HEALTH & SAFETY AT WORK ACT
HSWA

APPROVED
CODE OF PRACTICE

Ground or Strata Instability in Underground Mines and Tunnels

SEPTEMBER 2016

New Zealand Government

WORKSAFE
NEW ZEALAND | MAHI HAUMARU AOTEAROA

ACKNOWLEDGEMENTS

WorkSafe New Zealand (WorkSafe) would like to thank the members of the industry working group for their contribution to the development of this code. Our thanks also go to NSW Government Trade and Investment, Regional Infrastructure and Services; Safe Work Australia; Government of Western Australia Department of Mines and Petroleum; Open House Management Solutions, South Africa; Strata Control Technology, NSW, Australia; and the Health and Safety Executive (HSE), England for letting us use content from their publications.

NOTICE OF APPROVAL

The code of practice for *Ground or Strata Instability in Underground Mines and Tunnels* sets out WorkSafe New Zealand's expectations in relation to identifying and controlling the work health and safety risks arising from mining and tunnelling operations, in order to help PCBUs and workers achieve compliance with the Health and Safety at Work Act 2015 and the Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016.

WorkSafe New Zealand developed the code with input from unions, employer organisations, other key stakeholders and the public.

Together with the right attitudes and actions of PCBUs and workers focused on improving health and safety practices at work places, the code will contribute to the Government's targets of reducing the rate of fatalities and serious injuries in the workplace by at least 25% by 2020.

Accordingly, I Michael Allan Woodhouse, being satisfied that the consultation requirements of section 222(2) of the Health and Safety at Work Act 2015 have been met, approve the code of practice for *Ground or Strata Instability in Underground Mines and Tunnels* under section 222 of the Health and Safety at Work Act 2015.

Hon Michael Woodhouse
Minister for Workplace Relations and Safety

16 August 2016

FOREWORD

As the Chair of the Board of WorkSafe New Zealand, I am pleased to introduce this approved code of practice for *Ground or Strata Instability in Underground Mines and Tunnels*.

It was developed with input from our social partners, industry and public consultation.

This approved code of practice will help duty holders comply with their requirement to provide healthy and safe work for everyone who works in this industry. It will also help make sure that other people do not have their health and safety adversely affected by the work conducted.

A healthy and safe workplace makes good sense. An organisation with health and safety systems that involve its workers can experience higher morale, better worker retention, increased worker attraction and – most importantly – workers who return home to their families, healthy and safe, after they finish their work.

Organisations benefit from having less downtime from incidents and higher productivity. An organisation known for its commitment to health and safety can benefit from its improved reputation.

We must all work together to make sure that everyone who goes to work comes home healthy and safe. By working together, we'll bring work-related harm down by making sure that all work conducted is healthy and safe work.

Gregor D. Coster

Professor Gregor Coster, CNZM
Chair, WorkSafe New Zealand

TABLE OF CONTENTS

PART A

PART B

PART C

TABLES

FIGURES

KEY

C **Coal**

M **Metalliferous**

T **Tunnels**

PART A

IN THIS PART:

PART A

01/

INTRODUCTION

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work Act 2015

Section 22 *Meaning of reasonably practicable*

Section 30 *Management of risks*

Section 222 *Approval of codes of practice*

Section 226 *Use of approved codes of practice in proceedings*

Part 2 *Health and safety duties*

Part 3 *Worker engagement, participation, and representation*

Schedule 3:

Clause 1 *Interpretation – mine operator*

Clause 2 *Meaning of mining operation*

Clause 4 *Meaning of tunnelling operation*

Clause 8 *Power of health and safety representative to give notice requiring suspension of mining operation*

Clause 9 *Power of health and safety representative to require mining operation to stop in case of serious risk to health and safety*

Clause 11 *Competency and experience requirements for exercise of powers under clauses 8 and 9*

Clause 19 *Functions and powers of industry health and safety representatives*

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

Regulation 55 *Risk assessment*

Regulation 60 *Engagement*

Regulation 68 *Content of principal hazard management plans*

Regulation 71 *Principal hazard management plans for ground or strata instability*

Regulation 73(3) *Consideration of whether inundation and inrush is a principal hazard*

Regulation 109 *Worker participation practices must be documented*

Regulation 114 *Mine operator must investigate reported hazard*

Regulation 115 *Mine operator must advise mine worker of result of investigation*

Part 3 *Health and safety management system*

The Health and Safety at Work Act 2015 (HSWA) is New Zealand's key work health and safety legislation. It sets out work-related health and safety duties that must be complied with. Health and safety regulations sit under HSWA, expand on the duties under HSWA and set the requirements for managing certain risks and hazards.

Approved codes of practice (codes) set out WorkSafe New Zealand's (WorkSafe) expectations about how duty holders are to comply with their legal duties under HSWA and related regulations. The relevant legislation for this code is:

> Health and Safety at Work Act 2015 (HSWA)

> Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016 (the MOQO Regulations).

See WorkSafe's special guide *Introduction to the Health and Safety at Work Act 2015* for more information on health and safety law.

1.1 WHAT IS THE PURPOSE OF THIS CODE?

This code sets out WorkSafe's expectations for managing ground or strata instability in underground mining and tunnelling operations. It applies to all underground mining and tunnelling operations where ground or strata instability is a principal hazard. The code includes information on:

> causes of ground or strata instability

> geotechnical assessment

> design and implementation of control measures

> monitoring controls

> review and audit requirements.

This information contributes to the contents of the ground or strata instability principal hazard management plan (PHMP).

This code is for the site senior executive (SSE), mine operator, mine manager, and anyone else at the mining or tunnelling operation involved in managing the ground or strata instability principal hazard. This includes workers and other persons.

1.2 WHAT IS THE LEGAL STATUS OF THIS CODE?

This code has been approved under section 222 of HSWA. It can be used in court as evidence of whether HSWA has been complied with. Courts may use this code:

> as evidence of what is known about the ground or strata instability principal hazard at an underground mining or tunnelling operation and how those risks may be controlled

> to decide what is reasonably practicable for managing the ground or strata instability principal hazard at an underground mining or tunnelling operation.

Following the code may not be the only way of complying with HSWA and the MOQO Regulations. Other practices can be used as long as they provide a level of work health and safety equivalent to or higher than in this code, and comply with HSWA and the MOQO Regulations.

For more information about the hierarchy of the legislation and the relationship with other guidance documents, refer to WorkSafe's special guide *Introduction to the Health and Safety at Work Act 2015*. See also WorkSafe's interpretive guidelines *Developing a Ground or Strata Instability Principal Hazard Management Plan*.

1.3 HOW TO USE THIS CODE

1.3.1 INTERPRETING THIS CODE

Table 1 shows the terms used to describe the requirements in this code.

TERM	DEFINITION
Must	legal requirement that has to be complied with
Needs to, or content written as a specific direction (eg 'Make sure the...')	a practice or approach that has to be followed to comply with this code – WorkSafe's minimum expectation (subject to the legal status of this code described in section 1.2)
Should	recommended practice or approach, not mandatory to comply with HSWA or this code
May	permissible practice or approach, not mandatory to comply with HSWA or this code

Table 1: Requirements in this code

1.3.2 LEGISLATION

At the start of each section in this code, the legislation that applies is listed in a box.
For the full text see www.legislation.govt.nz

1.3.3 TERMS USED IN THIS CODE

MINING AND TUNNELLING

This code uses the terms 'mining operation' and 'tunnelling operation' even though the definition of 'mining operation' in HSWA includes a tunnelling operation. This is to emphasise that parts of the code apply to both mining operations and tunnelling operations.

'Tunnel operator' is used in this code to refer to the person responsible for the tunnelling operation and has the same meaning as 'mine operator' under HSWA.

COMPETENT PERSON

Competent person means a person who:

a. has the relevant knowledge, experience, and skill to carry out a task required or permitted by the MOQO Regulations to be carried out by a competent person; and
b. has a relevant qualification evidencing the person's possession of that knowledge, experience, and skill or – if the person is an employee – a certificate issued by the person's employer evidencing that the person has that knowledge, experience, and skill.

Other terminology used in this code is explained in the Glossary.

1.3.4 MINING OR TUNNELLING OPERATION TYPES

This code applies to all underground mining and tunnelling operations. Where content is specific to a particular operation an icon is shown as follows:

C Coal

M Metalliferous

T Tunnels

1.3.5 STANDARDS

Use the most recent version of any standards referred to in this code, unless otherwise specified.

Where applicable, and provided it does not contradict the legislation or requirements of this code, refer to BS 6164 *Code of practice for health and safety in tunnelling in the construction industry* for good practices in the construction of tunnels.

1.4 ROLES AND RESPONSIBILITIES

HSWA defines the roles and responsibilities of different duty holders. These include persons conducting a business or undertaking (PCBUs), officers, workers and other persons at workplaces. See WorkSafe's special guide *Introduction to the Health and Safety at Work Act 2015* for more information.

Schedule 3 of HSWA and Part 2 of the MOQO Regulations set out the specific mining sector-related roles including mine operator, mine worker, SSE, mine manager, safety critical roles, and industry health and safety representative.

All mine or tunnel operators must appoint a SSE and a mine or tunnel manager. The SSE is responsible for health and safety management and the mine or tunnel manager for the daily running of the mine or tunnel operation. Depending on the type of mining operation and the particular principal hazards other safety critical roles are required. For underground mining or tunnelling operations the SSE is required to appoint a number of safety critical roles. For more details, see regulations 28, 30, and 31.

1.5 WORKER ENGAGEMENT, PARTICIPATION AND REPRESENTATION

All mining and tunnelling operators must, so far as is reasonably practicable, engage with workers. Mining and tunnelling operations must also have effective worker participation practices, regardless of the size, location, hours of operation, or method of mining. A safe workplace is more easily achieved when everyone involved in the work:

> communicates with each other to identify hazards and risks

> talks about any health and safety concerns

> works together to find solutions.

1.5.1 DUTIES UNDER HSWA AND THE MOQO REGULATIONS

All PCBUs have worker engagement and participation duties under HSWA. Mine and tunnel operators have extra duties under the MOQO Regulations, as follows:

- The SSE must engage with workers and health and safety representatives (HSRs) when preparing and reviewing the health and safety management system (HSMS), including principal control plans (PCPs) and PHMPs.
- Mine and tunnel operators must document worker participation practices.
- If a worker reports the existence of a hazard, the mine or tunnel operator must:
  - make sure the report is investigated
  - promptly advise the worker of the result of the investigation.

1.5.2 HEALTH AND SAFETY REPRESENTATIVES

An HSR is a worker elected by the members of their work group to represent them in health and safety matters.

An industry health and safety representative (industry HSR) may be appointed to represent underground coal mine workers. An industry HSR is appointed by a union or by a group of underground coal mine workers. They must meet the competency and experience requirements for an HSR at a mining operation (see MOQO Regulation 110). As well as the functions and powers that all HSRs have, an industry HSR has additional functions and powers.

Details of the appointment, removal or resignation of the industry HSR must be provided to WorkSafe. WorkSafe issues an identity card to the industry HSR.

Trained health and safety representatives and industry HSRs can issue a notice to suspend or stop a mining operation if they believe on reasonable grounds that there is a serious risk to health and safety.

1.5.3 MORE INFORMATION ABOUT WORKER ENGAGEMENT, PARTICIPATION AND REPRESENTATION

For more information on worker engagement, participation and representation see WorkSafe's website and:

> good practice guidelines *Worker Engagement, Participation and Representation*

> interpretive guidelines *Worker Representation through Health and Safety Representatives and Health and Safety Committees.*

When reading the guidelines replace the following terms with the extractive industry terms:

> replace 'PCBU' with 'mine or tunnel operator'

> replace 'work group' or 'members of a work group' with 'a group of workers who are represented by a health and safety representative' or 'workers in a mining or tunnelling operation'

> replace 'business or undertaking' with 'mining or tunnelling operation'.

1.6 HEALTH AND SAFETY MANAGEMENT SYSTEM

All mining and tunnelling operations must have an HSMS. It is part of the mine or tunnelling operation's overall management system. The ground or strata instability PHMP is an essential part of the HSMS.

The SSE must:

> develop, document, implement and maintain the HSMS

> make sure it is easily understood and used by all workers

> engage with workers when preparing and reviewing the HSMS and when providing instruction before the workers start work at the mining or tunnelling operation.

1.7 HAZARDS AND RISKS

The PCBU must eliminate risks to health and safety, so far as is reasonably practicable. If it is not reasonably practicable to eliminate risks, they must be minimised, so far as is reasonably practicable.

The SSE must ensure there are processes in place to:

> identify hazards (appraise risks) at the mining or tunnelling operation

> assess the risks of injury or ill-health to workers from the hazards

> identify the controls required to manage the risks.

The risk appraisal could identify principal hazards; these are hazards that can create a risk of multiple fatalities in a single accident, or a series of recurring accidents, at the mining or tunnelling operation. They will either be one of ten specified hazards in the MOQO Regulations (which include ground or strata instability), or any other hazard identified during the risk appraisal that meets the definition.

Unless hazards are identified and risks assessed properly, no amount of risk management will ensure a safe place and system of work. Unrecognised risks can lead to serious consequences. See section 2 where the causes of ground or strata instability are discussed.

1.8 PRINCIPAL HAZARD MANAGEMENT PLAN FOR GROUND OR STRATA INSTABILITY

The ground or strata instability PHMP describes the principal hazard, records the risks of injury or ill-health to workers presented by ground or strata instability at the mining or tunnelling operation, and describes the controls that have been systematically identified to manage them. The PHMP must identify who is responsible for implementing, monitoring and documenting these controls. For detailed information, see:

> MOQO Regulations 68 and 71

> WorkSafe's interpretive guidelines *Developing a Ground or Strata Instability Principal Hazard Management Plan.*[1]

A PHMP for ground or strata instability must, at a minimum, address the following:

(a) the circumstances in which ground or strata failure may occur

(b) how potential ground or strata failure could be avoided through the design of suitable ground or strata support methods that must take into account:

  (i) characteristics of the area to be supported

  (ii) surrounding workings

  (iii) activities to be carried out

  (iv) size and geometry of the openings in underground workings

[1] The interpretive guidelines include a detailed example of a format that could be used to develop a ground or strata instability PHMP.

