

A1 Birtley to Coal House

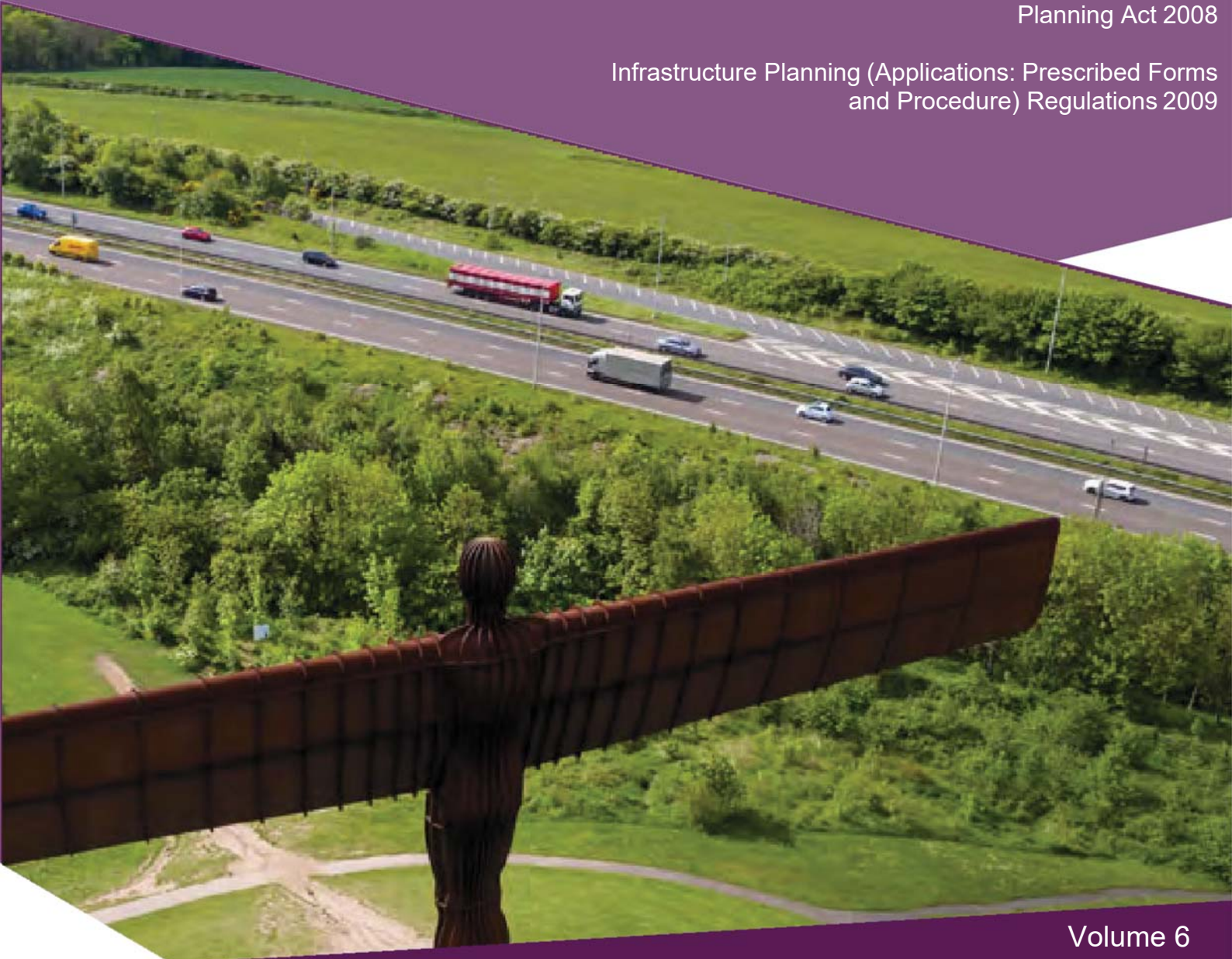
Scheme Number: TR010031

6.3 Environmental Statement – Appendix 9.3 Coal Mining Risk Assessment Report

APFP Regulation 5(2)(a)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms
and Procedure) Regulations 2009



Infrastructure Planning

Planning Act 2008

**The Infrastructure Planning
(Applications: Prescribed Forms and
Procedures) Regulations 2009**

**A1 Birtley to Coal House
Development Consent Order 20[xx]**

**Environmental Statement -
Appendix**

Regulation Reference:	APFP Regulation 5(2)(a)
Planning Inspectorate Scheme Reference	TR010031
Application Document Reference	TR010031/APP/6.3
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Version	Date	Status of Version
Rev 0	14 August 2019	Application Issue

TABLE OF CONTENTS

- 1. INTRODUCTION.....7
- 1.1 OBJECTIVE AND SCOPE OF THE ASSESSMENT 7
- 2. SOURCES OF INFORMATION USED TO INFORM THIS REPORT8
- 3. SCHEME OVERVIEW9
- 3.1 PROPOSED IMPROVEMENT WORKS..... 9
- 3.2 GROUND CONDITIONS 9
- 3.3 COAL SEAMS 10
- 3.4 MINE ENTRIES 11
- 3.5 OTHER MINING INFORMATION..... 12
- 4. ASSESSMENT METHODOLOGY13
- 4.1 GROUND MODEL 13
- 4.2 ASSESSMENT OF HISTORICAL SHALLOW MINING RISK..... 15
- 4.3 ASSESSMENT OF POTENTIAL MITIGATION MEASURES..... 16
- 5. RISK ASSESSMENT18
- 6. MITIGATION MEASURES.....22

TABLES

TABLE 1 - SUMMARY OF COAL SEAMS BENEATH THE SITE	10
TABLE 2 - SUMMARY OF MINE ENTRIES RECORDED WITHIN OR VERY CLOSE TO THE SCHEME.....	12
TABLE 3 - SUMMARY OF SECTIONS ADOPTED WITHIN THIS REPORT	13
TABLE 4 - SUMMARY OF RISK ASSESSMENT	18
TABLE 4 - SUMMARY OF MITIGATION MEASURES	22

