national highways

Coal Mining Hazard on the Strategic Road Network

Hazard Guidance Note

Version 6.0 November 2023

This guidance note is intended for non-specialists of ground-related hazards and describes the potential of coal mining to impact the safety and performance of the Strategic Road Network (SRN). Together with the Coal Authority's hazard mapping data on National Highways' Geotechnical and Drainage Management Service (GDMS), these products support effective management of the coal mining risk to the network.

Presence of coal mining activity can lead to widespread or localised subsidence or catastrophic collapse of the ground, and for example significantly impact geotechnical assets, pavements, structures, VRS and structures.

This guidance note does not replace the need for local and site-specific assessment by National Highways' geotechnical specialists.

Using this guidance note

Part I: provides an overview of National Highways' current risk management of coal mining hazards.

Part II: outlines steps in the risk management framework to enhance network resilience to coal mining.

Part III: provides further background information specific to coal mining, its relevance to the SRN, and key sources of information.

Part I: National Highways approach to managing coal mining risks

Coal has been mined in the United Kingdom since Roman times (or even earlier) and has left a legacy of past activity across a large proportion of National Highways' network. The history of coal mining and its impact on the SRN is summarised in Part III.

The risk presented by the legacy of coal mining is not new to National Highways. Any new assessment of the risk should consider the following factors:

- At the time of construction of the SRN or at the time of undertaking improvement schemes, coal mining and related risks should have been investigated and mitigated appropriate to the standards or advice that applied at the time. Where

available, relevant records are held on GDMS.

- Geotechnical risk management procedures were introduced in the 1990s. Specifically, 'CD 622 Managing geotechnical risk' was first published within the Design Manual for Roads and Bridges (DMRB) as 'HD22/92' in 1992. It is therefore reasonable to assume that for schemes post 1992 there is an improvement in the reliability of information captured and retained, along with increased standardisation in investigation, design, and mitigation methodologies across schemes.

Figure 1 Mineshaft collapse in Lane 1 of A1M in 2016 (Source: GDMS Geotechnical Event ID 45)

1.0 Current ground risk management requirements

CD 622 *'Managing geotechnical risk'* presents a framework for geotechnical risk management and is a mandated requirement on all schemes involving geotechnical activities. It establishes the principles of early risk identification and continuity of the geotechnical risk register through the project life cycle from concept to handover. CS 641 *'Maintenance of highway geotechnical assets'* provides guidance on the identification and management of 'At Risk Areas' including those of potential coal mining related risk.

Consideration of the hazard posed by coal mining to the existing SRN should form part of the Geotechnical Asset Management Plan (GeoAMP) process. The GeoAMP is prepared and reviewed annually by regional geotechnical teams overseen by the Geotechnical Maintenance Liasion Engineer, within the Operations Directorate, and submitted for agreement to the regional Geotechnical Advisor in the Technical Authority (Safety, Engineering and Standards).

For guidance on the application of current requirements please consult the relevant regional Geotechnical Advisor.

2.0 National Highways coal mining hazard mapping layers

The maps referred to in this section are intended as high-level hazard awareness maps only. They **do not replace the need to seek expert advice** from within National Highways and the undertaking of site-specific studies. As noted above, consideration of coal mining hazards along with all other ground-related hazards is an inherent part of risk management within National Highways' geotechnical standards.

2.1 Coal Authority Web Mapping Service Layers

The Coal Authority provides a Web Mapping Service (WMS) which contains a collection of information extracted from the National Coal Mining Database. This WMS has been integrated with GDMS and is viewable in the 'Map' viewer. Further technical information on the Coal Authority Data is available on

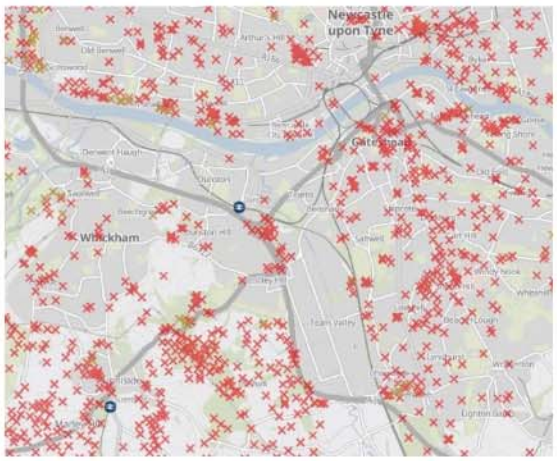

Figure 2: Section of the 'Mine entry' map layer (Source: GDMS).