(c) clear directions and diagrams for the implementation of suitable ground or strata support methods

(d) continuous[2] modelling, testing, and updating, where required, of ground or strata support methods

(e) appropriate equipment and procedures to monitor, record, interpret, and analyse data about seismic activity and its impact on the mining or tunnelling operation

(f) collection, analysis, and interpretation of relevant geotechnical data

(g) maintenance of the integrity of ground or strata support

(h) allowance for higher standards of support to be installed than that required by the PHMP.

Produce the PHMP in the context of the whole HSMS so that it relates to other PHMPs, PCPs, or processes and procedures that rely on the PHMP as a control. This helps to prevent gaps and identify overlaps in processes and information where it relates to ground or strata instability, or where ground or strata instability may impact other PHMPs and PCPs.

Develop the PHMP using information from the geotechnical assessment gathered at the exploration and pre-feasibility stage of a project and the subsequent design, planning and ongoing operations.

Complete design and stability studies using an appropriate Factor of Safety (FoS) or other appropriate risk management index or margin.

Other inputs that contribute to the PHMP include:

> a review of risk appraisals and risk assessments

> incident/near miss reports

> results of reviews or audits completed

> consultation with workers

> industry or manufacturers' reports, where relevant.

The risk appraisal and assessment methodology used needs to be consistent with that specified in the HSMS. The PHMP needs to include the results of the ground or strata instability risk assessment.

Controls need to be implemented to effectively manage the risks of harm and the level of ground support needed. The SSE must ensure the effectiveness of the controls is monitored and corrective actions taken, if required.

The components involved in the development and maintenance of a ground or strata instability PHMP are shown in Figure 1.

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[2] In this code, continuous means over the life of the mine or tunnel. The frequency (eg daily, weekly, or monthly intervals) will be determined by the risk assessment and the design.

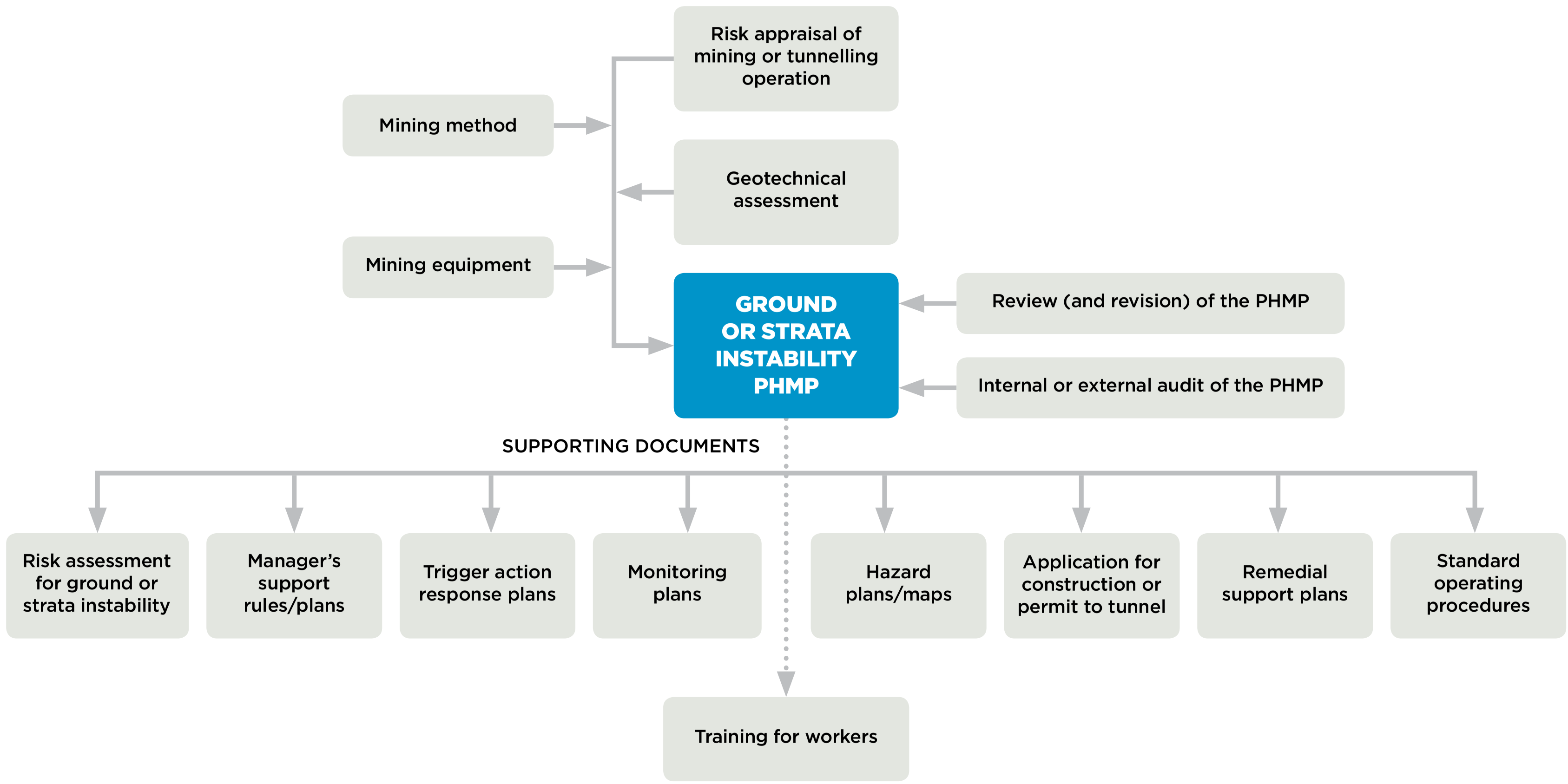

Figure 1: Development and maintenance of a ground or strata instability PHMP[3]

[3] Adapted from page 11: NSW Government|Trade & Investment Mine Safety.(2015). NSW Code of Practice|WHS (Mines) Legislation: *Strata control in underground coal mines*. New South Wales, Australia: NSW Department of Trade and Investment, Regional Infrastructure and Services.

PART B

IN THIS PART:

PART B

02/

CAUSES OF GROUND OR STRATA INSTABILITY AT THE OPERATION

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work Act 2015

Section 22 *Meaning of reasonably practicable*

Schedule 3, clause 4 *Meaning of tunnelling operation*

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

Regulation 3 *Interpretation – competent person*

Regulation 65 *Meaning of principal hazard*

Regulation 67 *General purposes of principal hazard management plans*

Regulation 68 *Content of principal hazard management plans*

Regulation 71 *Principal hazard management plans for ground or strata instability*

Regulation 73 *Consideration of whether inundation and inrush is a principal hazard*

Regulation 217(1)(k) *Details to be included in plans (the location of inrush control zones)*

2.1 IDENTIFY THE CAUSES OF GROUND OR STRATA INSTABILITY

Ground or strata instability is a principal hazard associated with mining and tunnelling operations. Some potential causes of ground or strata instability at a mining operation and tunnelling operation are listed below:

- inadequately designed ground support
- poor quality of ground support consumables
- poorly installed ground support
- deteriorated ground support
- mining induced seismicity
- natural seismicity
- excessive compressive stress around excavations
- excessive shear stress on discontinuities
- tensile forces around excavations resulting from strata relaxation
- ground water or artificially introduced water
- presence of adverse geological structures in immediate vicinity of excavation
- inappropriate choice of excavation or mining method
- loose blocks due to poor rock mass quality in the perimeter of the excavation
- collapse from localised or general thawing, or ineffective freeze due to moving ground water (ground freezing)
- excessive blast damage to the perimeter of the excavation
- inappropriate shape and size of pillars, roadways or roadway alignment
- pillar failure or collapse due to undersized pillars or poor mine layout
- load transfer, abutment stress, periodic weighting, face slabbing.

Identify, assess and detail the risks in the risk appraisal and risk assessment that forms part of the PHMP. For more information see section 1.8.

2.1.1 STRESS

A competent person must analyse the stress environment at the mining or tunnelling operation. This should include an assessment of the three-dimensional (3D) stress field across the relevant extent of the mining or tunnelling operation to develop an understanding of the magnitude and direction of the stress field, and any apparent variability present. This may be undertaken by a programme of in situ measurements, complemented by stress change monitoring during excavation, together with stress mapping and an awareness of stress conditions in adjacent operations, if present. This assessment informs the excavation and support design.

Options to measure stress in mining or tunnelling operations may include:

> in situ stress measurements

> stress change monitoring

> acoustic emission testing plus variation.

2.1.2 GEOLOGICAL HAZARDS

Some geological hazards encountered in excavations contribute to other principal hazards. Obtain specialist advice from a competent person if there is any indication of the presence or potential existence of one or more of the following hazards:

> significant water inflow

> gas outburst

> rock outbursts

> thermal activity

> discontinuity.

2.1.3 SEISMIC ACTIVITY

Under MOQO Regulation 71(2)(e) the PHMP must address the appropriate equipment and procedures to monitor, record, interpret and analyse data relating to seismic activity and its impact on the mining or tunnelling operation.

Natural seismicity is an earthquake that is caused through natural earth processes and needs to be considered in mine or tunnel design. Understanding the location and seismic hazard profile of major fault zones capable of producing strong ground motions at the mine or tunnel site is important. The competent person considers this when undertaking the geotechnical review. The potential for earthquakes may need to be factored into the design, both during excavation and construction, as well as the final tunnel or roadway formation.

Mining-induced seismicity occurs as a result of stress redistribution around underground openings. In some cases, such stress changes may trigger a sudden slip on a fault. This is almost always accompanied by ground vibration which may cause considerable damage to underground openings. In other cases, abutments or pillars may become overloaded and yield suddenly.

During the construction of tunnels, which can be of relatively short-term duration, the seismic risk may range from very low to moderate. When the tunnel construction, enlargement or extension has been completed the tunnel will no longer be a tunnelling operation by definition under HSWA Schedule 3, clause 4. The permanent tunnel must be designed for seismic loads in accordance with the New Zealand Building Code.

PART B

03/

GEOTECHNICAL ASSESSMENT

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

Regulation 3 *Interpretation – competent person*

Regulation 11 *Mine operator must ensure site senior executive has sufficient resources*

Regulation 69 *Review and revision of principal hazard management plans*

Regulation 71 *Principal hazard management plans for ground or strata instability*

3.1 REQUIREMENT FOR A GEOTECHNICAL ASSESSMENT AT MINING AND TUNNELLING OPERATIONS

The SSE must ensure that a competent person completes a geotechnical assessment to determine the level of ground or strata reinforcement required to safely conduct the mining or tunnelling operation.

When completing the geotechnical assessment obtain input from the relevant technical disciplines (eg mining engineers, geotechnical engineers, civil engineers, geophysicists, surveyors, geologists, and hydro-geologists).

The completed geotechnical assessment should be recorded, dated and signed by the competent person carrying out the assessment.

3.1.1 COMPONENTS OF A GEOTECHNICAL ASSESSMENT

The geotechnical assessment should cover proposed activities over the whole life of the mine or tunnel, from the feasibility study stage, operation of the mine or tunnel, to the final closure and abandonment of the mine or the full life of the tunnel.

The SSE needs to ensure the geotechnical assessment clearly defines the area the assessment relates to and the resulting ground control system design limited to that area.

The components of the geotechnical assessment and the outputs of that analysis are illustrated in Figure 2. They include:

> Site characterisation of the ground to be supported, including natural and geotechnical features such as:
  - lithology, seam thickness/orebody shape, stratigraphic variability, seam dip, depth of cover, geological structure including faults, bedding, joints
  - rock properties
  - measurement or assessment of rock stress magnitude and orientation, including excavation, pre-mining and mining-induced conditions and areas of high in situ stress
  - presence of water (eg aquifers, likely heads of pressures, water quality, inflows of water)
  - air temperature and humidity, gas inflows, and other variability in the rock (eg presence of contaminated ground)
  - hot groundwater or rock (geothermal)
  - earthquake potential, depending on the location of the operation in relationship to fault lines

  - obstructions, both man-made and natural
  - information about surrounding workings, including abandoned or previously excavated workings
- analysis and formulation of a geotechnical model, including definition of geotechnical domains, to classify volumes of rock with similar geotechnical properties and behaviours
- identification of failure processes and mechanisms
- ground support design using an appropriate Factor of Safety (FoS) or other appropriate risk management index or margin, including:
  - design of pillar and barrier sizes
  - design of mine or tunnel layouts including extraction/mining methodology
  - design of ground support for all stages of the operation development, extraction, and closure
  - design of the size, shape and orientation of openings
- development of a minimum ground support standard for each excavation type and geotechnical domain
- development of trigger action response plans (TARPs) for each excavation type
- identification of suitable monitoring systems, such as design verification monitoring and testing, routine monitoring, and requirements for seismic activity monitoring, where appropriate.

Consider the following in the geotechnical assessment:

- experiences from other local and/or equivalent mining or tunnelling operations, where applicable
- the mining method, mining direction, gradients, excavation sequence
- interdependencies between ground control design issues and other key aspects of design, such as inundation, ventilation and the management of subsidence.

The assessment may re-use relevant geological and geotechnical information previously collected as part of the feasibility studies or previous excavations, including:

- the results of further testing
- specific assumptions about the life of the mine or tunnel
- intended mining or tunnelling methods
- existing and proposed activities
- extraction rates.