APPENDICES

A P P E N D I X A REFERENCES AND GLOSSARY OF TERMS AND ACRONYMS

APPENDIX A-1 REFERENCES

APPENDIX A-2 GLOSSARY OF TERMS AND ACRONYMS

A P P E N D I X B CONSULTANTS COAL MINING REPORT

A P P E N D I X C DRAWINGS

A P P E N D I X D GEOLOGICAL SECTION

A P P E N D I X E

GEOLOGICAL MAPS

A P P E N D I X F

COAL AUTHORITY SEAM PLANS

A P P E N D I X G COAL AUTHORITY ABANDONMENT PLANS

A P P E N D I X H COAL AUTHORITY MINE SHAFT INFORMATION

A P P E N D I X I

COAL MINING RISK ASSESSMENT - SECTION 1

A P P E N D I X J

COAL MINING RISK ASSESSMENT - SECTION 2

A P P E N D I X K

COAL MINING RISK ASSESSMENT - SECTION 3

A P P E N D I X L

COAL MINING RISK ASSESSMENT - SECTION 4

A P P E N D I X M

COAL MINING RISK ASSESSMENT - SECTION 5

A P P E N D I X N

COAL MINING RISK ASSESSMENT - SECTION 6

1. INTRODUCTION

WSP has been commissioned by Highways England to undertake an assessment of the risks posed by historical coal mining to the proposed A1 road improvements between the Birtley Interchange (Junction 65) and Coal House Junction (Junction 67).

The aim of this report is to provide Highways England with a summary of pertinent available information on coal mining and provide an assessment of the potential coal mining related land stability and mine gas hazards that may affect the site.

1.1 OBJECTIVE AND SCOPE OF THE ASSESSMENT

The principal objective of this report is to present an interpretation of relevant recent, historical, archival and readily available information for the site and provide an assessment of the potential coal mining related land hazards that may affect it.

The scope of the works undertaken is as follows:

- Collate and review readily available information including geological, Coal Authority (CA) and site investigation data,
- Produce a ground model for the scheme focussing on the distribution of coal seams and recorded coal workings likely to affect the proposed improvement works;
- Assess the risks posed to the improvement works by historical mine working; and,
- Identify potential mitigation measures to reduce the risks to acceptable levels.

This report has made due reference to the guidance on assessing shallow coal mining risk in the following documents:

- CIRIA SPECIAL PUBLICATION 32, 'Construction over abandoned mine workings', 2002^[1];
- CIRIA C758, 'Abandoned mine workings'^[2], [as yet unpublished but Draft Chapters available]; and,
- The Coal Authority, 'Risk based approach to development management', Version 4 – 2017^[3].

The format of the document broadly follows the model report template provided within the Coal Authorities (CA's) '*Risk based approach to development management*'.

This report does not consider the mining risks from CH10000 to CH100320 where new signage is to be installed. Exploratory holes in this section were scoped out of the site investigation to reduce costs and is to be undertaken either during detailed design (Stage 5) or on a 'just-in-time' basis during construction (Stage 6). In addition, the positions of signage and gantries within the scheme have yet to be fixed and are not commented upon in this report. When their positions are fixed, this report should be revisited and the mining risk and potential mitigation measures identified for each structure.

2. SOURCES OF INFORMATION USED TO INFORM THIS REPORT

The following sources of information were reviewed as part of this assessment:

- British Geological Survey (BGS) geological maps and associated memoirs:
 - BGS 1:50,000 Sheet 20 (1989/1992), Newcastle;
 - BGS 1:50,000 Sheet 21 (1978), Sunderland;
 - BGS 1:10,000 NZ25NW (1982); and,
 - BGS 1:10,000 NZ25NE (1983).
- BGS information and datasets (including historical borehole logs) accessed through <https://www.bgs.ac.uk/>;
- Coal Authority (CA):
 - Mining information and datasets accessed through <http://mapapps2.bgs.ac.uk/coalauthority/home.html>;
 - Non-Residential CA Mining Reports 51000774297001 and 51000785025001 purchased in February 2015;
 - CA Seam Plans for NZ25NW and NZ25NE;
 - CA coal mining abandonment plans (catalogue references 11063, 11109 sheet info 5 of 11, 12509, 14445, D252, D270 and D1231);
 - CA additional coal mine entry data for shaft references 425558-016 and 427599-018, received in June 2017; and,
 - Consultants Coal Mining Reports (CCMRs) 51001862693001 and 51001885828001 purchased in July 2018.
- Existing information for the scheme from the Highways Agency Geotechnical data management System (HA GDMS) website, including various historical ground investigation records.
- Landmark Information Group Limited 'Envirocheck® Reports', including environmental datasheets and plans; as well as current and historical Ordnance Survey maps. (report references 61115198_1_1, October 2014; 62421084_1_1, November 2014; and 62421510_1_1, November 2014).
- WSP, '*Preliminary Sources Study Report – A1 Road Improvements: Allerdene Railway Bridge to Birtley Interchange*', HA544664-WSP-HGT-S01-RP-GE-0600-P-01Y, October 2015^[4].
- Central Alliance, '*Ground investigation factual report – A1 Birtley to Coalhouse*', HE551462-CAX-VGT-ZZ-RP-VG-00001 P3.0, September 2018^[5].

With the exception of the CCMR (Appendix B) and the ground investigation data from the site investigation undertaken in 2017 and 2018 presented in Central Alliance's Ground Investigation Factual Report^[5], all the information reviewed has previously been presented within the 2015 PSSR^[4] and this report should be read in conjunction with it.

3. SCHEME OVERVIEW

3.1 PROPOSED IMPROVEMENT WORKS

The proposed highway improvement works comprise the following:

- Approximately 2 km of dual three-lane all-purpose plus hard shoulders on the A1 mainline to the south of the existing alignment at Junction 67 (Coal House), a remodelled Junction 67, and new structures to carry the A1 over the East Coast Mainline high speed electrified railway.
- Upgrade from existing dual two-lane all-purpose provision to dual three-lane all-purpose plus associated improvements to connecting merge and diverge provisions from Junction 67 to Junction 65 (Birtley Interchange).