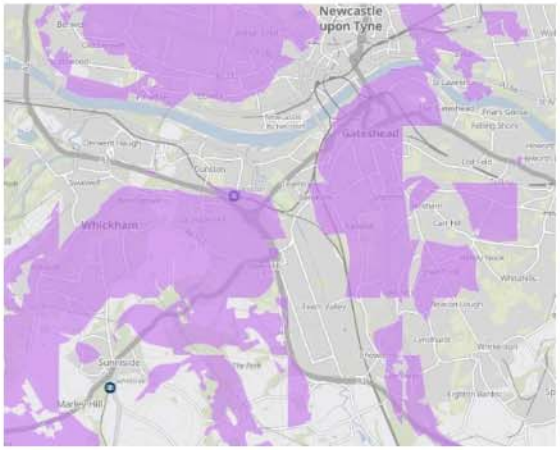

Figure 3: Section of the 'Probable shallow coal mine workings map layer (Source: GDMS).

their website (Coal Authority, 2023).

The following Coal Authority WMS data layers are available within GDMS:

- Mine entry
- Mine entry potential zone of influence
- Fissures and breaklines
- Surface mining (past and current)
- Past shallow coal mine workings
- Probable shallow coal mine workings
- Coal outcrops
- Coal mine reporting areas

These map layers can be accessed on GDMS through the 'Map' view ('Third party mapping> The Coal Authority').

Part II: Using the coal mining hazard maps to enhance the resilience of the SRN

Resilience of the SRN comes from both adequate design and maintenance, mitigation of hazards, and having appropriate response and recovery measures in place should the hazard occur. Selection of appropriate mitigation (proactive, pre-event) measures versus response and recovery (reactive, post-event) cannot be prescriptive, but the approach set out in Figure 4 can be used to support risk-based decision making.

The **Resilience Assessment Framework**, developed by Arup AECOM (2020a and 2020b), can be used to inform this assessment. The framework is available on the GDMS downloads page, and is provided in two parts, that include:

- *Resilience Assessment Framework: Part 1 – Assessment of current resilience (GDMS Report ID 31685)*
- *Resilience Assessment Framework: Part 2 – Assessment of options to improve resilience (GDMS Report ID 31686).*

1. Define the **hazard** event

A hazard 'event' can be defined as 'a source of potential harm, loss or failure'. The following are different hazard events related to the presence of coal mining beneath the SRN, and these present different risks to the network and third parties:

- Collapse of a very shallow mine working (may be either sudden or progressive)
- Collapse of a shallow (approx. 0m to 30m depth) mine working (may be either sudden or progressive)

- Subsidence/subsidence related to presence of deep mines (typically progressive)
- The collapse of a mine shaft or mine adit (typically sudden)
- The appearance of mine water on or adjacent to the SRN
- Presence of fractures at surface resulting from deep mining that could impact on drainage
- Displacement of ground gas by grouting

2. Consider potential external **triggers** of the hazard event

There may be little or no warning of a mine-related failure, but if specific triggers have been identified, these can be monitored to improve the management of the risk. The following are potential external triggers of a coal mining hazard event:

- A surface flooding event
- Change in surface water flow and changes in drainage
- Groundwater regime change (refer also to the Groundwater Flooding hazard guidance note) including that arising from grouting outside the highway boundary
- Erosion
- Change in surcharging or loading

Note that the above water related triggers (surface or groundwater, flooding etc.) may be exacerbated by climate change. For further information on the latest climate change projections, please refer to Technical Guidance Note 'UK Climate Projections 2018 (UKCP18) and Geotechnical Asset Management' (National Highways, 2021).

3. Assess the **likelihood** of the hazard event occurring

The Coal Authority WMS hazard layers on GDMS do not provide an absolute indication of the likelihood of a hazard event occurring, but a relative indicator of the potential presence of coal mining compared to the rest of the network.