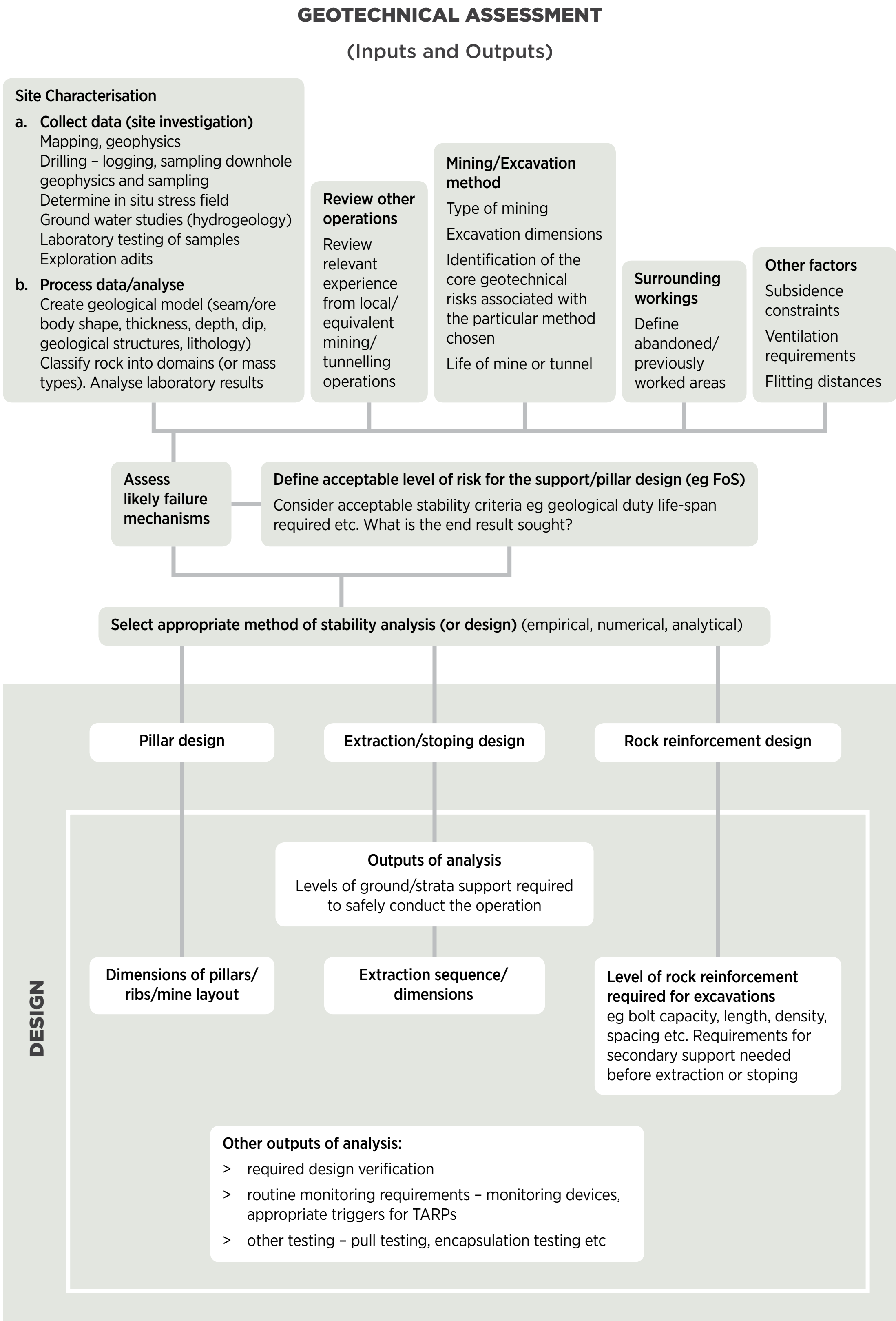

Figure 2: Components of the geotechnical assessment and design outputs

3.2 SITE CHARACTERISATION

Site characterisation provides an understanding of the physical characteristics of the rock mass to enable the design of ground support. Stages of site characterisation include:

> review of regional geology and information gathered earlier as part of feasibility studies
> site investigation
> lab testing
> preparation of a geological model
> interpretation of geotechnical and geophysical data to define soil and rock parameters for use in ground support design
> classification of rock mass into geotechnical domains.

Characterisation data is gathered from drilling logs or cores, observation, sampling, testing and analysis of a range of information and data about the ground, and other physical characteristics of the natural environment of the mining or tunnelling operation. This informs the geotechnical assessment.

Characterisation provides an estimate of rock mass strength and the in situ stress environment, to enable the prediction of how the ground will respond to the effects of excavation. It also provides information on the rock mass variability, including the impact of lithological changes and geological anomalies such as faults and dykes, and risks associated with seismicity.[4]

Ongoing updating and recalibration of the geological/geotechnical model is required throughout the operating stage.

The mine or tunnel operator must ensure the SSE has adequate resources for site investigations to effectively assess ground control risks.

3.3 COLLECTION, ANALYSIS AND INTERPRETATION OF GEOTECHNICAL DATA

The PHMP must address how relevant geotechnical data will be collected, analysed and interpreted, including the monitoring of openings and excavations, where appropriate.
The mining or tunnelling operation should have a database of geological and geotechnical data that is regularly updated as new data is acquired. This data includes:

> geological/geotechnical logging records (eg downhole geophysics, core photographs)
> geotechnical test results and rock mass properties (eg uniaxial compressive strength, fault/defect properties, shear strength and modulus as required).

3.3.1 GEOLOGICAL/GEOTECHNICAL MODEL

The mine or tunnel operator needs to have a geological/geotechnical model with regularly updated information, including:

> geological structure
> geological boundaries

[4] Adapted from page 11: NSW Government|Trade & Investment Mine Safety.(2015). NSW Code of Practice|WHS (Mines) Legislation: *Strata control in underground coal mines*. New South Wales, Australia: NSW Department of Trade and Investment, Regional Infrastructure and Services.

> seam/ore body grid models or 3D models
> overburden/host rock grid models or 3D models
> rock mass classification.

3.3.2 GEOTECHNICAL MAPPING

Geotechnical mapping needs to be regularly done in all active and accessible excavated areas. This includes:

> face mapping
> structural mapping
> geotechnical conditions observations or inspections
> excavation behaviour reports
> evidence of stress through deformation/failure mapping.

3.3.3 REPORTING OF GEOTECHNICAL INFORMATION

Standard operating procedures (SOPs) need to be developed to support regular reporting of geotechnical information by the relevant workers to the mine or tunnel manager and other workers. The mine or tunnel operator needs to retain evidence of this reporting.

3.4 RE-USING A GEOTECHNICAL ASSESSMENT

Where an existing design has already been proven, it may be used as a basis for the design of ground control measures for a new operation in the same area, provided that:

> the ground conditions at both operations are in the same domain or are not significantly different, and
> the excavation method is the same.

Sufficient site investigation should be carried out to confirm that the ground conditions at the new excavation are similar to those at the previous operations. Mine or tunnel operators need to complete a geotechnical model verification to compare old with new ground conditions. If ground conditions are confirmed as being similar, the information from these previous operations may be used. References to any earlier assessments must be included.

3.5 REVIEW OF THE GEOTECHNICAL ASSESSMENT

The SSE must ensure that the PHMP is reviewed at least once every two years after the date the PHMP was initially developed, being the date it was initially approved by the SSE, or as when required under the circumstances listed in MOQO Regulation 69(2).

Assumptions from the geotechnical assessment must be checked against what has actually happened with the ground. See MOQO Regulations 71(2)(d),(e) and (f).

Events that can trigger a review of the geotechnical assessment and review of the ground or strata instability PHMP include the following:

> a major change in the ground conditions encountered – conditions outside the site characterisation or the assumptions used for the design in the geotechnical assessment

> monitoring information that indicates the ground is not behaving as predicted in the geotechnical assessment
> a change in the mining method
> a change in the mining sequence
> a major change in the mine or tunnel layout
> a major change in the equipment used to install ground support such that the design specified in the geotechnical assessment cannot be implemented
> a major change in ground support type
> a significant accident involving ground instability.

See section 10 for information on review and audit.

PART B

04/

DESIGN OF CONTROL MEASURES/ SUPPORT METHODS TO AVOID GROUND OR STRATA INSTABILITY

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

***Regulation 3** Interpretation – shaft*

***Regulation 71** Principal hazard management plans for ground or strata instability*

***Regulation 117** Installation of ground or strata support*

4.1 DESIGN DETAILS AND SUPPORT METHODS

The design details and support methods are outputs of the geotechnical assessment. The excavation design and the systematic installation of suitable support of openings during excavation are the primary controls to prevent ground or strata instability occurring at a mining or tunnelling operation.

Components of the design include some or all of the following:[5]

> limits of extraction

> excavation dimensions

> pillar sizes

> type and spacing of support or reinforcement density; typically this will take the form of a support plan

> specifications for any material or equipment forming part of any ground control system, including quality and capacity verification testing

> timing of installation of the support or reinforcement

> proposed method of work (mining method and its compatibility with support systems)

> procedures for dealing with material changes in conditions (ie conditions that are more adverse or favourable) such as TARPs

> information on other risks such as known zones of weakness or proximity to other workings

> rationale for sequencing extraction and filling (if appropriate)

> backfill that provides confinement for roof/backs and ribs.

The designed or selected control measures must be able to be implemented without unnecessary risks to any person during the installation, operation and abandonment of the mine or tunnel.

4.1.1 DESIGN DOCUMENT

Include the geotechnical assessment in the design document. A competent person should sign the design document. For tunnelling operations, a producer statement (PS1)[6] should be signed by the designer. These documents form the basis of the manager's support rules. Include the manager's support rules as part of the PHMP.

Technical specifications need to be prepared for all ground support products or components of the system used at the mining or tunnelling operation, such as load capacities (support resistance) and energy absorption capacities. These technical specifications need to be included in the PHMP.

[5] Adapted from page 11: Health and Safety Executive (HSE) (2015) Guidance on Regulations: The Mines Regulations 2014. Retrieved from: www.hse.gov.uk/pubns/priced/l149.pdf

[6] A PS1 (Producer Statement 1) confirms that design work has been carried out by a competent design professional and is expected to comply with the relevant legislation.

4.2 DESIGN METHODOLOGIES USED TO DETERMINE GROUND SUPPORT NEEDED

A competent person needs to apply an appropriate design methodology (during the geotechnical assessment) to determine the level of ground support required to safely conduct the mining or tunnelling operation, including roadways, pillar or tunnel design and ground reinforcement requirements.

The competent person needs to use an appropriate FoS, or other appropriate risk management index or margin, depending on the duty and lifespan of the mine or tunnel opening. For example, the support system for an excavation planned to be open for a short time may be designed to a lower FoS than a roadway that needs to be stable for the entire life of the mine or tunnel.

The design methodologies are generally empirical, analytical or numerical analyses. These methodologies apply to both mining and tunnelling operations.

4.2.1 EMPIRICAL METHODS

Empirical design methods are design approaches and formulations developed from statistical analysis of controlled, quantified databases of experience on ‘real-world’ projects. The approach relies on comparing the experiences of past practices to predict future behaviour based upon the factors most critical for the design.

Empirical methods are reliant on credible databases. Note that:

> The risk-based parameters quoted for a particular database and design system are unique to that system. They are not to be applied to other applications without due consideration.

> An understanding of the origins, nature and limitations of the database is important. Uncertainty increases towards the boundaries of the database. Particular caution should be adopted in attempting to apply the results of an empirical study outside the range of the underpinning database.

An example of an empirical design method is the use of rock mass classification methods calibrated against large databases to provide guidelines for support design or cavability. Determining the rock class, span of the opening and rock mass quality will provide guidance as to the reinforcement category required and, if applicable, support system for a particular set of characteristics.

4.2.2 ANALYTICAL METHODS

Analytical design methods apply equations developed from basic mechanistic or engineering principles to the analysis of ground behaviour, so that when controls are applied, design outcomes can be expressed numerically (eg FoS).

These design methods typically require input parameters measured in the laboratory and/or field. An example of an analytical design method is the calculation of a dead weight load and the associated design of support to carry that load.

A disadvantage of analytical models is that it is rare for a design problem to involve one mode of behaviour or failure only. Stress and deformation are generally more complex, with multiple potential failure modes or varying ground loads. Most geotechnical design problems have input parameters that are not fully defined, either in terms of the expected value or the degree of variability. Engineering judgement is required, with a link to actual experience to provide design 'calibration'[7].

4.2.3 NUMERICAL METHODS

Numerical design methods involve a range of different underpinning capabilities, referred to as constitutive equations, used to describe the type of rock behaviour and potential failure criteria. The numerical code selected needs to have the capabilities that are applicable to the geotechnical environment being modelled; otherwise results will potentially be incorrect and could be misleading.

Modelling accuracy is highly dependent on input parameters that typically require extensive, high-quality site investigations and laboratory testing. Numerical models should address:

> calibration to 'real-world' experience/empirical outcomes

> sensitivity analysis to test the model's rationale

> the results of comparisons with the outcomes of alternative design methodologies.[7]

4.3 DESIGN REQUIREMENTS FOR ROCK REINFORCEMENT SYSTEMS

The design of rock reinforcement systems needs to consider:

> if the design is capable of being implemented without undue risk to any worker

> the prevailing geotechnical hazards and mining abutment effects over the life of the excavation, as well as taking account of other non-geotechnical operational constraints

> the profile, use and anticipated life cycle of the opening/roadway, leading to determination of appropriate support methodologies, materials and installation equipment

> the timing of both primary and any secondary support installation. This needs to be assessed relative to the prevailing geotechnical environment and likely impact on stability

> whether the support design methodologies selected and justified for each application are applicable to the expected ground behaviour and potential failure mechanisms

> establishing the protocols for confirming appropriate quality and adequacy of support materials and control systems for validating installation practices.

The complex nature of reinforcement design requirements means design methods should not be relied upon in isolation but considered as interdependent on each other. Reinforcement design should not rely on one single strategy, or expect only one single failure mode, especially in critical excavations. Rock failure is usually multi-modal and complex.

[7] Adapted from page 19: NSW Government|Trade & Investment Mine Safety. (2015). NSW Code of Practice|WHS (Mines) Legislation: *Strata control in underground coal mines*. New South Wales, Australia: NSW Department of Trade and Investment, Regional Infrastructure and Services.

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4.4 STOPE OR PILLAR DESIGN REQUIREMENTS FOR COAL AND METALLIFEROUS MINES

Pillar dimensions need to take account of the loads expected to be imposed on the pillars, the estimated pillar strengths and the influence of the width-to-height ratio on pillar failure behaviour.

The SSE must ensure all pillars are designed by a competent person. The design approach should consider the:[8]

> mine layout design and stope design
> type of pillar and the purpose(s) for which the pillar is to be used (eg standard roadway support pillars [inter-room], barrier pillars to separate areas of room and pillar mining, crown pillars used for long-term protection of specific areas of the mine, yielding and abutment pillars)
> specific associated geotechnical duty or function that the pillar must perform (eg local or regional load bearing, abutment stress protection, surface protection)
> pillar life expectancy
> engineering determination/judgement of the acceptable level of risk associated with the pillar not performing each duty. Pillars may be required to perform different duties over their lifetime, either in series or in parallel. Different duties may require different levels of risk management.
> FoS or other appropriate risk management index or margin
> operational requirements such as travelling distances and ventilation
> design of the extraction sequence, stoping and pillar sizing for subsequent stoping/extraction
> artificial support (backfill) requirements, if relevant
> need to have some areas unmined or to install a larger pillar where necessary.