In order to deliver these improvements, the following works are anticipated to be required:

- Earthworks: Construction of new embankments to service the remodelled Junction 67 and realigned road on either side of the East Coast Mainline, alterations of existing earthworks including potential regrading or retention of cutting slopes;
- Excavations: e.g. for installation of foundations or installation of new / amendment of existing drainage;
- Foundations: e.g. for new bridge abutments, relocation and / or installation of signage, gantries, lighting columns etc. and amendment / strengthening works to existing structures (such as bridge structures);
- Retaining Structures: where required by the design of the remodelled alignment or in areas where regrading of existing slopes is not feasible; and,
- Pavement Design: alterations of the existing and installation of new areas of running surface / pavement.

The General Arrangement (GA) for the scheme is presented in Drawing HE551462-WSP-HGN-S1-X-Dr-CH-01001-01006 P08 in Appendix C. The GAs for the retaining walls are presented in Drawings HE551462-WSP-SBR-BR008-DR-S-0009, 0011, 0013 and 0014 P02 in Appendix C.

3.2 GROUND CONDITIONS

TOPOGRAPHY

From the north the A1 traverses the base of the River Team Valley, with natural ground elevations between circa 10 and 15 m above ordnance datum (AOD) and the existing carriageway generally being elevated above natural ground on embankments or existing structures (Kingsway Viaduct and Allerdene Railway Bridge). Ground levels then increase as the A1 traverses the eastern flank of the Team Valley, from circa 15 m AOD adjacent to Allerdene Railway Bridge to circa 85 m AOD at Junction 66 (Eighton Lodge), where the ground levels falls slightly (to circa 75 m AOD) before rising gently to 110 m AOD at the North Side Overbridge.

GENERAL

Ground conditions along the length of the scheme can be broadly split into two.

From Coal House (CH10320) to the Smithy Lane Overbridge (CH 11720), ground conditions are dominated by an infilled north to south trending Glacial Valley that forms the base of the Team Valley. Rockhead of the Pennine Middle Coal Measures (PMCM) falls from approximately 15 m below ground level (bgl) at the western extent (CH 10260) to circa 50 m bgl below the Kingsway

Viaduct (CH 10850), before rising again toward the Smithy Lane Overbridge. Within the infilled valley the drift geology predominantly comprises ‘*Glacial Lake Deposits: mainly laminated clays*’, with locally Made Ground and Alluvium at the surface and Glacial Till at the base.

Coal seams within the PMCM beneath this area are generally recorded to have a horizontal or sub-horizontal dip. A number of coal seams sub-crop (i.e. are present at rockhead beneath the overlying drift deposits) on the eastern (Smithy Lane Overbridge) side of the glacial valley, as rockhead cross-cuts the stratigraphy. Through the centre and east of the glacial valley the coal seams are displaced by faults, and only a single coal seam sub-crops on the western side.

From Smithy Lane Overbridge (CH11720) to Birtley (CH14170) the ground conditions typically comprise predominantly cohesive Glacial Till underlain by solid strata of the PMCM. South of Smithy Lane Overbridge an area of Made Ground associated with colliery spoil from the former Ravensworth Anne Pit is recorded.

A number of coal seams are present within the Coal Measures, generally dipping at a shallow gradient to the northwest below this section of the scheme. With the coal seams dipping at relatively shallow gradients, sub-crops are governed by topography and are generally recorded to the south and west of the scheme within the valley side. As ground levels fall from Eighton Lodge toward the Smithy Lane Overbridge, a number of these seams become shallower and sub-crop beneath the line of the A1.

The general distribution of strata along the length of the seam can be seen in the cross section presented on Drawing HE551462-WSP-HGT-BCH-DR-GE-0104 in Appendix C. Geological maps are presented in Appendix E.

3.3 COAL SEAMS

Many of the coal seams beneath the scheme are recorded to have been worked and a summary of the shallow seams and recorded working present beneath the site is given in Table 1. The mining information is taken from the CCMR in Appendix B and the CA abandonment plans presented in Appendix G.

Table 1 - Summary of Coal Seams Beneath the Site

Coal Seam	Standard NCB* Letter	Thickness** (m)	Recorded as worked by CA	Worked Thickness*** (m)	Year Last Mined
High Main (Locally splits into the Top and Bottom High Main)	E (E1 and E2)	1.50 – 2.50	No, but identified as ‘ <i>seam workable</i> ’	N/A	N/A
Metal	F1	0.40 to 0.90	No, but identified as ‘ <i>seam workable</i> ’	N/A	N/A
Five Quarter (Bottom Main)	F2	0.50 to 1.05	Yes, from Ravensworth Colliery	0.60	1935
Main (Yard)	G	0.60 to 1.90	Yes, from Ravensworth, unnamed,	0.60 to 1.90	1939

Coal Seam	Standard NCB* Letter	Thickness** (m)	Recorded as worked by CA	Worked Thickness*** (m)	Year Last Mined
			Blackhouse and Hallingwell Collieries		
Maudlin	H	0.45 to 1.85	Yes, from Ravensworth, Springwell and Blackhouse Collieries	1.10 to 1.52	1933
Durham Low Main (Brass Thill)	J	0.45 to 2.40	Yes, from Ravensworth Colliery	0.85	1935
Top Brass Thill (Bottom Low Main)	K	0.25 to 1.20	Yes, from Ravensworth, unnamed and Vale Collieries	0.91 to 1.50	1947
Hutton	L	0.9 to 2.10	Yes, from Ravensworth, unnamed, Blackhouse and Mountmoor Collieries	1.30 to 1.70	1947
Plessey	M	0.25 to 0.7	No	N/A	N/A
Harvey (Beaumont);	N	0.45 to 1.20	Yes, from unnamed and Ravensworth Collieries	0.50	1947

* National Coal Board

**Thickness based on BGS Geological Map NZ25NE

***Based on CA records

Mine abandonment plans (Appendix G) are interpreted to indicate that many of the workings feature total extraction (by panel working or longwall) rather than pillar and stall workings.

3.4 MINE ENTRIES

The CA reports indicate that fourteen recorded mine entries lie within the vicinity of the scheme, of which thirteen are between Allerdene Railway Bridge and the Birtley Interchange and one between Coal House and the Allerdene Railway Bridge.

Three shafts are recorded to be located within or very close to the scheme boundary. Additional information (Appendix H) was obtained from the CA for two of these by Highways England. Details for the three shafts are summarised in Table 2.