To undertake a qualitative assessment of the likelihood of coal mining related hazard, the following factors are relevant:

A. **The likely presence of coal mining**

Figure 4: Risk management framework for understand ground-related hazard risk to the Strategic Road Network.

- Refer to the Coal Authority WMS hazard map layers on GDMS and the Coal Authority interactive map
- Refer to area-specific report records held on GDMS, historical maps, geological maps and memoirs.
- Indicators that mines would not be captured by records and therefore not included within the Coal Authority hazard map layers:
    - Areas of mining pre-1872 – i.e. prior to regulatory registration of mines
    - Areas where mining records are incomplete – such that low confidence that all mines are captured

B. **Inherent properties and characteristics**

- Age of mining / method of extraction / date of abandonment – indicative of inherent stability and original measures to make the mine safe
- Age or construction/maintenance records of the SRN – indicative of the types, current effectiveness (including age degradation) and completeness of any investigations and measures undertaken to manage the mine

C. **Indicators that a triggering action (as listed in Step 2: Triggers) is likely to occur.**

These may be considered by the type of triggering mechanism:

- Weakening of the mine structure, as may be indicated by:
    - A history of flooding (refer also to the Groundwater Flooding hazard guidance note, available on GDMS Downloads)
    - Recent / forecast heavy or prolonged rainfall
    - Blocked / insufficient / absent drainage
    - Water/wastewater pipes in poor condition, e.g. aged or damaged through construction-induced ground movements, and may leak or cause local flooding
    - Groundwater extraction / dewatering, soakaways, irrigation
- Destabilisation through additional loading, as may be indicated by:
    - Traffic loading (volume) increases
    - Construction / demolition activities, excavations, and temporary plant
    - New structures and permanent loads or grouting elsewhere

An understanding of the likelihood of a coal mining hazard event occurring may also be assessed from historical records and frequency of similar problems on the SRN and the surrounding area. Where GDMS contains report records demonstrating that this hazard was assessed in accordance with current risk management procedures and standards it is reasonable to assume a lower likelihood of a hazard event. In-situ and remote sensing techniques and data are available to support the identification of the presence of coal mining related hazards (e.g. Aerial photography, LiDAR, InSAR and SAR; see GDMS Downloads for relevant guidance, Arup AECOM (2022a and 2022b) or CIRIA (2022).

4. Consider the potential **impact** on the safety and/or performance of the SRN

A quantitative assessment of impact on a national scale is not possible, but at a local level, the following factors should be considered to understand the potential impact:

A. **Factors specific to the hazard event:**

- The rate of failure and the amount of warning available – a rapid, catastrophic failure presents the highest safety consequence.
- The size of the potential failure – a large failure presents a much higher safety risk to potentially many more users of the network than a small one would. Estimation of failure size requires local consideration and expert input.
- The location of the potential failure – ground movement directly beneath a main running lane presents both higher safety impact, and higher performance impact than beneath a hard shoulder or beyond.
- Consideration of potential investigation and remedial works – the longer these could take, the longer the performance impact.

B. **Factors specific to the location of the hazard event on the network:**

- The speed and volume of traffic using the road – where higher it typically correlates to an increased safety impact.
- The type of pavement – a sudden/catastrophic failure is more likely where there is loss of support beneath by a rigid pavement whereas a flexible pavement show early signs of a failure. Note that GDMS has a data layer that indicates the presence of pavement quality concrete (see 'NH reference datasets>Geohazards>Presence of PQ concrete').
- The type of road – smart motorways being the most important in terms of performance, down to All Purpose Trunk Roads (APTR).
- Presence of technology – all-lane running sections could be assumed better able to respond to an event in terms of traffic management.

5. What is the **risk** (considering likelihood and impact) that coal mining presents to the SRN?

This can be qualitatively assessed and should inform subsequent decision making. Uncertainty should be recognised and decisions should typically be cautious, particularly where there are high levels of uncertainty (or lack of data).