The design document needs to detail the pillar design methodology and stope/extraction design methodology. The pillar design calculations and stope/extraction design calculations should be kept in a database.

It is critical to understand the relationship of mining-induced stresses on all pillars in a mining operation. As mining progresses/advances, stress will transfer from inter-room or yielding pillars and onto abutment pillars. Pillars should be designed taking into account the overall mining excavation void.

4.4.1 FACTORS INFLUENCING PILLAR STABILITY

The stability of pillars is a function of the:

> depth of cover
> strength of overlying or underlying ground
> rock/ground material properties

[8] Adapted from page 8: NSW Government|Trade & Investment Mine Safety.(2015). NSW Code of Practice|WHS (Mines) Legislation: *Strata control in underground coal mines*. New South Wales, Australia: NSW Department of Trade and Investment, Regional Infrastructure and Services.

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- geometry of the pillar, including both its shape and its width-to-height relationship – the absolute and relative dimensions
- extraction ratio
- geological structure
- confinement (eg by backfill)
- hydraulic radius
- extraction sequence
- stress regime.

The ratio of pillar width-to-height is a critical geometrical consideration in determining a pillar's strength and stability. For non-square shaped pillars, length is also a consideration.

Large-scale collapses of underground mining areas, or in some cases even the whole mine, can occur due to multiple pillar failures. Such failures can occur in a domino effect if pillars are undersized and the mine layout is poor. The main controls for these types of large-scale failures are correct mine layout design and pillar sizing. Barrier pillars are large pillars that will prevent a failure in one mining area being transferred to the other parts of the mine.

Geological structures, such as faults or joints in a pillar, can decrease the pillar strength and individual pillars can fail if they have been weakened. The main controls for these types of failure are on-site observation of conditions, leaving areas unmined, or installing a larger pillar where necessary.

Where the floor lithology, hanging wall or footwall rocks are weak relative to the pillar, a pillar support system may fail and pillars may punch into the floor or the orebody peripheral rock. An example of this is the punching of coal pillars into low stiffness claystone floor. This mode of failure is comparable to the bearing capacity failure of a foundation. Signs that this may have occurred are floor heave, or extensive fretting and collapse of rock around a pillar.

The hydraulic radius is the surface area of an opening divided by the perimeter of the exposed area being analysed. This is commonly used as a basis for stability estimates.

4.4.2 CONSIDERATIONS FOR BARRIER PILLAR DESIGN

Water inrush is one of the major hazards in an underground mine or tunnel and needs to be considered when designing barrier pillars. Control measures include identification of the inrush zone. The SSE, through a competent person, must determine the thickness of the intervening ground between the mining or tunnelling horizon and disused mine workings or bodies of water (see MOQO Regulation 73(3)). Disused mine or tunnel workings can contain accumulated water or material that flows when wet in underground mining or tunnelling operations. In underground coal mines, there should be a minimum separation of 50 metres in any plane. This measurement may be significantly more depending on the volume of material and the pressure head that it creates. For underground metalliferous mines, the separation distance between the mining horizon and disused mine workings or bodies of water should be determined by the geotechnical assessment and risk assessment.

Be cautious if referring to mine or tunnel plans or survey plans that were not drawn by a competent person. Plans of abandoned mines or tunnels and bore hole surveys may not be reliable.

Inrush control zones must be clearly indicated on the mine or tunnel plan as required by MOQO Regulation 217(1)(k). Figure 3 is an example of a plan showing an inrush control zone.

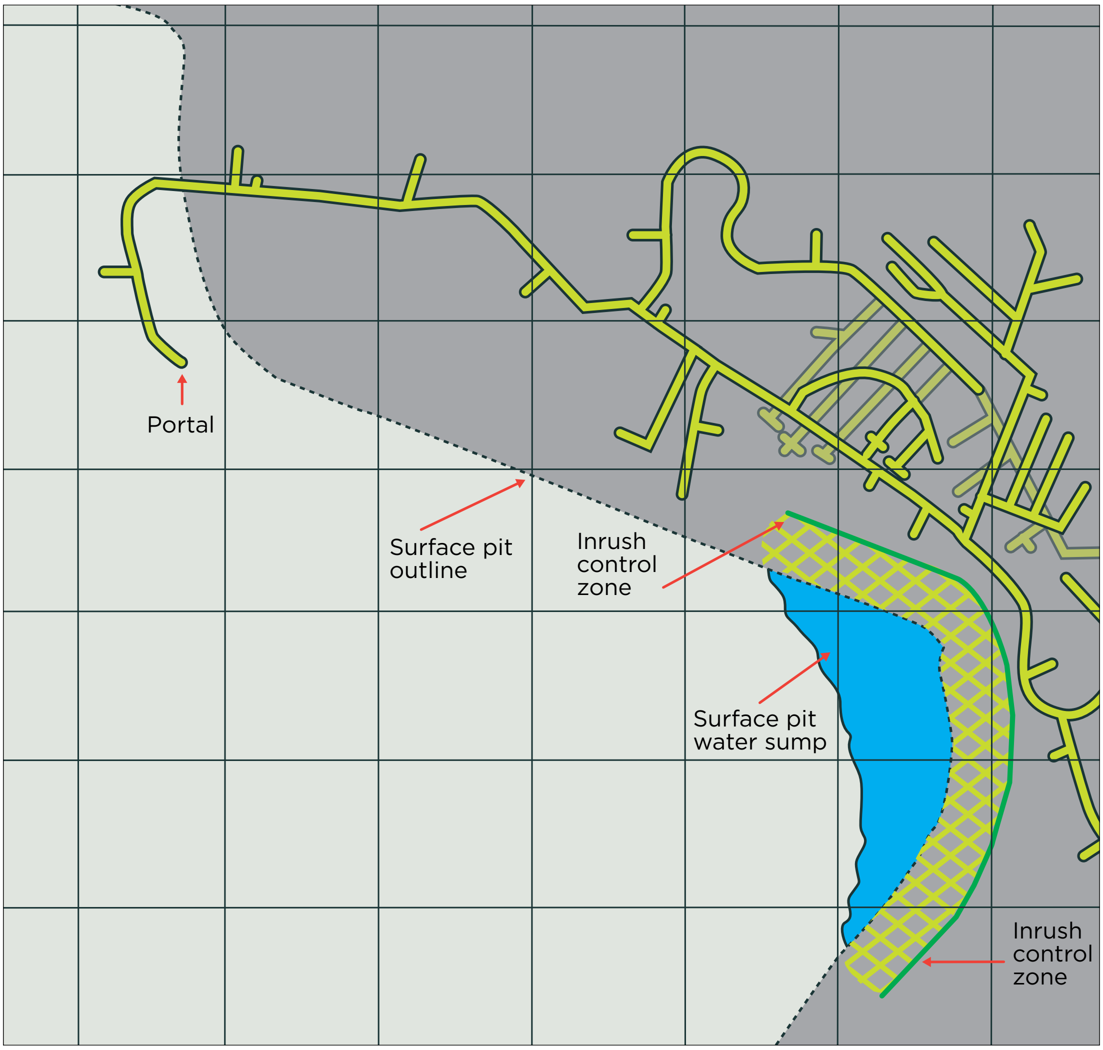

Figure 3: Example of inrush control zone marked on a plan

Coming into contact with unconsolidated deposits such as water bearing sands and gravels is a hazard of near surface working. This type of material can be very difficult to control with typical mine or tunnel support systems.

4.5 TEMPORARY AND PERMANENT GROUND SUPPORT SYSTEMS

Ground support, whether temporary or permanent, will be either local support or area support. Local support is used to prevent smaller rocks from falling from the roof/backs, sides or ribs. Area support is used to prevent major ground failure (total ground control).

The terminology used to refer to support systems differs between mining and tunnelling operations. Table 2 shows these differences. All support methods need to be determined by the geotechnical assessment and design.

<table>
<tr><th>TYPE OF OPERATION</th><th>COAL MINES</th><th>METALLIFEROUS MINES</th><th>TUNNELS</th></tr>
<tr><th>SUPPORT</th><th></th><th></th><th></th></tr>
<tr><td>Temporary</td><td>Any support device that creates a physical barrier between the heading and personnel installing ground support. The support system is usually hydraulic or air-operated in combination with mesh and/or straps.</td><td>Support installed with a specified service life, typically associated with areas planned to be stoped. Examples include ungalvanised mesh and split sets.</td><td>Ground support needed immediately after excavation, or close to the excavation face, to support or stabilise the ground in order to facilitate safe construction. This is also known as initial support. Can be temporary or permanent, depending on design life (see below).
Short-term ground support has a design life equal to or greater than the construction period. Temporary support may or may not form part of the permanent support.</td></tr>
<tr><td>Permanent (Primary)</td><td colspan="2">A support system to provide long-term support to a roadway or opening. Usually installed at, or close to, the working face. The primary support system is typically a combination of rock bolts, cable bolts and mesh, depending on the support design requirements established.</td><td>Primary or initial permanent ground support that has a design life equal to or greater than the operational life of the tunnel. It is usually installed at, or close to, the working face.</td></tr>
<tr><td>Permanent (Secondary)</td><td colspan="2">The installation of additional support either as planned infilling or in response to deteriorating conditions of the roadway or opening. The process is iterative. If the roadway continues to deteriorate, the support installed is escalated consistent with the established TARP thresholds. Support components may consist of any combination of active and passive support types.</td><td>Secondary or final permanent ground support that has a design life equal to or greater than the operational life of the tunnel.</td></tr>
</table>

Table 2: Terminology used to refer to support in coal mines, metalliferous mines and tunnels

4.6 PRIMARY AND SECONDARY SUPPORT SYSTEMS

Based on the geotechnical assessment, a competent person needs to identify appropriate support or reinforcement appropriate to achieve the required performance during the designed life of the mine or tunnel.

Potential corrosion of support and degradation of softer rocks is a consideration for areas where groundwater is present in longer life roadways. Where a corrosive environment exists, and long life is required from the support materials, consideration should be given to using galvanised or stainless steel support materials. Double corrosion protection may be achieved through plastic sheathed rock bolts with cement grout encapsulation inside and outside the sheath, such as a CT-Bolt system.

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4.6.1 ROCK BOLTS TO SUPPORT ROADWAYS

Rock bolts can be used as the principal support in an underground coal mine, provided this is supported by the site investigation and geotechnical assessment.

The diagrams in Figure 4 illustrate the stress regime and how roof rock bolts improve stability in an underground coal mining operation according to the four theories of roof bolting support:

a. simple skin support
b. suspension of thin roof/backs from a massive bed
c. beam building of laminated strata
d. keying of highly fractured and blocky rock mass.

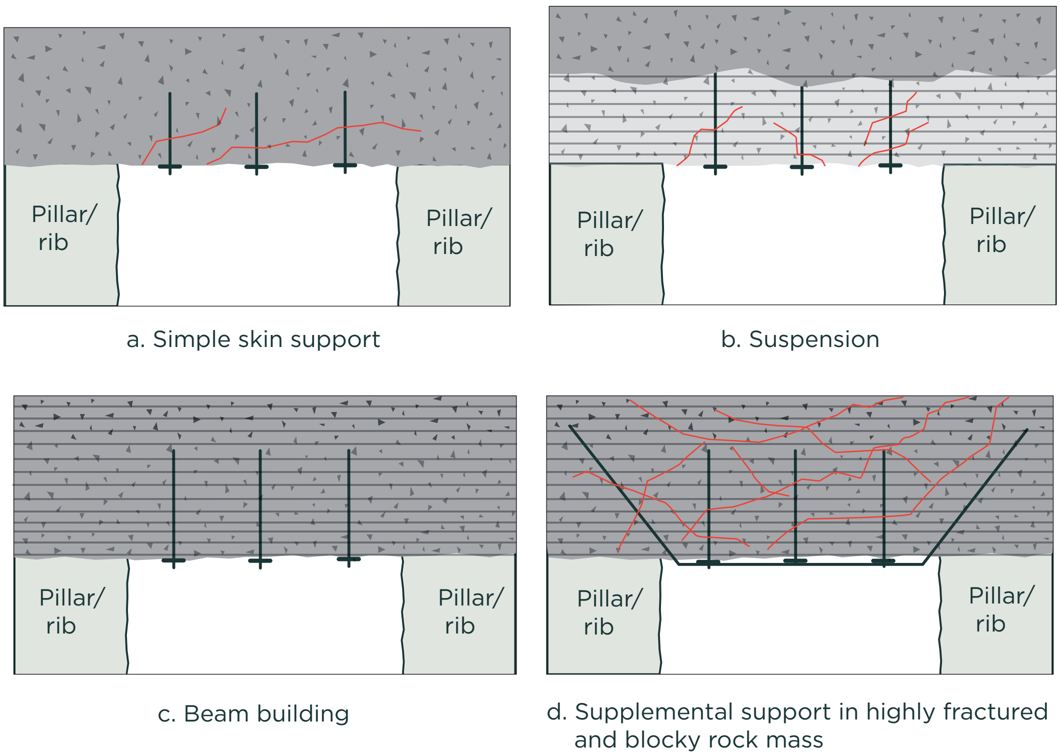

Figure 4: How tensioned rock bolts clamp the strata

With an effective rock bolt support design, the clamping of the roof bolts mitigates mobilisation of the rock mass and prevents the blocks from sliding past each other.

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4.6.2 ROCK BOLTS IN UNDERGROUND METALLIFEROUS MINING OPERATIONS AND TUNNELLING OPERATIONS

Provided the site investigation and geotechnical assessment indicates that rock bolts can be used as the primary support, they can be installed in:

> development backs and walls

> intersections, along with suitable secondary support

> wide spans, along with suitable secondary support

> portal face/high wall.

In an underground metalliferous mine or tunnel, rock bolts in backs and sides are usually bolted using the pattern shown in Figure 5.