Table 2 - Summary of Mine Entries Recorded within or Very Close to the Scheme

CA Mine Entry ID	Co-ordinates		Name	Treatment Details in CA Report	Other details
425558-016	425799	558233	Nanny Pit	Filled in 1951 to an unknown specification. A 1m thick concrete plug was placed 3m below the surface in 1952. In 1986, as part of the A69 Eighton Lodge Road Junction improvement, consulting engineers Mott Hay & Anderson constructed a 4.35m x 4.35m x 0.4m reinforced concrete cap on top of the concrete plug	Shaft depth from 58.52m AOD to the Five Quarter Seam Shaft diameter of 2.5m
427556-018	427800	557000	Moor Inn Pit	No Treatment Details. Owned by: J.B.Bellerby, S.Storey and M.P.Knight	Shaft depth unknown. Shaft diameter unknown
428556-004	428159	556547		Filled during 1967. Details unknown	-

3.5 OTHER MINING INFORMATION

In addition to the information presented above, the CA information reviewed also identifies that:

- No remedial sites are located within 50 m of the site;
- The CA has not received any damage notice or claim for any property within 50 m of the site since 31st October 1994;
- No mine gas or mine water treatment schemes are recorded within 500 m of the sites limits.
- The site is not in an area where the CA has granted a licence, or is determining whether to grant a licence to remove coal using underground methods;
- The site is not in an area likely to be affected at the surface by any planned future workings. However, reserves of coal do exist in the local area that could be worked at some point in the future; and,
- No open cast mines are recorded within 500 m of the site's boundaries.

It is understood from correspondence and consultation with the CA that there is currently a study underway to assess the potential changes to groundwater if regional mine water pumping was to cease/be switched off within the Gateshead area. The impact of this on groundwater levels and their effect on the scheme is to be assessed as part of a report being commissioned from the CA by Highways England. At the time of writing the report is not available, so the potential impact of these changes on coal mining risk has not been considered within this report.

4. ASSESSMENT METHODOLOGY

4.1 GROUND MODEL

In order to consolidate all the different sources of data into one location, a three-dimensional model was created in AutoCAD Civil 3D 2018. This model was used to superimpose the proposed improvement works onto the existing road alignment and incorporate geological, CA and ground investigation data to produce a ground model for the site. The ground model was then interrogated to assess the potential ground risks associated with known and potential historical workings within influencing distance/depth of the scheme.

To import information into the ground model, geological and CA data was digitised using Ordnance Survey (OS) coordinates to align the information to the base drawing. Where drawings were not to OS Grid (e.g. CA Abandonment Plans), known fixed points (e.g. mine shafts) were identified and the drawings scaled and oriented such that they matched their recorded position on the base drawing. Abandonment plans with elevation levels given in feet below sea level were converted into metres AOD. Whilst some degree of inaccuracy may have been introduced by having to adopt this method due to scaling and transposition errors, spot checks of the data suggest that there is a reasonable consistency between the various data sources.

Ground investigation data were inputted into the model using Association of Geotechnical and Geoenvironmental Specialists (AGS) data files, with both historical and recent (2017 - 2018) exploratory hole data being imported using OS coordinates and elevations.

To aid the assessment and reporting of mining risk to the scheme, it has been split into six sections based on the distribution of geological strata and the nature of the proposed improvement works. The six sections adopted are shown on Drawing HE551462-WSP-HGT-DR-GE-00 in Appendix C and are summarised in Table 3.

Table 3 - Summary of Sections Adopted within this Report

Section	Chainage*	Main Improvement Works	Geology
1	CH10320 to CH10540 (220 m length)	<ul style="list-style-type: none"> Widening of existing embankments. Construction of concrete retaining wall. 	Drift deposits, deepening to the east from circa 15 to 40 m bgl. One shallow** coal seam sub-cropping with no recorded workings.
2	CH10540 to CH11000 (460 m length)	<ul style="list-style-type: none"> Widening of existing embankments. Widening of existing slip road embankments. Widening of Kingsway Viaduct. Construction of reinforced concrete, reinforced earth and bored pile retaining walls. 	Deep (up to 45 m) drift deposits with recorded workings within the underlying PMCM strata.

Section	Chainage*	Main Improvement Works	Geology
3	CH11000 to CH11680 (680 m length)	Two options are being considered: Option 1 <ul style="list-style-type: none"> Construction of carriageway on new embankments supported by rigid inclusion ground improvement and a load transfer platform / distribution mat. Construction of a new Allerdene Railway Bridge. Option 2 <ul style="list-style-type: none"> Construction of carriageway on a new viaduct incorporating the new Allerdene Railway Bridge. Construction of new viaduct approach embankments supported by rigid inclusion ground improvement and a load transfer platform / distribution mat. 	Deep drift deposits, shallowing to the east, with faulted PMCM strata containing a number of shallow coal seams, some of which are recorded as having been worked.
4	CH11680 to CH12500 (820 m length)	<ul style="list-style-type: none"> Widening of embankments. Widening of cuttings., Widening of at grade sections. 	Shallow drift deposits with a number of shallow coal seams sub-cropping beneath the line of the carriageway as it rises up toward Eighton Lodge.
5	CH12500 to CH13400 (900 m length)	<ul style="list-style-type: none"> Widening of embankments: Widening of cuttings. Widening of existing underbridges at Eighton Lodge. 	Shallow drift deposits with one coal seam sub-cropping beneath the scheme and a number of underlying shallow seams.
6	CH13400 to CH14710 (1410 m length)	<ul style="list-style-type: none"> Widening of embankments. Widening of cuttings. Widening of at grade sections. Extension of the Long Bank Bridleway Underpass. Replacement of the North Dene Footbridge. Construction of king post retaining wall. 	Shallow drift deposits with a number of shallow seams underlying the scheme.

*All chainages relate to the main carriageway

** Note: within this report, 'shallow seams' refer to seams that may be located within influencing distance of rockhead, rather than their depth below ground level (bgl), which is influenced by the thickness of overlying superficial deposits.