6. Select appropriate **response measures**

Measures taken to mitigate risk and enhance resilience may be either proactive or reactive. Typically, the greater the safety or performance risk to the SRN in terms of both likelihood and impact of an event, the greater the benefits of undertaking proactive mitigation. When selecting appropriate measures, there should be early engagement with geotechnical specialists from National Highways and the Coal Authority.

High level risk management measures are likely to be specific to both the hazard event

and whether it is a construction and/or on-going operations risk, but all measures would fall into one of the following categories:

- **Investigation:** To understand the current condition and therefore likelihood of the hazard event. Investigation may reduce the uncertainty and hence reduce the need for additional mitigation measures.
- **Intervention:** Where there is an evident cost-benefit in implementing measures to prevent the hazard event from occurring, or mitigating measures to limit the impact should it occur.
- **Monitoring:** To allow appropriate operational responses to be implemented in anticipation of a potential hazard event.
- **Response and recovery:** To respond rapidly to a potentially unexpected hazard event, development of response plans is recommended for areas of known coal mining risk. Response plans should include:
    i. Engagement with National Highways technical specialists – named focal points (and responsibilities) should be clearly identified.
    ii. Being prepared to close lanes and/or implement diversions and have an understanding of the potential duration of these measures until the SRN may be fully operational – this includes a broad range of communications, such as National Highways' suppliers, road users and the general public. These should be linked to Incident Response Plans (IRPs).
    iii. Likely response options should be identified – based on the particular hazard events and anticipated consequences. The time and resources that would be required to implement the options should also be considered.
    iv. Incident recording – following initial recovery, a full record of the mitigation works (as part of Health and Safety file recording), the cause of the event assessed, the risk of similar events occurring elsewhere on the network evaluated, and appropriate actions taken to manage the incident should be recorded. **All 'Geotechnical Events' must be recorded on GDMS; see GDMS User Guidance documentation**
- **Schemes:** Where there is an evident cost-benefit in implementing measures (barriers) to prevent the hazard event from occurring, or mitigating measures to limit the impact should it occur. These should be managed in accordance with the requirements of CD622.

Part III: The legacy of coal mining in England

1.0 History

Coal mining has been carried out throughout England. Arup (1990) reports that mining was particularly extensive and covered over 20% of the county area in: the West Midlands (Staffordshire, Warwickshire and West Midlands); East Midlands (Derbyshire, Nottinghamshire); North West England (Greater Manchester, Lancashire, Merseyside); Yorkshire (North, South and West Yorkshire); and North England (County Durham, Northumberland, Tyne & Wear).

Early mining was opportunistic, extracting coal from surface outcrops. As these sources were exhausted mining began to move underground, following seams in simple drift mines (adit mines) and shallow excavations known as 'bell pits' (see Figure 5).

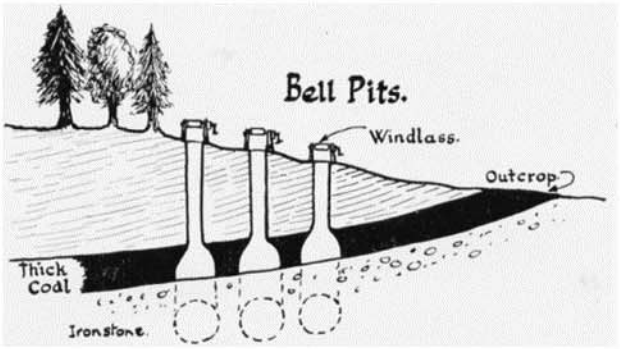

Figure 5:: Coal mining with Bell Pits (Source: HD Poole, The Blackcountryman Magazine) .

Coal mining increased significantly during the industrial revolution, and rose to a peak of production in 1913, before declining slowly to the 1960s and rapidly declining thereafter as North Sea oil and gas began to replace coal as the main energy source for the UK.

With increasing production, the means of excavation became more mechanised and took place at greater scales, and to ever increasing depths. Excavation by pillar and stall techniques (where some coal is left in place as pillars to support the roof above) allowed large volumes of coal to be removed (see Figure 6). This was largely replaced by longwall mining, where full extraction of the available coal is carried out, and the ground behind the mining is allowed to collapse. In addition, advances in plant and extraction techniques allowed large scale opencast mining to be undertaken for coal near to the surface. Following a long decline, the last deep coal mines in England closed in 2015. Opencast mining continues, but at much smaller scales than previously.