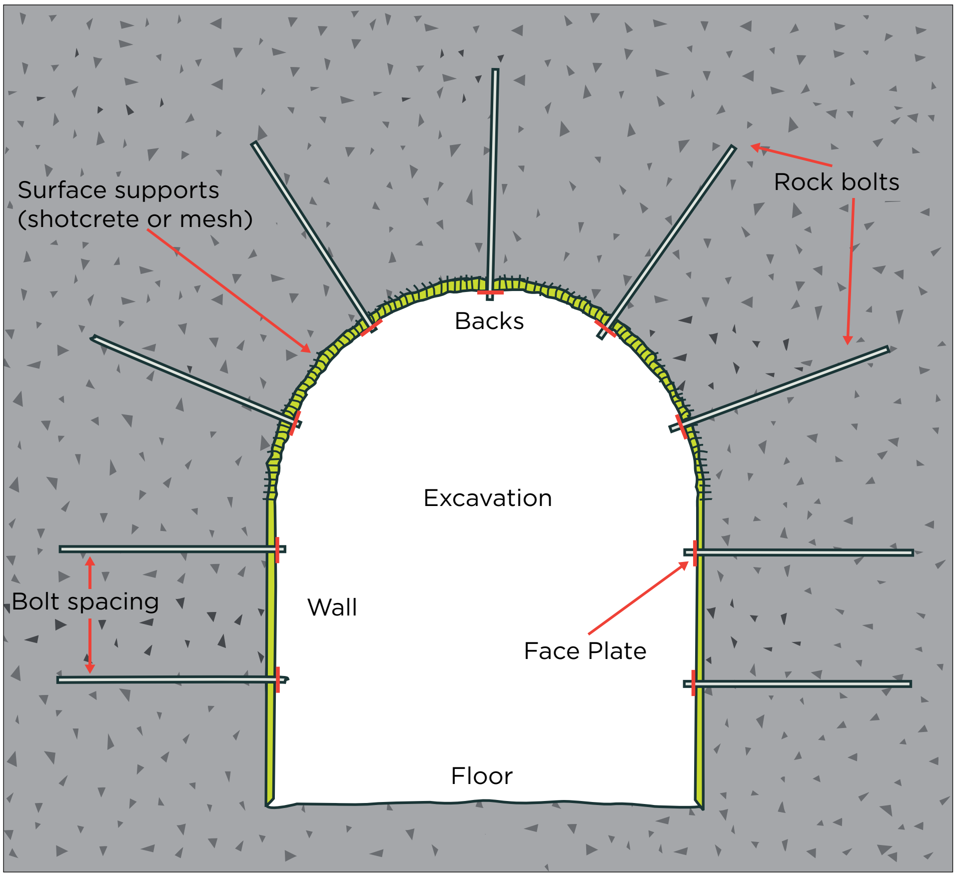

Figure 5: Rock bolts in a metalliferous mine or tunnel

4.6.3 CABLE BOLTS

Cable bolts are constructed from high-strength steel rope strands wound together. Single or double strand bird cage bolts may be used. Cable bolts can be used as part of the systematic support. The details need to be specified in the design.

Cable bolts are flexible and can be installed in longer lengths than conventional rock bolts or roof bolts, due to the height restriction an underground mine or tunnel roadway will have on installing steel bolts. Cable bolts can be installed using either pumpable cement grout or polyester resin cartridges, depending on the cable type and stiffness. They can be either fully or partially anchored by grout/resin.

The cable(s) are usually tensioned. The steel rope may be plain strand, or modified in a way to achieve the appropriate load transfer from the grout and the steel strand to the rock mass.

Where cable bolts are installed as a secondary support system after mesh and rock bolts, full interaction between support elements is achieved by plating and tensioning the cable bolts.

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4.6.4 PRECAST SEGMENTAL LININGS AND STEEL LINER PLATES

Soft ground tunnels excavated by shielded tunnel boring machines (TBMs) are often supported by precast concrete segments. The precast segments are installed in the tail of the TBM during a support cycle to form a ring which is connected to the ring erected in the previous excavation cycle. For expanded segmental linings, the rings are not connected and butt against each other. The TBM thrusts against the previously constructed ring during the excavation cycle forming a fully supported tunnel. Workers are not exposed to unsupported ground.

Below the groundwater table, the segments are bolted with gaskets for water tightness. Above the groundwater table, unbolted, expanded segmental linings are sometimes used, followed by a cast in situ concrete lining, pipeline installation, or other permanent lining.

All precast linings are reinforced against bending moments in the lining using traditional steel bars (rebar) or steel fibres. Precast linings need to be designed to withstand:

> ground loads
> groundwater loads if the lining is undrained
> construction loads, including thrust of the TBM while mining
> handling loads of the segments during the manufacturing process (precast yard) during transport into the tunnel and during erection of the ring.

Soft ground hand-mined tunnels or tunnels excavated with open shields can be supported by bolted steel liner plates. Steel liner plates need to be designed for ground, groundwater (if undrained) and construction/handling loads, similar to precast concrete segmental linings.

4.6.5 STEEL ARCHES AND LATTICE GIRDERS

It is usually faster and more economical to reinforce rock with rock bolts, steel mesh or straps, and shotcrete so the rock will support itself. If the anticipated rock loads are too great, such as in faulted or weathered ground, more robust steel supports may be required. Steel arches and lattice girders can be used in such rock or soil conditions.

Steel arches and lattice girders are usually installed in roadways in sections within one width spacing of the working face. Steel arches and lattice girders are generally assembled from the bottom up making certain that the arch/girder has adequate footing and lateral rigidity. Lateral spacer rods (collar braces) are usually placed between arches/girders to assist in the installation and provide continuity between ribs. During and after a steel/girder arch is erected, it is blocked into place with wood, grout-inflated sacks as lagging, or shotcrete. Current civil engineering tunnel practice discourages the use of wood blocking because it is deformable and can deteriorate with time. For the arch or girder to function as an arch it needs to be confined properly around the perimeter. Manufacturers of steel arches provide recommendations about the spacing of blocking points that should be followed closely.

When shotcrete is used as lining, it is important to make sure that no voids or laminations are occurring as the shotcrete spray hits the steel elements. Steel arches should be fully embedded in the shotcrete. Lattice girders are filled in by shotcrete in addition to being embedded in shotcrete.

Steel arches can provide localised support in areas where more robust support is required (eg under surface water bodies, such as streams, rivers and lakes) and in zones such as at the start of a mine where there are significant transitions from soil to competent rock, and rock arching does not occur due to low cover and/or weak ground.

4.6.6 SHOTCRETE LININGS

Shotcrete plays a vital role in metalliferous mines, tunnels and shaft construction because of its versatility and adaptability. Desirable characteristics of shotcrete include:

> its ability to be applied immediately to freshly excavated surfaces and to complex shapes such as shaft and tunnel intersections, enlargements, crossovers, and bifurcations, and

> the ability to change the applied thickness and mix formulation to suit variations in ground behaviour.

Shotcrete that is used for ground support often requires reinforcement to give it strain capacity in tension (ie ductility) and to give it toughness. Unreinforced shotcrete can be used for ground support if tensile capacity demand is low.

Shotcrete can be applied as a wet or dry mix, and can be reinforced with steel or plastic fibres, or welded wire fabric (steel mesh). It is typically used to provide longer term surface protection of large openings.

Design of a shotcrete programme should consider the following:[9]

> amount of shotcreting required, thickness and layers of application

> strength required including strength gain with time

> presence of ground water (eg quantity, chemistry, pressure)

> need for drainage of groundwater from behind the shotcrete

> water quality

> type of shotcrete mix (wet or dry)

> use of admixtures (plasticisers, accelerators, micro silica)

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[9] Adapted from pages 6-7: Mines Occupational Safety and Health Advisory Board (MOSHAB). (1999). Code of practice: *Surface Rock Support for Underground Mines*. Western Australia, Australia: Government of Western Australia.

> type of fibre reinforcement
> curing requirements
> testing and monitoring
> correct spraying equipment and application
> the need to include the anticipated/estimated deformation of the opening following excavation.

4.6.7 STEEL STRAPPING

Steel strapping panels provide surface support between rock or roof support components. When used with rock bolts, steel strapping can be considered to provide long-term support. Steel straps need to be designed to support the predicted rock or roof loads between rock support components. Often these loads are from loose rock of limited size between the rock or roof support.

Profiled steel straps (typically 2 mm thick and 20 tonnes tensile strength) with pre-drilled holes for roof bolts can be used as a template for roof bolt installation and to support the ground between the roof bolt positions.

4.6.8 WOOD AND STEEL PROPS, INCLUDING HYDRAULIC PROPS

Traditional wood props are used to provide temporary support. Engineered wood props are produced with up to 50 tonnes capacity and progressive yield. Steel hydraulic props work on the car jack principal and typically have 20-30 tonnes capacity. Single use types are also available. They can be extended using water pressure and left in place. Steel and wood props are designed primarily as axial support members for predicted ground loads and should not be exposed to bending moments.

4.6.9 WOOD CRIBS OR CHOCKS

Wood cribs or chocks (also known as pigsties) are made by building up layers of horizontal wood chock pieces between the floor and roof/backs, placing each layer at right angles to the previous one. Wood cribs are primarily axial support members similar to props. Ensure the correct quality, size, strength and moisture content of the wood is used for support props or cribs.

4.7 TEMPORARY SUPPORT SYSTEMS

The mine or tunnel operator must ensure that no one enters an area of unsupported ground which may be a hazard unless they are installing ground or strata support (or supervising that work). See MOQO Regulation 117.

Where unsupported ground is a hazard to workers, and primary support cannot immediately be installed, then suitable ground or strata temporary support must be designed and implemented. This includes those areas where workers are installing or supervising the installation of temporary support. The plans showing the ground or strata support arrangements in areas of unsupported ground must be displayed in locations readily accessible to all workers. See section 5 for further information on implementing the control measures.

Examples of temporary support are described below. Their use will be determined by risk assessment or established in a TARP.

4.7.1 SPILES, CANOPY TUBES AND FOREPOLING (PRE-SUPPORT)

Sometimes, it is necessary to enhance (pre-support) the ground to provide adequate stand-up time to accommodate mining and installation of either temporary or permanent ground support. Pre-support can consist of driven steel rods, steel sheets or wood boards/timbers (known as forepoling or spiles), or drilled and grouted rods and pipes (known as spiles or canopy tubes). Pre-support is integrated into the excavation cycle, installed ahead of the next excavation round. The heading or crown is supported on the next excavation cycle, providing enough stand-up time to safely install the designed support system, usually in conjunction with shotcrete support. Pre-support is usually required in soil and weak rock conditions or when recovering fallen ground.

Design of pre-support needs to consider the excavation cycle, and provide adequate overlap between successive installations of spiles/forepoles. Pre-support should be spaced around the excavation perimeter so that ground instability cannot take place between individual pre-support elements. The pre-support elements need to be designed for longitudinal bending (ie along the axis of the roadway) considering the predicted ground loads upon excavation of the heading.

4.7.2 GROUND MODIFICATION AND DEWATERING

Ground modification is usually implemented before mining or tunnelling begins and can include:

> grouting with cement or chemical grouts
> ground replacement with cementitious materials mixed with in situ soils
> ground freezing
> dewatering.

When used in relation to ground support, the ground modification is intended to enhance the strength of the ground and reduce ground loads by improving the ability of the ground to be self-supporting. Ground modification can also be used to fill voids and/or to reduce ground permeability and thereby reduce groundwater inflows.

The design will usually target achievable ground strength after modification. In this case, the design needs to include a verification methodology to ensure that ground improvements have met design strength requirements prior to mining or tunnelling. Design of ground modification as a support element needs to consider loads and bending moments in the support system.

4.7.3 MESH CAGES

The mesh cage is a temporary support system used to protect workers when installing roof bolts using portable hand-operated rock bolting drills. Where on-board bolter miner systems cannot be used, a mesh cage system of temporary support is used. The mesh cage has been adopted in most coal mines where rock bolts are used as the primary support system and in roadways that are passively supported with steel delta type supports.

The mesh cage system enables workers to work under supported ground at all times when at the face of the heading. Before bolt installation commences, a mesh panel is pushed to the roof/backs using two 'Stinger' air leg machines and another mesh panel is hung vertically from the roof/backs at the face. These panels hang down in front of the working position to protect against lumps falling from the face and to act as a barrier demarcating the

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unsupported area. The side mesh is unfolded from the roof mesh and draped down the rib side and fixed to the previous panel. The roof and rib bolts are then installed. When the bolting cycle is completed the remaining unbolted mesh panel is tied horizontally to the roof/backs ready for the next cutting cycle.[10]

Steel wire mesh panels can be used with rock bolts or standing support and are used to contain the roof/backs and ribs between the support components. When used with rock bolts, the system becomes a permanent support.

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4.7.4 PIPE ROOF METHODS

A pipe roof (also known as a pipe arch or cellular arch) is often installed between two shafts. Large diameter steel pipes are installed by drilling or micro-tunnelling methods around the periphery of the tunnel, either in an arch shape or as a flat roof (box section). Pipes are installed adjacent to one another with both a structural and watertight seal between each pipe. Each pipe is typically filled with concrete and the interior of the pipe arch or box is excavated. Temporary supporting struts are sometimes required before placement of permanent cast in situ concrete lining inside the pipe arch or box.

The pipe roof method is usually used for large span tunnels in soil in areas of very low cover, where surface settlement needs to be kept to a minimum. It is a very robust support system, as the pipe roof provides very stiff supports which serve as pre-support before the interior is excavated.

4.7.5 COMPRESSED AIR TUNNELLING

The use of compressed air shields to control groundwater has decreased with the advent of pressure-face TBM technology. Compressed air can be an effective method of stabilising soil and controlling groundwater in open-face tunnel excavations and can be especially useful in squeezing soft clayey (cohesive) soils.

In granular soils, compressed air can be used to offset the water pressure at the tunnel face, preventing the flow of groundwater (and fine-grained soils) into the face. In cohesive soils, the objective is to provide enough air pressure so that the combination of the soil's natural strength with the air pressure stabilises the tunnel for excavation and support operations. Compressed air is usually limited in soil grain sizes ranging from fine silt to medium sand; in coarse sand and gravel air losses are often unacceptably high.

Disadvantages of using compressed air include:

- The need to install air locks between the tunnel face and the construction access shaft. In some cases, more than one airlock will need to be installed.
- Inefficient use of labour, with limited work time for workers under compressed air. It is essential that workers undergo decompression after work periods. This further adds inefficiencies. If the air pressure is suddenly lost, workers may experience decompression sickness (ie 'the bends').