A long section down the centreline of the proposed improvement works was cut through the ground model and is presented in Drawing HE551462-WSP-HGT-BCH-DR-GE-00104 in Appendix D. It should be noted that in places the coal seams within the long section do not

exactly match the recorded coal seams shown on the boreholes sticks. This can be as a result of the boreholes being located off the centre line of the road and the dip of the strata causing the coal seam to appear either higher or lower than its modelled position on the centre line.

The strike, dip angle and throw of the faults is based on a combination of geological and CA records. Given the potential inaccuracies within the mapping and transposition of the CA data, the location, strike, dip angle and throw on these faults should be viewed with an appropriate level of caution.

It should be noted that the identification of coal seams and historical workings on borehole logs can be difficult, especially where the boreholes have been formed using rotary open hole techniques. Zones of 'core loss' or 'no recovery' can be indicative of workings, but may also be due to coal or soft stratum being lost into the drilling flush during drilling. Comments on drillers logs can be subjective and, without full drilling information (e.g. loss of flush, drill torque, penetration rate), their observations can be open to interpretation. A suitable degree of caution should therefore be used when considering the findings of this report, especially where there is limited data over a long length of the scheme.

4.2 ASSESSMENT OF HISTORICAL SHALLOW MINING RISK

The assessment of mining risk for specific sections and elements of the scheme is based on a number of factors, including:

- The depth and thickness of coal seams recorded in exploratory holes, including the rock cover above the seam;
- The recorded presence of voids or backfilled historical workings in exploratory holes;
- The presence of CA recorded mineworkings within the seam in the section being considered and in adjacent sections;
- The type of mineworkings suggested on the CA abandonment plans (e.g. total extraction or pillar and stall workings);
- The presence of shafts; and,
- The position of coal subcrops relative to the scheme and their dip and strike.

In assessing the mining risk associated with ground instability, the following categories have been adopted:

- Very Low** The evidence suggests that there is a low likelihood of open workings being present at a shallow depth and the likelihood of unrecorded features leading to surface or ground instability is also low (i.e. no mitigation is required); or
- The mitigation measures recommended, when implemented, result in a very low risk of an unacceptable degree of ground movement / failure of the carriageway or structure should surface or ground instability occur.
- Low** There is no particular evidence of shallow workings being present and, should unrecorded workings be present, there is a low likelihood that these could cause ground instability.
- Medium** There is some evidence for shallow workings which, under some circumstances, may lead to ground instability; or, foundations will be constructed close to shallow coal seams where insufficient evidence is available to discount the risk of shallow workings.
- High** There is significant evidence for workings being present and there is a high likelihood that these could lead to ground instability affecting the scheme.

In considering the risk of void migration above any workings, reference has been made to the guidance included with CIRIA SPECIAL PUBLICATION 32, 'Construction over abandoned mine workings', 2002 ^[1] and CIRIA C758, 'Abandoned mine workings' ^[2] (as yet unpublished). Where the ratio of competent rock cover to seam thickness is considered to be greater than 10 : 1 then the risk of void migration reaching rock head, and hence the risk of ground instability to the proposed scheme, is considered to be Low. Where the ratio is considered to be between 10 : 1 and 5 : 1 the risk is considered to be medium and where the ratio is considered to be less than 5 : 1 the ratio is considered to be High. No distinction has been made at this stage for the nature of the rock strata overlying any workings due to the current lack of sufficiently robust data to enable a detailed assessment of its effect on void migration.

Additionally, no distinction has been made to account for the variable thickness of drift above rock head, although it is acknowledge that a void migrating to rock head would cause a different surface expression of subsidence depending on drift type and thickness. Where drift is very thin, such a void may express at the surface as a crown hole whereas, where drift is particularly thick, any subsidence would most likely propagate through the drift and result in a wider shallow settlement trough.

It should be noted that where the risk is identified as Low, Medium or High, some degree of mitigation is recommended, with the distinction between these categories determined by both the perceived likelihood of a mining related hazard being present and the severity of the potential impact on the scheme should this occur.

It should be noted that this risk assessment does not specifically consider the risks posed to the existing highway by shallow workings beneath the existing earthworks, carriageway and structures, albeit that these risks are likely to be similar to those for the improvement works in the same geographical area.

In assessing the mining risk associated with mine gas, the following categories have been adopted:

- Very Low** There are no records of mine gas issues (CA records or recorded during drilling), no evidence of shallow coal workings and no intrusive construction works (e.g. piling) are proposed; or, the suggested mitigation measures result in a very low risk of hazardous mine gas accumulations or migration from the site.
- Low** There are no records of mine gas issues (CA records or recorded during drilling) and no evidence of shallow coal workings, but intrusive construction works (e.g. piling) are proposed.
- Medium** There is mine gas recorded (CA records or recorded during drilling) and / or evidence of shallow coal workings, but no intrusive construction works (e.g. piling) are proposed.
- High** There is mine gas recorded (CA records or recorded during drilling) and / or evidence of shallow coal workings, and intrusive construction works (e.g. piling) are proposed.

Assessment of mine gas risks has been included to be enable consideration of future risks for drilling into coal seams or workings, seams susceptible to spontaneous combustion, choice of drill flush etc and to be consistent with the Coal Authority recommended scope for Coal Mining Risk Assessments.

4.3 ASSESSMENT OF POTENTIAL MITIGATION MEASURES

Any assessment of appropriate mitigation measures is dependent on the risk owner's attitude toward risk. It needs to balance the probability of a risk being realised and the likely impact of it

should it occur (including financial, health and safety, reputational, social) against the cost and practicality of removing or reducing the probability of the risk being realised.

Potential mitigation measures have been suggested which are considered proportionate to the perceived risk and the impact it would have should it be realised. However, other options may be available which offer a greater degree of certainty but are associated with increased cost or construction / programme impacts. In addition, measures that could give greater certainty regarding the actual risk, or provide an increased level of safety should a risk be realised (e.g. areas of potential shallow workings are not investigated / treated but measures are put in place to minimise the impact should a failure occur) are suggested.

It should be noted that any mitigation intervention will need to consider any potential increase in risk to existing highways / railway lines / structures. Any such risk will need to be taken into consideration during detailed design of the mitigation measures, such that the risk is managed appropriately (e.g. use of grout curtains, low injection pressure, water flush drilling, close control on grout takes, monitoring and observation of adjacent structures etc.).