In 1872 the Coal Mines Regulation Act of Parliament was passed that included the requirement of mine owners to deposit plans with the state after mine closure. The Coal Authority is the current government body that maintains the historical records. Mines that were closed prior to 1872 may well be absent from the records, or incomplete.

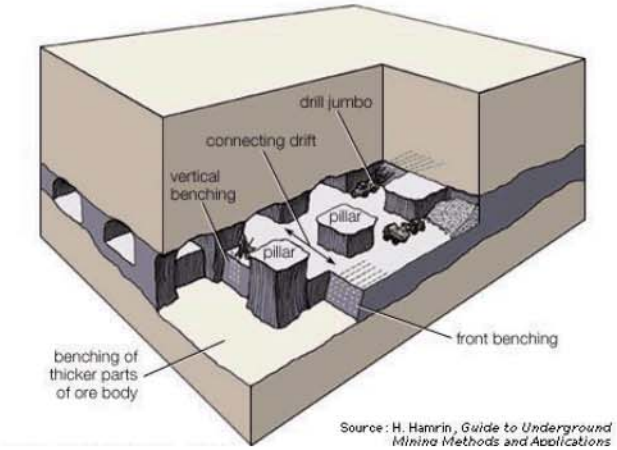

Figure 6: Pillar and stall mining (Source: Encyclopaedia Britannica)

The Coal Authority also has the wider responsibility of managing the effects of past coal mining, including safety and mine water pollution. It is within the Coal Authority's remit to respond to any emerging coal hazard and is financially responsible for making mines safe and compensating for any damage caused. **The Coal Authority must be informed immediately should a hazard be identified, and a licence obtained for any investigation or grouting of coal measures.**

Part III 2.0 Coal mining and the SRN

The hazard posed can be considered to arise from the potential for:

- voids beneath the National Highways' estate to either collapse suddenly and catastrophically or to cause subsidence. These voids could be present due to:
    - unidentified, and hence unmanaged, mines or mine shafts (often older mines or mine entries are more difficult to locate)
    - inadequate stabilisation methods (compared to current practice/guidance), which may correlate to the approximate date of works

  - the measures employed have deteriorated subsequently due to changes since the time of works (e.g. chemical, groundwater or surface flooding) or have reached the end of their serviceable life
  - undetected fissuring in certain surface rocks resulting from ground strains caused by longwall mining at depth
- abandoned coal mine workings to produce dangerous emissions, such as mine gas or polluting mine waters. For further details see the Aggressive/Corrosive Ground Conditions Hazard Guidance Note on GDMS Downloads.

This note focuses on the potential for voids and subsidence, but the potential for release of hazardous gas or polluted waters or other contaminants should not be ignored – also see the Aggressive / Corrosive Soil and Groundwater hazard guidance note.

The type of hazard that the presence of these mines presents to the SRN is further significantly influenced by the age and depth of the mines. Broadly speaking, the hazard type can be grouped as follows:

- **Outcrop and very shallow mine workings:** (typically within 50m of the seam outcrop, although the location of the outcrop and exact distance to mine workings are both uncertain), exploited via open excavations, bell pits and perhaps local underground workings. These can date back to Roman times or earlier. Workings may be unconsolidated, and there is a greater likelihood of unrecorded workings and mine entries. There is also a risk of spontaneous combustion from some seams if exposed to air.
- **Shallow (typically less than 30m deep) mines:** These will be a mix of recorded and unrecorded mine workings, mined using a variety of support solutions. These typically date from the early 1800s to the early 1900s. The hazard to the SRN is again due to the likelihood of unconsolidated mine workings or entries that could allow voids to migrate to the surface and affect highway infrastructure. The risk increases if the mine workings or entries are unrecorded and therefore have not been assessed and mitigated in the past. Previously identified workings may have had mitigation works undertaken (to mine workings and entries). However, these may become compromised where measures were incomplete, have deteriorated and/or are influenced by external factors (e.g. water infiltration) representing a further hazard to the SRN.
- **Deep mining:** Largely undertaken during the 20th century using longwall techniques. In deeper workings the likelihood of a hazard of void migration from mine workings is significantly lower due to higher overburden pressures and the method of mining used. Ground settlement also generally occurs contemporaneously with the workings and is therefore less likely once mining has ceased. This may change should underground coal mining resume in the future. The hazard is therefore primarily from mine entries. The available information on deep mining is typically of better quality (hence reduced uncertainty), but hazards exist where the shaft de-commissioning did not adequately mitigate risks appropriate to a location beneath or close to SRN. Moreover, shaft de-commissioning methods are susceptible to similar compromises as identified for mitigation measures on shallow workings.