These disadvantages mean compressed air shields are often not favoured compared to pressure-face TBMs. However, due to requirements for regular manned inspection and maintenance of the pressure-face TBM cutterheads, compressed air support is often required

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[10] Adapted from page 17: Arthur, J. (2006, July). *Ground Control in Coal Mines in Great Britain*. Paper presented at Coal Operators' Conference, University of Wollongong, New South Wales, Australia. Retrieved from: www.undergroundcoal.com.au/acarp_dev/Coal%2098-09/Proceedings%202006%2027-06-06VF.pdf

as a contingency. The use of compressed air for special purposes such as cutterhead maintenance is common throughout the tunnelling industry. The compressed air pressures used will be related to the hydrostatic groundwater heads.

Control measures need to be implemented to eliminate or minimise, so far as is reasonably practicable, the risks associated with compressed air tunnelling.

Workers entering a compressed air environment must be suitably trained and competent. It is essential that they have proof of hyperbaric fitness before being allowed to enter the pressurised tunnel or cutterhead area. See WorkSafe's code *Emergency Preparedness in Mining and Tunnelling Operations* for more detailed information.

4.8 SHAFTS

A shaft is an opening or blind heading that is excavated at an angle of more than 15 degrees below the horizontal in any underground or tunnelling operation. The general application of ground support remains the same, but with the added complication of working close to or at the vertical. For this reason, precast segments or poured concrete linings are often used.

Shaft construction methods and excavation techniques vary depending on conditions and the purpose of the shaft. During construction, shafts can provide entry for people, materials, equipment and/or ventilation to a mine or tunnel.

The competent person needs to determine the appropriate shaft lining or ground support based on the geotechnical properties of the rock which the shaft passes through. The shaft lining/support can perform several functions. It is a safety feature preventing loose or unstable rock from falling into the shaft, and a place for shaft sets to bolt into to enable heavy loads to be suspended in the shaft. It may require a smooth surface to minimise resistance to airflow for ventilation.

Install temporary ground support to ensure the safety of persons working at the base of the shaft using for example an artificial roof (pentice) or working stage to provide overhead cover while permanent support is installed. Refer to section 4.7 for more information.

Shafts in soils should have systematic lining or support to safely accommodate ground and groundwater loads and isolate workers from exposed ground.

4.9 CONTINUOUS MODELLING AND DESIGN VERIFICATION

The mine or tunnel operator must ensure continuous modelling of the ground or strata support methods is undertaken. This is a requirement of MOQO Regulation 71(2)(d). The task and frequency of continuous modelling needs to be specified in the geotechnical assessment.

This may include:

- design verification of support system
- testing of support systems
- analysis of monitoring results
- back analysis of ground failures
- reviewing the geotechnical assessment when ground conditions are encountered that are outside the limits assumed in the geotechnical assessment
- monitoring of production blasts (for drill-and-blast) to address any rock damage at the excavation perimeter.

As part of the design, the geotechnical assessment needs to specify what design verification is required. The design is verified through monitoring. This is one part of continuous updating of the geotechnical modelling. See section 6 for more information.

The mine or tunnel operator should verify the design to ensure:

> Inspections and hazard mapping done at the mining or tunnelling operation confirm the validity of assumptions made in the geotechnical assessment during the design of the ground support systems.
> Sufficient investigation is undertaken during development to confirm ground conditions particularly where roof/backs geology are subject to change. This could include drill cores or other geological logging/mapping techniques.
> A monitoring plan is prepared. See section 6.3 for further information.
> Comprehensive monitoring of rock bolted sites, subject to local change, is undertaken for design verification. This involves detailed measurement of roof convergence and the performance of the bolt system. It may also involve detailed measurement of rib dilation and roadway internal measurements.
> Measurement of roadway convergence in underground mining operations or tunnelling operations is completed using multiple point extensometers. See section 6.5 for information about selecting suitable monitoring methods and instrumentation.
> Resin encapsulated rock bolt loads are measured on a minimum of four rock bolts/roof bolts distributed across the roadway section.

The results of design verification activities may require the geotechnical assessment to be updated. Changes may then be required to the PHMP, including: updates to the manager's support rules, TARPs and SOPs. Provide training for workers about any changes made to the PHMP.

4.9.1 MEASURING ROADWAY OR TUNNEL DEFORMATION BEHAVIOUR

Monitoring roadway or tunnel deformation behaviour determines potential failure modes that are occurring around the roadway or tunnel. This involves the measurement of the timing, style and magnitude of roof, pillar and, where required, floor deformation and convergence. Monitoring provides an understanding of the design requirements and effectiveness of roadway or tunnel support systems on the stability of the roadway.

When undertaking a ground support design programme, the measurement of roadway deformation behaviour for the existing (old) support system needs to be undertaken at the start of the design investigation programme. Monitor the roadway deformation behaviour to optimise and verify the new design.

4.9.2 SITE SELECTION

When selecting representative monitoring sites for roadway or tunnel deformation behaviour, consider the following:

> Monitoring sites should not be located within the transition zone between the old and new support systems. The monitoring site should be at least 10 m from any sections supported by different support systems.
> No major geological structures or abnormalities should be in the vicinity of the site.

> There should not be any significant variations in roof/backs lithology, unless they are representative of the target area as a whole.
> Monitoring sites should be installed close to the excavation that is currently being advanced or will be advanced.
> Where convenient, the site should be close to other measurement or monitoring sites for easier data collection.

Two techniques commonly used for measuring deformation are:

> direct measurement within the strata, using extensometry
> indirect measurement of total deformation using closure around the roadway (ie convergence measurement).

See section 6.9 for further information.

PART C

IN THIS PART:

PART C

05/

IMPLEMENTING THE CONTROL MEASURES

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

***Regulation 68** Content of principal hazard management plans*

***Regulation 69** Review and revision of principal hazard management plans*

***Regulation 71** Principal hazard management plans for ground or strata instability*

***Regulation 117** Installation of ground or strata support*

***Regulation 118** Obligations relating to ground or strata support*

Health and Safety at Work (General Risk and Workplace Management) Regulations 2016

***Regulation 9** Duty to provide information, supervision, training and instruction*

5.1 GROUND SUPPORT/CONTROLS AND EXCLUDED AREAS

The design document and the PHMP detail the control measures to be implemented to manage the ground or strata instability hazard. Parts of the mine or tunnel may be excluded from support system requirements and are considered unsafe to enter. These places, for which no future access is anticipated, include waste areas, some stopes and disused areas of the mine, and roadways leading to these areas. These areas need to be barricaded to prevent entry. Ideally, the roadway is fully closed off with mesh if it is not stopped or sealed. Chains are not a suitable barrier to these areas. Signs should also be in place to explain the reason for the barricade.

The mine or tunnel operator needs to have procedures for preventing unplanned access to vertical openings and unsupported ground. Workers must be made aware of these procedures. The procedures need to be checked by a nominated person to ensure they are being followed. Include these procedures in the PHMP.

The SSE also needs to consider the possible effects of ground movement in these parts of the mine and if there are any potential risks to workers working or travelling to other parts of the mine or tunnel.

5.2 APPLICATION FOR CONSTRUCTION OR PERMIT TO TUNNEL

The SSE should ensure the PHMP includes details about the process required for the development of the ‘application for construction’ or ‘permit to tunnel’. In coal mines in New Zealand the term ‘authority to mine’ is used. In this section the term ‘application for construction’ includes ‘permit to tunnel’ and ‘authority to mine’.

Development of an application for construction is a process that ensures that all assessments have been done, design completed and signed off, controls put in place, workers trained, and equipment ready (including emergency equipment). After an application for construction has been signed off, mining or excavations can proceed in a specified area or panel, under a specific minimum support regime (manager’s support rules), and specified mine or tunnel design. An application for construction is authorised by the mine or tunnel manager.

The application for construction process includes a review of the expected geotechnical conditions for the relevant area and ensures the support plans and TARPs are prepared for the area. A hazard plan/map will be developed for each application for construction. See section 6.7 for information on geotechnical hazard zones.

Mining or excavation should cease if the observed geological/geotechnical conditions for the area covered by the application for construction are not within the range of expected geotechnical conditions considered during the design process. The support requirements should be reassessed by a competent person.

The mine or tunnel manager or shift supervisor should brief the workers about the specific area covered by the application for construction and draw their attention to any particular hazards and risks. This ensures all workers have prior awareness of the area they are working in, including any associated support rules and TARPs.

5.3 SELF-SUPPORTING MINES OR TUNNELS

In some circumstances, the geotechnical engineer may determine that the ground in a particular mine or tunnel, or in a particular section/part of a mine or tunnel can be self-supporting. Provided that the conditions of the manager's support rules are followed this ground is defined as supported.

These self-supporting mining or tunnelling operations will still require a monitoring plan to check if the conditions have changed. Monitoring may later reveal that ground or strata support is required in particular areas.

Self-supporting does not mean unsupported. Unsupported ground refers to ground that has not been supported as per the requirements of the geotechnical design or the manager's support rules. A person must not enter an area of unsupported ground including an area of unprotected, unstabilised or freshly shotcrete sprayed areas.

The mining or tunnelling operation needs to have a formalised, clear definition of 'unsupported' and 'supported' ground and a formal protocol for people working near these areas.

5.4 INSTALLATION TRAINING

Workers involved in the installation of ground support and reinforcement must, so far as is reasonably practicable, complete training before installation commences. These workers are required to be competent to perform their roles. They need to have an understanding of the:

> contents of the ground or strata instability PHMP
> effectiveness of ground support or ground reinforcement and how it works
> ground instability hazards at the operation
> scaling and barring down (see section 5.5)
> support installation methods and procedures outlined in the plan
> support and reinforcement components and consumables used at the operation and the equipment involved (see section 5.9)
> importance of installing the correct support materials in accordance with the approved support rules
> correct installation techniques
> handling, storage, application and disposal of polymeric chemicals and the personal protective equipment (PPE) required
> monitoring arrangements and testing procedures.

SOPs need to be readily available to all workers involved in installation so they are fully knowledgeable about the type(s) of ground support and reinforcement in use. These SOPs must be referred to in the PHMP. See section 5.10.

Additional training should be provided where there are changes to ground conditions or support and/or reinforcement. Refresher training should be provided to workers when needed. Records of training should be kept.

5.5 SCALING AND BARRING DOWN

Scaling (also known as barring down) should be done by workers before starting work, and on an ongoing basis, to ensure that the ground, walls, face and roof/backs are made – and kept – safe from loose and/or potentially unstable rock or coal.

No ground should be assumed to be stable until it has been sounded and scaled with a scaling bar or drill steel. If there are any doubts about the stability of the ground, no person should enter that area. The shift supervisor or deputy needs to be notified.

Scaling needs to be undertaken:

> for drill and blast excavation, after each blast, when the face, roof/ backs and wall areas and spoil heap have been washed down
> before and during the installation work, and
> during the shift, in all working faces where new ground is exposed.

There should be a programme in place for check-scaling of all active travel ways. Develop SoPs for scaling for each mine taking into account the combination of manual or mechanised scaling, the ground conditions, drilling and blasting techniques, heading geometry, equipment, and mining method(s).[11]

Scaling needs to be continued until the mine or tunnel is abandoned.

5.6 INSTALLING TEMPORARY SUPPORT

The mine or tunnel operator must ensure that workers installing or supervising the installation of ground or strata support who are exposed to a ground or strata instability hazard are protected with temporary support. See MOQO Regulation 117(1)(b).

The manager must ensure that plans showing the ground or strata support arrangements for temporary support are displayed in locations readily accessible to all workers. See MOQO Regulation 118(b).

Mine or tunnel operators need to ensure that workers installing hand-held temporary support are:

> given relevant training
> told about restrictions on entering areas of unsupported ground
> advised that they are not to move beyond the last line of overhead support
> provided with plans of areas of unsupported ground.

Where mesh and bolts are used, the boundary between supported and unsupported ground should not extend beyond the last complete row of rock bolts. The exception is where the distance between the working face and the last row of bolts is less than the interval between each row of bolts. The area between the last row of bolts to the face needs to be scaled by workers. This must occur with appropriate temporary support provided to protect workers from the hazard. Procedures should allow for spot bolting in this area if required.

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[11] Adapted from page 16: Government of Western Australia, Department of Industry and Resources. (1997). Guideline: *Underground barring down and scaling*. Western Australia, Australia: Author.

5.7 EQUIPMENT USED DURING INSTALLATION

The equipment used to install the ground support and reinforcement components needs to be, where practicable, purpose designed and built for the particular range of components in use at the mine or tunnel. Equipment specifications should be documented.

SOPs should cover the maintenance and operation of the equipment (according to the manufacturer's instructions), formal equipment inspections (including functionality), and reporting required. SoPs may include:

> The reach and capacity of the equipment. They should be matched to the opening dimensions.

> The placement of the support and reinforcement element(s), including mesh, on the equipment. This should be carried out from a secure position, prior to installation.

> The correct alignment of the support or reinforcing element relative to the orientation of the previously drilled hole.

> The appropriate operation of the insertion device (eg if a drifter is being used, the mode of drifter operation should be 'percussion off' or 'no percussion' while travelling up the slide).

> The use of rotation only (no percussion) when tensioning threaded reinforcement components, where appropriate.

> The required torque that needs to be applied to the rock or roof bolt or dowel nut without damaging the individual components.

5.8 TIMING OF SUPPORT/REINFORCEMENT INSTALLATION[12]

The timing of the installation of ground support and reinforcement is an integral part of the design to limit the potential for ravelling of the rock mass. In excavations requiring control, the delay in the installation of the ground support should be minimised so far as is reasonably practicable. It can be up to 24 hours from the firing of a development face before the heading is clear of post-detonation explosive fumes, watered down, scaled and cleaned out ready for the installation of ground support and reinforcement. Extended delays of weeks to months in the installation of ground support may jeopardise the effectiveness of the ground control because the rock mass loosens and there may be a reduction in the shear strength.

When the ground conditions are poor, there may be less than 24 hours where the excavation will remain open and stable (the stand-up time). Special measures may be required to promptly install ground support and reinforcement prior to the removal of broken rock from the face. Shotcrete may be applied to the exposed roof/backs and walls before the heading is cleaned out. This will minimise the time that the ground has to stand unsupported.