It should be noted that the mitigation measures being proposed in this report are restricted to the new build elements of the scheme and are not intended to address any existing coal mining risks posed to the existing highway. Whilst no records have been reviewed that suggest there have been mining related issues to the highway within this scheme, it is worth noting that during the widening of the A1 Northbound carriageway between Coal House and Metro Centre in June 2016, a known shaft located beneath the existing carriageway collapsed. This resulted in the carriageway being closed for 4 days between the problem being identified and remedial treatment being completed. Management of the risk to the improvement works will not reduce the risk to the existing highway.

5. RISK ASSESSMENT

The coal mining risk assessments for Sections 1 to 6 are provided in Appendices I to N respectively. This includes the source data used, geological map extracts, relevant CA abandonment plans, exploratory hole locations plans, the interpretation of ground conditions, and a geological section taken through the ground model. The findings of the risk assessments are summarised in Table 4 and on Drawings HE551462-WSP-HGT-BCH-DR-GE-00097 to HE551462-WSP-HGT-BCH-DR-GE-00104 in Appendices I to N.

An additional set of drawings has been produced which shows a simplified approach to the coal mining risk, by way of hazard zoning based purely on the ratio of competent rock cover to coal seam thickness, indicated on Drawings TBC in Appendix TBC. These show areas where this ratio is considered to be greater than 10 : 1, between 10 : 1 and 5 : 1 and less than 5 : 1. Where more than one coal seam is expected with less than 10 : 1 ratio, the most onerous condition is indicated. Note that due to complexity of the scheme the simplified assessment indicated on those drawings does not take into account the distinction between earthworks, structures (piled or otherwise), any expected changes in ground level, or whether the various sources of evidence (records / boreholes) indicate the seam is worked at that location, and as such must be used as a general indicator only, to be used in conjunction with the detailed assessments presented in this report. These drawings may also be useful in a preliminary consideration of coal mining risks to the existing carriageway, which is not specifically addressed in this report.

Table 4 - Summary of Risk Assessment

Section	Assessed Overall Mining Risk	Reason	Limitations
1	Earthworks and Carriageway – Low Structures – Low Mine Gas – Low	<ul style="list-style-type: none"> One shallow coal seam (Hutton L) sub-crops beneath the section but is shown to be unworked. The CA does not identify the sub-crop as an area of probable shallow mineworkings. The CA records show recorded workings in the Seam (Hutton L) abandoned to the west of the section due to a washout. There are no recorded mineshafts within the improvement works. The depth to the sub-crop is circa 30m, suggesting that incidental coal extraction is unlikely. No deep foundations are anticipated as part of the improvement works. There are no records of mine gas issues, but recorded shallow workings (in the Hutton L seam) within close proximity to the site (30m to the west). No intrusive construction works likely to intersect coal seams / potential workings are proposed. 	<ul style="list-style-type: none"> No deep boreholes undertaken to investigate for presence of un-worked coal*. Assumes accuracy of CA records.

Section	Assessed Overall Mining Risk	Reason	Limitations
2	<p>Earthworks and Carriageway – Very Low</p> <p>Structures – Very Low and Low</p> <p>Mine Gas – Low and High</p>	<ul style="list-style-type: none"> • CA abandonment plan suggests total extraction of the Harvey coal seam. • No evidence of voids or coal identified at anticipated depth of Harvey (N) seam. • Greater than 10 times seam thickness of rock expected between recorded level of workings in the Harvey (N) seam and the anticipated toe of piles** for structures. • Greater than 10 times seam thickness of rock expected between recorded level of workings in the Harvey (N) seam and rockhead below widened embankments and retaining walls. • No recorded mineshafts within the improvement works. • No records of mine gas issues but recorded shallow workings beneath the site. • Intrusive construction works (piling) to be undertaken. 	<ul style="list-style-type: none"> • Assumes pile rock socket less than 5m**. • Deep boreholes advanced through recorded depth of mineworkings via rotary open hole techniques.
3 Option 1	<p><i>Option 1 (Embankment and Bridge)</i></p> <p>Earthworks and carriageway – Low</p> <p>Structures – High</p> <p>Mine Gas – Low and High</p>	<ul style="list-style-type: none"> • Several worked seams (H,J,K & L) recorded at shallow depth beneath rockhead. • 2.5 m thick coal seam and 3 m high voids recorded in exploratory holes. • Significant structures to be constructed as part of the improvement works, including interaction with sensitive third party assets. • Less than 10 times seam thickness of rock expected between recorded level of workings and the toe of piles for structures**. • Less than 10 times seam thickness of rock expected between recorded level of workings and rockhead. • No recorded mineshafts within the improvement works. • Earthworks to be constructed on rigid inclusion ground improvement and a load transfer platform / distribution mat. • Mine Gas recorded during drilling and shallow workings present. 	<ul style="list-style-type: none"> • Area is faulted and position, dip and throw of faults may not be accurately defined.

Section	Assessed Overall Mining Risk	Reason	Limitations
		<ul style="list-style-type: none"> Intrusive construction (piling) to be undertaken. 	
3 Option 2	<p><i>Option 2 (Viaduct and Bridge)</i></p> <p>Earthworks and carriageway – Low Structures – High Mine Gas – Low and High</p>	<ul style="list-style-type: none"> Several worked seams (H,J,K & L) recorded at shallow depth beneath rockhead. 2.5 m thick coal seam and 3 m high voids recorded in exploratory holes. Significant structures to be constructed as part of the improvement works, including interaction with sensitive third party assets. Less than 10 times seam thickness of rock expected between recorded level of workings and the toe of piles for structures**. Less than 10 times seam thickness of rock expected between recorded level of workings and rockhead. No recorded mineshafts within the improvement works. Mine gas recorded during drilling and shallow workings present. Intrusive construction (piling) to be undertaken. Earthworks to be constructed on rigid inclusion ground improvement and a load transfer platform / distribution mat. 	<ul style="list-style-type: none"> Area is faulted and position, dip and throw of faults may not be accurately defined. Small number of deep boreholes undertaken outwith the footprint of Allerdene Railway Bridge. Additional ground investigation will be required if this option is progressed through detailed design.
4	<p>Earthworks and Carriageway – Medium Structures – N/A Known shaft – Low Mine Gas – Low</p>	<ul style="list-style-type: none"> Shallow seams present and sub-crop within the section. No recorded workings within shallow seams. No evidence of workings or voids recorded in boreholes within shallow coal seams. Known mine shaft (Nanny Pit) has previously been capped and filled. No records of mine gas issues. Deep intrusive construction works (e.g. piles) if proposed may intersect coal seams / potential workings, although proposed works at this stage restricted to shallow earthworks only. 	<ul style="list-style-type: none"> Small number of boreholes taken into rock to investigate shallow coal seams*.
5	<p>Earthworks and Carriageway – Low and Medium</p>	<ul style="list-style-type: none"> Shallow seams are present beneath the section. Borehole evidence of workings or voids recorded within shallow coal seams. 	<ul style="list-style-type: none"> Small number of boreholes taken into rock to investigate shallow

