is proposed to accommodate a substation between the existing railway embankment and Kirkby Brook. In addition to earthworks to form the platform and approach ramp it is anticipated that retaining walls or reinforced soil structures or slopes (~2 to 3m high) will be required to avoid the substation platform encroaching into the maintenance easement associated with Kirkby Brook.

The requirement for structures to form the compound requires review but reinforced concrete stem walls or reinforced soil structures founded on sandstone are considered suitable options for the compound walls. Reinforced soil slopes may also be an option. High quality granular fill will be required for backfill to structures and for reinforced soil structures/slopes and will need to be imported to site.

There is a level difference between the substation platform and track alignment (~2.5m). The horizontal separation between platform and track alignment reduces

towards Headbolt station. In areas where an earthwork slope is not suitable a retaining wall will be required to accommodate the level difference. If a wall is required a reinforced concrete stem wall founded within the earthwork platform or a sheet piled retaining wall are considered the most likely options.

8.2.6 Geoenvironmental issues

The soil assessment identified that the existing made ground is unlikely to pose a risk to human health if reused within the final development. Exposure of construction workers to potentially contaminated soils should be controlled to be as low as reasonably practicable (ALARP). No soil remediation is likely to be necessary to protect the health of future site users.

The soil assessment indicates that soils may be chemically suitable for reuse within the site. A Materials Management Plan (MMP) prepared in accordance with the CL:AIRE Definition of Waste Code of Practice would enable excavated materials to be reused within the development and avoid the material being considered as waste.

If soft landscaping areas are proposed then a validated clean topsoil and subsoil will be required, it is possible that some of this material could be site-won.

Risks to controlled waters are considered to be low and limited perched shallow groundwater was recorded within the made ground beneath the site.

The ground gas risk assessment suggests that the gassing regime within the site conforms to Characteristic Situation 1 and therefore gas protection measures in new station buildings will not be required.

It is considered that all buried concrete at the development site should be designed in accordance with DS-1 and AC-1.

8.3 Further ground investigation

The ground investigation undertaken to date is considered appropriate to inform development of approval in principle designs for the scheme. Further ground investigation will be required to inform detailed design and is summarised below.

- **UB55** - ground investigation is required to provide further information on depth and strength of sandstone rockhead. Additional investigation to provide information on form of construction and founding depth to existing abutment and pier foundations and relict temporary works is recommended to inform design and construction sequencing.
- **Highway brook crossing & associated wingwalls** – additional exploratory holes at proposed abutment and wingwall locations are recommended to inform substructure, approach earthworks and retaining wall design. These should confirm depth and strength of sandstone rockhead and the extent of former quarry
- **Car Park and Station** – additional exploratory holes are recommended to provide further information to inform design of platform foundation and

associated retaining structures, earthworks modelling and substructure design for footbridge brook crossings. Investigation at the highway junction to confirm existing road pavement build-up should also be undertaken

- **Headbolt Substation** – exploratory holes to confirm ground conditions beneath the proposed substation platform and the composition of the adjacent existing embankment should be undertaken to inform design of earthworks and retaining structures associated with the proposed substation platform.
- **Embankment widening** – additional holes at the toe and crest of the embankment are required to provide more detailed information on the embankment composition and underlying natural ground. This will be used to inform design of cess retention/embankment widening, earthworks stability assessment and track bed design.
- **Supplementary track bed investigation** – additional exploratory holes are recommended to inform detailed track bed design. This should include targeted investigation to delineate the extent of pitching stones and shallow rock in the Kirkby station area. A typical hole spacing along the rail corridor of c.50m is recommended (across all phases of investigation).
- **Ancillary Civils** – for most locations it is anticipated that holes scoped for embankment widening and track bed design will provide sufficient information on ground conditions for ancillary civils sub-structure elements. The requirement for targeted investigation locations is anticipated to be limited but will require review during design development.

8.4 Geotechnical Risks

An extract from the CDM Designers Risk Assessment detailing the geotechnical and geo-environmental risks identified and their associated mitigation measures is included in Appendix G.

9 References

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Appendix A

Pre-Planning Application Drawings

Pre Planning Application Proposed Works

General Arrangement

170248-15854-ZZ-ZZZ-DRG-C-CV-023020 P01

Pre Planning Application Proposed Elevation

170248-15854-ZZ-ZZZ-DRG-C-CV-029001 P01

Pre Planning Application Cross Sections

170248-15854-ZZ-ZZZ-DRG-C-CV-029002 P01