At the time of mine abandonment, works such as capping of shafts and backfilling of workings may have been carried out, depending on when the mine was closed.

Equally, these activities may have been undertaken at a later stage, for example at the time of construction of the SRN. Historical reports on GDMS may provide further information on this and any changes since construction. It is reasonable to assume that if during SRN works a mine was known to be present, there will have been investigation and stabilisation measures undertaken, with the following broad observations:

- Mine stabilisation undertaken before the publication of the CIRIA SP32 (1984) may have been less effective and more ad hoc.
- Mine stabilisation measures implemented before 1984 have now been in place for over 30 years and therefore carry uncertainties about the deterioration due to ageing or other external factors.
- Between 1984 and the first publication of the DMRB in 1992, there should have been an

  improvement in the investigation and stabilisation of mines based on the level of guidance available.

  - Since the publication of the DMRB in 1992, (i.e. HD22 now CD 622) there has been less uncertainty, better records on GDMS, and more effective and consistent investigation and stabilisation.
  - Where stabilisation has been undertaken in the last 10 years and has experienced less age-related deterioration the above-mentioned issues of deterioration of stabilisation are less significant, and records should be easily accessible to confirm adequate investigation and stabilisation.

References and further information

Arup (1990) Review of mining instability in Great Britain.

Arup AECOM (2020a) Resilience Assessment Framework, Part 1 – Assessment of current resilience (GDMS Report 31685).

Arup AECOM (2020b) Resilience Assessment Framework, Part 2 – Assessment of options to improve resilience (GDMS Report 31686)

Arup AECOM (2022a) Earth Observation Trials on the SRN (GDMS Report ID 37378).

Arup AECOM (2022b) Geotechnical Asset Improvement: Remote Inspection using Earth Observation Techniques. Final Report, v1 (GDMS Report ID 37419).

CIRIA (1984) SP32 Construction over abandoned mine workings.

CIRIA (2019) Abandoned mine workings manual (C758D)

CIRIA (2022) InSAR and Earth Observation techniques for infrastructure (C805). Available here.

Coal Authority (2023) Coal Authority Metadata. Available here.

DMRB (2020a) CS 641 – Managing the maintenance of highway geotechnical assets. Available here.

DMRB (2020b) CD 622 – Managing geotechnical risk. Revision 1. Available here.

National Highways (2022) UK Climate Projections 2018 (UKCP18) and geotechnical asset management. Available here.

Further advice

To obtain further advice on the hazard coal mining poses to the SRN, please contact one of the regional Geotechnical Advisors in the Technical Authority (Safety, Engineering and Standards). Your Geotechnical Advisor may also wish to contact **the Coal Authority who**

have a statutory responsibility for managing the effects of past coal mining. The Coal Authority can be contacted on 0345 7626 848 (Mon-Thurs: 0845-1700, Fri: 0845-1630) or at customerservice@coal.gov.uk. The organisation also has a 24-hour number for reporting public safety hazards and incidents associated with coal mining and it can be reached at 0800 288 4242.

Role of National Highways' Regional Geotechnical Advisors

- Technical oversight of schemes, to ensure the technical input is appropriate, complies with National Highways standards and delivers good value
- Cascading local knowledge and good or bad experiences from other projects
- Evaluating and supporting innovation opportunities to promote efficient delivery
- Providing asset data and information management services
- Managing knowledge improvement for the geotechnical discipline, including standards and advice notes and supporting integrated asset management in National Highways.