Section	Assessed Overall Mining Risk	Reason	Limitations
	Structures – Medium and High Mine Gas – Low and High	<ul style="list-style-type: none"> No recorded mineshafts within the improvement works. No records of mine gas issues but recorded shallow workings beneath the site. Intrusive construction works (piling) to be undertaken. 	coal seams outwith Eighton Lodge*.
6	Earthworks and Carriageway – Low and Medium Structures – Low and High Known shaft - Low Mine Gas – Low, and High	<ul style="list-style-type: none"> Shallow seams are present beneath part of the section at depths of around 5 times seam thickness below rockhead. No evidence of workings or voids recorded within shallow coal seams beneath the section. Less than 10 times seam thickness of rock expected between shallow coal seams and the toe of piles for structures**. Recorded mineshafts within the vicinity of the improvement works. No records of mine gas issues and no recorded shallow workings beneath the site. Intrusive construction works (piling) to be undertaken. 	<ul style="list-style-type: none"> Small number of boreholes taken into rock to investigate shallow coal seams*. Assumes piles will have a rock socket of less than 5m.

*The number of rotary boreholes to investigate shallow coal seams was reduced to bring 2017 / 2018 ground investigation with Highways England's budget. The number and spacing of exploratory hole positions away from the major structures (Kingsway Viaduct, Allerdene Railway Bridge and Eighton Lodge) is therefore less than optimal to assess the risk of shallow workings with a high degree of confidence.

** The anticipated depth of proposed piles/foundations is based on the current preliminary design for the scheme (refer to associated structural Approval in Principal (AIP) reports for further information). This assessment should be revisited if the foundation depths vary significantly as the designs progress, particularly through detailed design.

6. MITIGATION MEASURES

Potential measures to mitigate / manage the potential risks identified for the different sections for Sections 1 to 6 are provided in Appendices I1 to N1 respectively. The identified measures are summarised in Table 4 and on Drawings HE551462-WSP-HGT-BCH-DR-GE-00097 to HE551462-WSP-HGT-BCH-DR-GE-00104 in Appendices I to N.

The implementation of the proposed mitigation measures requires further consideration by the Client, with commercial considerations balanced against acceptance of some residual risk to the network from mining hazards. Where the perceived risk is categorised in this report as *Medium* or *High*, it is considered that the proposed mitigation measures should be implemented to reduce the risk to *Very Low*. Where the risk is categorised in this report as *Low*, the proposed mitigation measures could be implemented if the Client considers it is desirable to reduce the risk to *Very Low* for that element of the scheme, taking commercial cost / benefit analysis into account.

Table 5 - Summary of Mitigation Measures

Section	Assessed Overall Mining Risk*	Proposed Mitigation
1	Earthworks and Carriageway – Low Structures – Low Ground Gas - Low	<p>The risk rating for earthworks and carriageway could be reduced to very low through one or more of the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary); or, • Incorporation of a high strength basal geogrid beneath new earthworks to control settlement in the case of surface movement due to the collapse of any unrecorded workings**. <p>The risk rating for structures could be reduced to very low through the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation to confirm the absence of shallow workings and treatment of any identified workings (as necessary); or, • Designing spread foundations (for small / minor structures) to be able to span a crown hole in the event of a shallow working collapse reaching the surface. <p>The risk rating for mine gas could be reduced to very low by undertaking gas monitoring in any excavations prior to man entry during construction or maintenance.</p>

Section	Assessed Overall Mining Risk*	Proposed Mitigation
2	<p>Earthworks and Carriageway – Very Low Structures - Low Ground Gas - High</p>	<p>The risk rating for structures could be reduced to very low through ensuring that the pile designer for the Kingsway Viaduct extension and bored pile wing wall takes into account the recorded workings in the underlying Harvey (L) coal seam within their design. Depending on pile type and toe depth, the impact on pile capacity of possible ground disturbance above the deeper workings (e.g. bed separation or fracturing) will need to be considered.</p> <p>The risk rating for mine gas should be reduced to very low by undertaking the proposed piling works in accordance with the Coal Authority Permit and HSE guidance^[6] and undertaking gas monitoring of any excavations or confined space prior to man entry.</p>
3 <i>Option 1</i>	<p>Option 1 - (Embankment and bridge)</p> <p>Earthworks and Carriageway – Low or Very Low Structures – High Mine Gas - High</p>	<p>The risk rating for earthworks and carriageway could be reduced to very low through one or more of the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary); or, • Incorporation of basal geogrid beneath new earthworks outwith the rigid inclusion ground improvement to control settlement in the case of the surface movement due to the collapse of unrecorded workings**. • Designing additional capacity into the rigid inclusions and load transfer platform/distribution mat combination to further increase its ability to tolerate minor ground movements resulting from any shallow working collapse. <p>The risk rating for structures should be reduced to very low through the following:</p> <ul style="list-style-type: none"> • Drilling and grouting of historical workings beneath piled foundations for the Allerdene Railway Bridge. Note: care will be required when drilling and grouting adjacent to the East Coast Mainline to minimise risk of heave or settlement. Careful control of the grouting operation and the monitoring of adjacent third party assets will be required (railway infrastructure, structures or services) including pre-works baseline monitoring; and, • Pile designer to ensure that the impact of treated shallow workings and shallow coal seams is allowed for within the pile design, by selecting conservative design parameters for coal strata or grouted workings. <p>The risk rating for mine gas should be reduced to very low by undertaking the proposed piling works in accordance with the Coal Authority Permit and HSE guidance^[6] and undertaking gas monitoring of any excavations or confined space prior to man entry.</p>
3 <i>Option 2</i>	<p><i>Option 2 (Viaduct and Bridge)</i></p>	<p>The risk rating for earthworks and carriageway could be reduced to very low through one or more of the following:</p>