Before advancing, ground support and reinforcement should be installed and tensioned, if appropriate, preferably on a hole-by-hole basis or at the very minimum on a row-by-row basis. If the ground conditions are considered to be poor, or there is a high potential for a failure of the block, use the hole-by-hole installation technique.

The timing and type of support required needs to be specified in the design document and detailed in the manager's support rules.

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[12] Adapted from pages 37-38: Government of Western Australia, Department of Industry and Resources & Mines Occupational Safety and Health Advisory Board (MOSHAB). (1997). Guideline: *Geotechnical considerations in underground mines*. Western Australia, Australia: Government of Western Australia.

5.9 SUPPORT MATERIALS/CONSUMABLE ITEMS

5.9.1 SELECTION

The technical specifications from the geotechnical assessment need to be used to guide the selection of consumables (eg bolts, cables, nuts, plates for the bolts, the resin, shotcrete, grout, mesh, and straps). All consumable items forming part of the support system need to be suitable for the purpose when installed according to the manufacturers' instructions. Consumables are suitable for use if:

> an assessment of any risk to safety and/or health has been carried out

> a reputable independent lab testing provider confirms product suitability[13] for use underground under the specific site conditions, and precautions to be taken

> field or installation trials or other procedures have validated performance

> chemicals and grout have not passed their 'use by' date.

5.9.2 ADEQUATE SUPPLY (QUANTITY AND QUALITY)

The mine or tunnel manager should ensure the correct support materials (quality and amounts) are available at the right place in the mine or tunnel for workers responsible for installation. An appropriate management process, supported by SOPs, should be implemented to ensure the quantity and quality of support materials are:

> correctly ordered

> continuously monitored

> correctly handled

> correctly stored, according to the manufacturer's specifications, to ensure:
  - product quality is maintained with stock rotated; particularly items with a defined shelf life (especially resins and chemical binders)
  - resin cartridges are protected from direct sunlight and high temperatures and used before the expiry date
  - threaded components are protected from rain, groundwater, and contamination during storage and general damage during transportation
  - pallets of bagged cement or water-based grout materials are (ideally) shrink-wrapped.

Quality assurance checks of the support materials and consumables should be undertaken (eg to check that the length of drill steels and bit sizes are according to specifications).

5.10 STANDARD OPERATING PROCEDURES

The mine or tunnel operator needs to ensure Standard Operating Procedures (SOPs) are in place for the installation, maintenance, removal, and quality control of ground support and reinforcement for each stage of mining or changed circumstances. Good quality installation of ground support and reinforcement components is critical to ensuring that ground control conforms with the designs developed as part of the geotechnical assessment.

Development of SOPs should take into consideration the manufacturer's instructions for achieving good quality installation of their components, and what is required to implement the design safely. This information must be available to all workers involved in the installation of support and reinforcement. SOPs should incorporate manufacturers' specifications, where relevant, and they should also be referred to in the PHMP.

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[13] Various consumables are tested in a laboratory-simulated environment (or as near as possible to an underground mine or tunnel environment) for performance, load capacities (support resistance) and energy absorption capabilities.

Topics for SOPs may include the following:

SCALING AND BARRING DOWN

> See section 5.5.

CONSUMABLES

> See section 5.9.

INSTALLATION

> A procedure for each component of the support system – that is, for each different type of bolt or support being installed (incorporating the manufacturers' instructions for correct installation, and testing for each element type). This SOP can be referenced in the support plan, or vice versa.
> Use of a suitable barrier or enclosure while the support is being installed, or whilst the packing or backfilling of excavated areas is occurring. This is to safeguard against any risks to workers' health and safety during excavation.
> The equipment used to install each element.
> Assessment of installation standards by a competent person as ground support and reinforcement components are being installed. This will ensure the support system is installed correctly and follows quality control procedures.
> Maintenance of equipment used to install support.
> The actions required by the installer where there is an insufficient supply of suitable support material.

QUALITY ASSURANCE

> Quality assurance checks of installation and maintenance, such as:
  – routine inspections
  – task observations
  – installation audits at varying stages of installation and maintenance
  – inspections to ensure the support is installed correctly, in accordance with specifications and the SOPs, and remains effective.
> Pull testing.
> Checking that installed support is in accordance with the manager's support rules, TARPs and ground conditions.
> Checking length of holes drilled, spin and hold times for resin bolts.
> Borehole micrometer testing.
> Encapsulation testing for resin encapsulated bolts.

CONSULTATION AND TRAINING

> Consultation and training for workers about installation.

MONITORING

> See section 6.

REPORTING OF GEOTECHNICAL INFORMATION

> See section 3.3.3.

5.11 MANAGER'S SUPPORT RULES FOR INSTALLATION

The manager's support rules specify the minimum ground support requirements for individual sections of the mine or tunnel as determined by the geotechnical assessment. Different manager's support rules are developed detailing the arrangements for all the various types of ground support that are used at the mining or tunnelling operation.

The support rules need to also refer to the geotechnical hazard plans/maps and the hazard level to which they are applicable. It is likely and appropriate to have multiple (three or more) sets of support rules to suit different hazard levels. See section 6.7.

The manager's support rules show the ground support requirements, with written directions and diagrams. The manager's support rules need to be prepared, dated and signed by the mine or tunnel manager. These rules should be filed in the mine or tunnel records system and readily accessible.

The following statement needs to be included in the manager's support rules: "Nothing in this support plan prevents a worker from installing higher standards of support than those specified."

Manager's support rules may include the following:

- diagrams or photographs
- excavation dimensions (including tolerance)
- maximum advance per cycle
- preferred sequence of excavation
- the support system layout, pattern and dimensions (see section 4.1):
  - support materials, method of work and equipment to be used during installation
  - layout pattern and dimensions of the support system, including maximum spacings between support components and tolerances
  - additional support arrangements for areas such as roadway intersections
  - method of any necessary temporary support to secure safety
  - method and equipment for the withdrawal of support
- monitoring arrangements using a TARP (that could include observation and measurements, where appropriate) to ensure ongoing effectiveness of the support system (see section 6.4)
- the area or site to which the support plan applies
- the date the plan becomes effective and when the plan is no longer valid.

If a competent geotechnical engineer has assessed ground as self-supporting (see section 5.3), and the excavation is secure without the requirement for reinforcement or support, the manager's support rules should include:

- preferred sequence of excavation
- excavation dimensions
- maximum advance per cycle
- procedures for scaling or barring
- procedures for dealing with abnormalities.

Examples of support plans are shown in Figures 6 and 7. The code green support plan shows the minimum support requirements. The code red support plan shows additional support that is required for specified circumstances. An example of a TARP is shown in the Appendix.

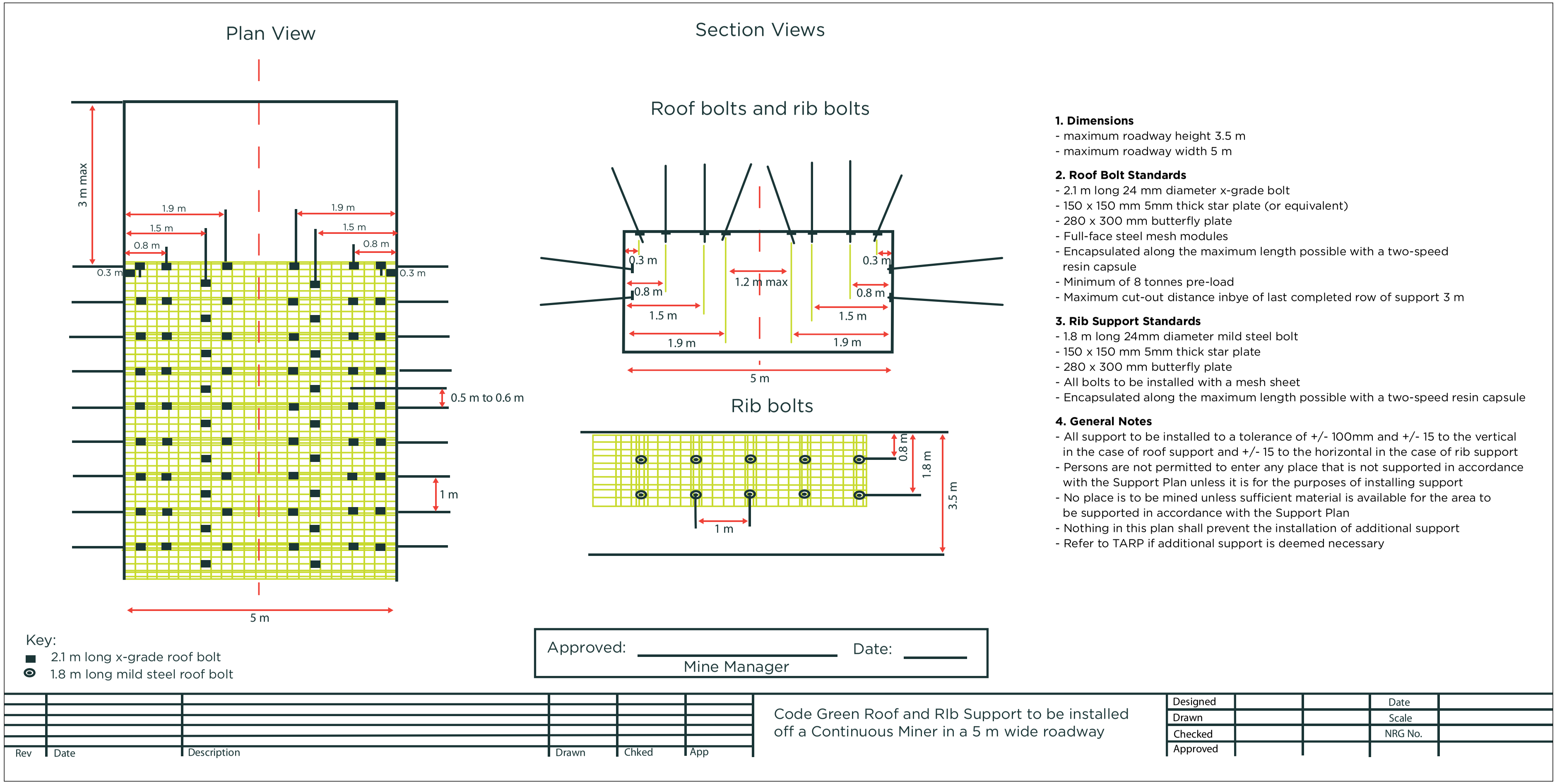
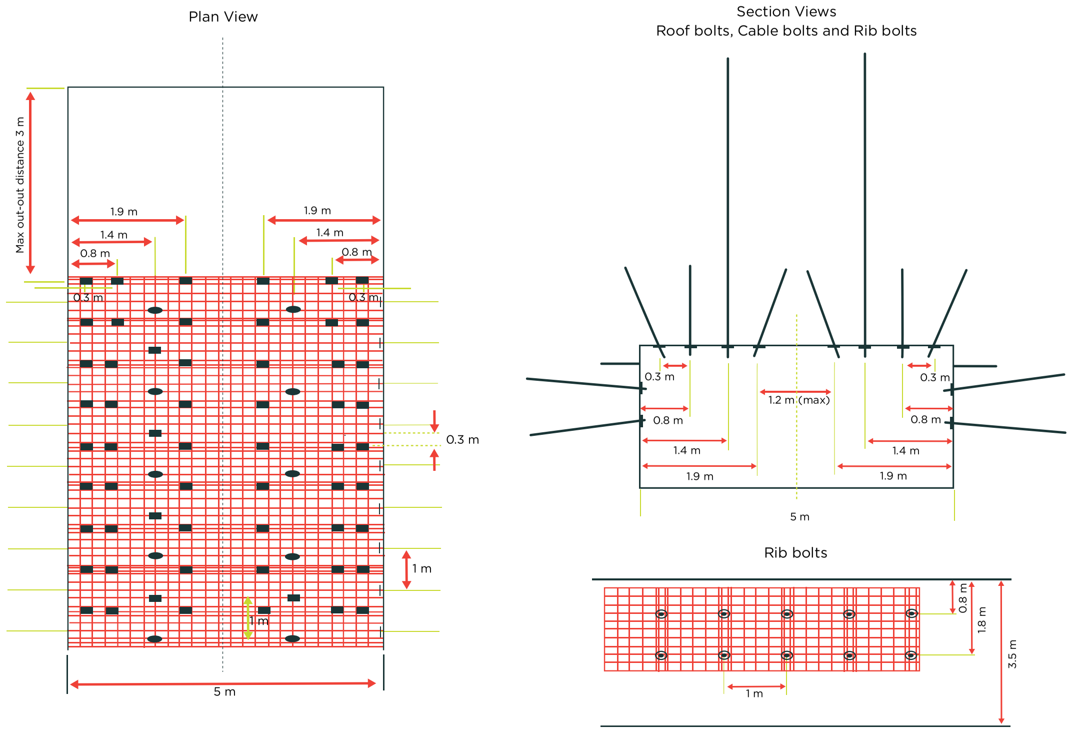


Figure 6: Code green support plan[14]

[14] Adapted from page 60: NSW Government|Trade & Investment Mine Safety. (2015). NSW Code of Practice|WHS (Mines) Legislation: *Strata control in underground coal mines*. New South Wales, Australia: NSW Department of Trade and Investment, Regional Infrastructure and Services.