Section	Assessed Overall Mining Risk*	Proposed Mitigation
	<p>Earthworks and Carriageway – Low and Very Low Structures – High Mine Gas - High</p>	<ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes beneath new earthworks outwith the viaduct to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary); or, • Incorporation of a high strength basal geogrid beneath any new earthworks outwith the rigid inclusion ground improvement in case of surface movement due to the collapse of unrecorded workings**. • Designing additional capacity into the rigid inclusions and load transfer platform / distribution mat combination to further increase its ability to tolerate minor ground movements resulting from any shallow working collapse. <p>The risk rating for structures should be reduced to very low through the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation beneath viaduct piers to confirm the presence or otherwise of shallow workings***; and, • Drilling and grouting of historical workings beneath piled foundations (Note: care will be required when drilling and grouting adjacent to the East Coast Mainline to minimise risk of heave or settlement. Careful control of the grouting operation and monitoring of the works and adjacent third party assets likely to be required); and, • Pile designer to ensure that the impact of treated shallow workings and shallow coal seams is allowed within the pile design. <p>The risk rating for mine gas should be reduced to very low by undertaking the proposed piling works in accordance with the Coal Authority Permit and HSE guidance^[6] and undertaking gas monitoring of any excavations or confined space prior to man entry.</p>

Section	Assessed Overall Mining Risk*	Proposed Mitigation
4	<p>Earthworks and Carriageway – Low Structures – N/A Known Mine shaft – Low Mine Gas - Low</p>	<p>The risk rating for earthworks and carriageway could be reduced to very low through one or more of the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary); or, • Incorporation of a high strength basal geogrid beneath new earthworks to control settlement in the case of the surface movement due to the collapse of unrecorded workings**. <p>The risk rating for structures could be reduced to very low through the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary). • Designing foundations (for small / minor structures) to be able to span crown hole in the event of a shallow working collapse reaching the surface. <p>The risk rating for the known mineshaft could be reduced to very low through a programme of intrusive probing and if necessary, grouting of the shaft backfill beneath the previously installed concrete plug and cap.</p> <p>The risk rating for mine gas could be reduced to very low by undertaking gas monitoring of any excavations and confined space prior to man entry.</p>
5	<p>Earthworks and Carriageway – Low and Medium Structures – Medium and High Mine Gas - Low</p>	<p>The risk rating for earthworks and carriageway should be reduced to very low through one or more of the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary); or, • Incorporation of high strength basal geogrid beneath new earthworks to control settlement in the case of surface movement due to collapse of any unrecorded workings**. <p>The risk rating for structures should be reduced to very low through the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary) below piled and spread foundations; and, • Designing spread foundations (for small / minor structures) to be able to span crown hole in the event of a shallow working collapse reaching the surface.

Section	Assessed Overall Mining Risk*	Proposed Mitigation
		<p>The risk rating for mine gas could be reduced to very low by undertaking the proposed piling works in accordance with the Coal Authority Permit and HSE guidance^[6] and undertaking gas monitoring of any excavations or confined space prior to man entry.</p>
6	<p>Earthworks and Carriageway – Low and Medium Structures – Low and Medium Known Mineshafts – Low Mine Gas - Medium</p>	<p>The risk rating for earthworks and carriageway should be reduced to very low through one or more of the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary); or • Incorporation of a high strength basal geogrid beneath new earthworks to control settlement in the case of the surface movement due to the collapse of unrecorded workings**. <p>The risk rating for structures should be reduced to very low through the following:</p> <ul style="list-style-type: none"> • Intrusive ground investigation by drilling a grid of boreholes to further assess the risk of shallow workings and treatment by grout injection of any identified workings (as necessary); or • Designing spread foundations (for small / minor structures) to be able to span a crown hole in the event of a shallow working collapse reaching the surface. • <p>The risk rating for known mineshafts could be reduced to very low if the location of the shafts were proven conclusively to be outside the influence distance of the proposed improvement works through intrusive investigation.</p> <p>The risk rating for mine gas should be reduced to very low by undertaking the proposed piling works in accordance with the Coal Authority Permit and HSE guidance^[6] and undertaking gas monitoring of any excavations or confined space prior to man entry.</p>

* From Table 3

**High strength basal geogrid intended to prevent crown hole from reaching surface. May not prevent settlement and serviceability issues which may require future maintenance / treatment. This option to be considered only for areas of earthworks or carriageway currently considered Low Risk but where a degree of additional mitigation is desirable to reduce the risk to Very Low. Further consideration of the long term durability of the selected geogrid and any potential restrictions to future drilling through the geogrid in the event that remedial grouting be required at a later stage should be undertaken.

***Small number of deep boreholes undertaken outwith the footprint of Allerdene Railway Bridge

^[6] 'Guidance on Managing the Risk of Hazardous Gases when Drilling or Piling Near Coal: The Coal Authority, Health and Safety Executive, British Drilling Association, Federation of Piling Specialists and the Association of Geotechnical and Geoenvironmental Specialists. Published 2012. Contains public sector information licensed under the Open Government Licence v1.0.

Irrespective of what mitigation measures are adopted, during construction the exposed formation should be inspected by a suitably qualified and experienced engineer to check for evidence of unrecorded mineshafts or surface disturbance due to the collapse of shallow workings. If any such evidence is observed, further investigation and, if required, treatment should be undertaken.

It should be noted that a Coal Authority Permit is required for intrusive activities (e.g. site investigation, drilling and grouting, excavation, piling) which will or potentially could disturb or enter any coal seams, coal mine workings or coal mine entries (shafts and adits). A permit has previously been obtained for the 2017 to 2018 intrusive investigation but no permit has been applied for to cover any future investigation or constructions works.

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