Key:
- 2.1 m long x-grade roof bolt
- 8 m long 60 tonne capacity cable to be installed and tensioned within 3 m of the face
- 1.8 m long mild steel roof bolt

1. Dimensions
- maximum roadway height 3.5 m
- maximum roadway width 5 m

2. Roof Bolt Standards
- 2.1 m long 24 mm diameter x-grade bolt
- 150 x 150 mm diameter 5mm thick star plate (or equivalent)
- 280 x 300 mm butterfly plate if bolt installed outside of overlapped mesh
- Full-face steel mesh modules or sheets
- Encapsulated along the maximum length possible with a two-speed resin capsule
- Minimum of 8 tonnes pre-load
- Maximum cut out distance inbye of last completed row of support 3 m

3. 8 m Cable Bolt Standards
- 8 m long 60 tonne capacity bulbed cable
- All cables to be installed and tensioned no further than 3 m outbye of the face
- All cables to be point anchored with resin and fully encapsulated with grout
- All cables to be post-grouted no further than 20 m outbye of the face
- All cables to be pre-loaded to a jack load of 20 t0 25 tonnes
- 300 x 300 mm square 12 mm thick face plate and 150 x 150 mm square backing plate

4. Rib Support Standards
- 1.8 m long 24 mm diameter mild steel bolt
- 160 x 160 mm diameter 5 mm thick Star Plate (or equivalent)
- 280 x 300 mm butterfly plate if bolt installed outside of overlapped mesh
- All bolts to be installed with a mesh sheet
- Encapsulated along the maximum length possible with a two-speed resin capsule
- Maximum cut-out distance inbye of last completed row of support 3.5 m

5. General Notes
- All support to be installed to a tolerance of +/- 100 mm and +/- 15 to the vertical in the case of roof support and +/- 15 to the horizontal in the case of rib support
- Persons are not permitted to enter any place that is not supported in accordance with the Support Plan unless it is for the purposes of installing support
- No place is to be mined unless sufficient material is available for the area to be supported in accordance with the Support Plan
- Nothing in this plan shall prevent the installiation of additional support
- Refer to TARP if additional supports is deemed necessary

Approved: ____________ Date: ______
Mine Manager

Rev	Date	Description	Drawn	Chked	App

Code Red Roof and Rib Support to be installed off a Continuous Miner in a 5 m wide roadway

Designed			Date	
Drawn			Scale	
Checked			NRG No.	
Approved				

Figure 7: Code red support plan[15]

[15] Adapted from page 61: NSW Government|Trade & Investment Mine Safety. (2015). NSW Code of Practice|WHS (Mines) Legislation: *Strata control in underground coal mines*. New South Wales, Australia: NSW Department of Trade and Investment, Regional Infrastructure and Services.

5.11.1 DISPLAYING MANAGER'S SUPPORT RULES

The mine manager must ensure the manager's support rules, showing the ground or strata support arrangements to be put in place, are displayed in locations readily accessible to all workers. For example:

> in the relevant crib rooms

> in the relevant mining or tunnelling section (eg on the continuous miner or jumbo)

> at a suitable location close to the working area that the plan applies to.

5.11.2 REVIEWING MANAGER'S SUPPORT RULES

The manager's support rules need to be periodically reviewed and updated to reflect any changes in:

> ground or tunnelling conditions

> consumables or equipment used

> management structure for implementing the support system.

Update the rules, where relevant, with matters arising from an audit or in response to any risks or areas of non-compliance identified by the inspectors.

Manager's support rules need to be reviewed after:

> any fall of ground or failure of the support system, including self-supporting roadways

> any worker involved in implementing the support system informs the mine or tunnel manager that the support plan cannot be complied with.

5.12 INSTALLING HIGHER STANDARDS OF SUPPORT

Workers may need to install higher standards of support if they consider that the ground needs extra support – that is, more support installed at more frequent intervals than that required by manager's support rules. If workers have installed higher standards of support they are to report this to the shift supervisor. See MOQO Regulation 71(2)(h).

5.13 INADEQUATE GROUND OR STRATA SUPPORT

If any part of the roof/backs or sides has become exposed, and ground support is needed to keep the exposed area safe, workers responsible for installing ground support need to immediately install ground support in accordance with the manager's support rules. If the workers are not able to install ground support immediately they need to:

> withdraw immediately to a place of safety

> prevent access to the exposed area

> report the issue to the supervisor or underviewer.

If any installed ground support appears to be unsuitable or unstable, workers responsible for installing ground support need to replace that ground support, or make it stable, as soon as possible. If the workers are not able to replace or make the ground support stable as soon as possible, they need to:

> withdraw immediately to a place of safety

> prevent access to the area where ground support is unsuitable or unstable

> report the issue to the supervisor or underviewer.

Any supervisor or underviewer who is notified about unsuitable or unstable ground or strata support needs to make sure that:

> anyone working in or passing the area where the ground support needs to be installed, replaced, or made stable withdraws to a place of safety
> access to that area is prevented
> as soon as possible, ground support is installed, or the ground support which has become unsuitable or unstable is replaced or made stable in accordance with the manager's support rules.

5.14 ROCK BOLT INTEGRITY

Rock bolts need to be examined, tested and monitored throughout their life cycle to ensure they are providing the support they were designed for. Rock bolt testing and monitoring arrangements need to be installed in accordance with the manager's support rules. For further information on monitoring see section 6.6.

5.14.1 PULL TESTING OF ROCK BOLTS

Rock bolt pull testing can be used to confirm the strength of the anchorage for partially anchored rock bolting systems, unless this exceeds the strength of the rock bolt.

For fully encapsulated anchored systems it should not be possible to pull out the bolt without breaking it. If the bolt pulls out, then this indicates a very poor rock bolt bond strength. Short encapsulation pull testing can be used to measure the bond strength of fully encapsulated bolt systems. This is commonly used as part of a geotechnical assessment. A similar test method using short test bolts can also be used for friction anchored systems. The test is performed underground and is the appropriate proof test of a bolt/resin/rock system. It should replicate the procedures, consumables and equipment in use for the support.

To do a short encapsulation pull test, drill a series of holes to varying depths. Bolts of the required length are installed with a short resin capsule to give an encapsulated bolt length of not more than 300 mm. The pull test needs to be performed as soon as possible, after allowing an initial curing period of 30 minutes. After this time an axial load is applied to the end of the bolt using the pull testing equipment, and the bolt deflection measured. The load is applied up to 80% of the tensile yield load of the bolt, unless the maximum system load is achieved first. The measured anchorage or bond strength can be used by the support designer to confirm that the bolt system is capable of providing adequate support in the ground conditions and to help determine the number of rock bolts required.

For friction anchored bolts (split sets) the manufacturer must specify the tension (pull) to be applied in order to test that the bolt is providing the required support.

Pull testing should be repeated at suitable intervals as part of a monitoring plan. It can be used to check for any change in ground conditions that could reduce the anchorage or bond strength and so invalidate the design. It should also be used for partially anchored systems as a proof test to check installation quality.

Pull testing does not provide direct information on actual loading or adequacy of the installed bolt pattern.

5.14.2 NUMBER OF TESTS

The designer should specify the required minimum number of tests to be undertaken at a mine or tunnel in order to ensure the support system is performing to the design.

For coal mines, ideally at least four roof horizons should be chosen for testing, depending on the planned bolt length and roof lithology. A minimum of three tests should be carried out at each of the chosen roof horizons. For example, for a 2.4 m bolt, the horizons would normally be at 600, 1200, 1800 and 2400 mm. If significant changes in lithology are present within the bolted horizon, tests may need to be carried out at different horizons to determine the influence of each lithogical unit on the bond strength of the proposed bolting system.

For tunnels, support strain or load monitoring may be appropriate for more complex standing support structures and for precast concrete linings, where excessive loading is not always evident prior to failure. Load cells can be used in some cases (for example, under a vertical steel leg) but in general surface-mounted strain gauges are the most convenient means of measuring strains in steel supports.

5.14.3 PULL TESTING OF FRICTION BOLTS

As friction bolts (split sets) or similar do not have a thread to attach, a pulling device (pull collar) needs to be positioned onto the bolt before it is inserted in the hole. The position of these pull test friction bolts should be shown on the manager's support rules and sufficient collars provided for the workers. This enables pull testing, as per the manufacturer's or designer's requirements, to be undertaken at a later date.

5.14.4 INSTALLING CABLE BOLTS

Install cable bolts in accordance with the support rules and SOPs.

Cable bolts can be full column grouted, or partially encapsulated in certain circumstances. This should be determined as part of the support design process.

Where cementitious grouts are used, ensure the liquid-to-solids ratio of the mixed grout is accurately measured to achieve the correct consistency for both pumping and strength. Recommendations on the correct liquid-to-solids ratio should be made by the grout manufacturer. Sufficient grout should be mixed to fill the hole in one operation.

The quality of the pumped grout should be checked by sampling on a regular basis. The uniaxial compressive strength and density of these samples are determined by mix ratios and laboratory testing.

5.15 LIFTING AND SUSPENSION OF EQUIPMENT IN ROCK BOLTED ROADWAYS OR TUNNELS

Where rock bolts are used for lifting or suspending loads, the mine or tunnel operator needs to ensure appropriate bolts are used, and installed using the SOP. An example of a special purpose bolt is an anchor bolt that is used to avoid bolt breakage or a roof/backs fall.

SOPs should include the following requirements:

> An assessment of the roof/backs condition in the proposed anchor bolt location, to ensure the ground is suitable for the proposed duty.

> Any bolt used for the lifting or suspending equipment (other than as above) should be an anchor bolt.
> Anchor bolts and their associated lifting shackles should be installed in compliance with instructions provided by the manufacturer. They should be readily identifiable as anchor bolts both before and after installation.

Rules covering the lifting or suspending of equipment in roadways or tunnels using rock bolts should take into account:

> the specifications of the bolts and lifting shackles
> the weight of the equipment
> any induced load that may act on the bolts or suspension equipment (eg the dynamic load from the inflexion point of a tensioned conveyor)
> the number and layout of the bolts to ensure stability of the equipment
> the manufacturer's instructions for the installation and use of the bolts
> the integrity of the bolt and the effects of corrosion
> the additional imposed loading on the strata
> the need for additional roof/backs support.

Before anchor bolts are installed a competent person (appointed by the SSE, or mine or tunnel operator) should examine and test, if necessary, the roof/backs where the bolts are to be installed. This inspection is to ensure that the current support is adequate and the roof/backs in a suitable condition. This inspection should also include inspection of nearby monitoring devices.

The competent person appointed by the manager should examine the installation of the anchor bolts before they are first used, supplemented by tests if necessary. This will confirm that the bolts have been installed in accordance with the manager's support rules and the roof/backs support has not deteriorated since the previous examination.

Where anchor bolts are installed for lifting or suspending equipment, a suitable monitoring plan for the area should be included in the manager's support rules. Dedicated monitoring should be installed prior to lifting. Monitoring devices should be read before and after all lifting operations and should be monitored at regular intervals when lifting is taking place.[16]

5.16 WITHDRAWAL OF SUPPORT MATERIAL

The mine or tunnel operator needs to ensure the following:

> No person withdraws support material from any place in a mine or tunnel other than by a safe method and from a position of safety.
> There are suitable rules that describe the measures to be taken in withdrawing support materials. It is good practice to take steps to support temporarily or reinforce the ground to facilitate the withdrawal of permanent supports.

[16] Adapted from page 31: Health and Safety Executive (2007) *Guidance on the use of rock bolts to support roadways in coal mines*. Retrieved from: www.hse.gov.uk/pubns/mines01.pdf

PART C

06/

MONITORING, INSTRUMENTS AND REPORTING

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

Regulation 61 *Maintenance of records of health and safety management system*

Regulation 71 *Principal hazard management plans for ground or strata instability*

Regulation 117 *Installation of ground or strata support*

Regulation 221 *Shift reports*

Regulation 222 *Examination of mining operations*

6.1 MONITORING GROUND OR STRATA INSTABILITY

Ground or strata instability must be monitored at the underground mining or tunnelling operation. This is to identify changes in the ground conditions or roof loading, and to ensure the controls implemented continue to be effective in managing the hazards and potential risks to workers. This requires accurate measurement and monitoring of different parameters, such as rock properties, stresses, strata deformation and support behaviour.

The geotechnical assessment and design document need to be used to help to define the monitoring and the monitoring system to be implemented. These documents reflect the risks to ground or strata instability associated with specific excavations, mining methods, rates of extraction and other factors.

Instrumentation, visual inspections, automated or manual recording of data may be used. Monitoring may be required on a routine basis (daily, weekly, monthly) or on a planned project-specific basis, such as a detailed study of all extensometers.

Monitoring methods and plans may need to be changed if there has been a change to the support design, changes to ground conditions or work practices, new technology or equipment, or as a result of reviews, audits or inspections.

6.2 BENEFITS OF MONITORING

Monitoring can help to explain observed ground or strata behaviour and to test theoretical models which have been applied in the design of controls. Routine and systematic measurement and monitoring of the ground control system achieves the following:[17]

> **Provides geotechnical data and validates design assumptions**

Geotechnical data can be obtained from monitoring and instrumentation, for example:

- recording rock strengths with pressure gauges during rock testing
- using graphical presentation to plot the fracturing pattern along an excavation during ground
- penetration radar testing.

This data can be used to calibrate and check support designs for early detection and prevention of ground movement or instability. The data helps to define ground or strata

[17] Adapted from Open House Management Solutions. (2015). *Strata Control Training Manual*, unpublished manual prepared by A.P. Esterhuizen. Klerksdorp, South Africa.

behaviour and the performance of installed support. If monitoring or instrumentation indicate values different to the design assumptions, review the design and make adjustments if required. The manager's support rules need to be modified to reflect any changes.

> **Monitors rock mass response**

If rock mass characteristics change during operations, it is likely the support design will no longer be suited to the change in characteristics. Closure meters, strain gauges and crack meters are used to determine the response of the rock mass as a result of stress changes. Variations in rock properties such as strengths are detected from instrumentation and monitoring. This information is also used to calibrate and check support designs.

> **Confirms layout performances**

The use of suitable monitoring devices (eg tell tales) determines and defines roof/backs behaviour trends. This information is used to check the suitability of a design or to confirm layout performances.

> **Confirms support performances**

Load and closure monitors installed with support units can indicate where an adjustment to the designed support is required.

> **Assists in managing the risks associated with falls of ground and rock bursts**

Accelerated movements observed through monitoring may result in the evacuation of workers before catastrophic fall of ground or support failure.

> **Identifies remedial work required**

Repair or replace faulty or failed monitoring devices as soon as practicable. If monitoring devices have been installed incorrectly, reinstall them the right way.

6.3 MONITORING PLAN

A monitoring plan or SOP needs to specify the monitoring activities. Include details about:

> areas of the underground mining or tunnelling operation that are covered by the monitoring plan or SOP

> each monitoring station, including:

- location
- unique identification and code
- instrumentation in relation to the geological and mining features
- the type of monitoring to be carried out.

A schedule may set out details of the data to be collected, frequency, analysis methods, reporting of monitoring data, roles and responsibilities. The mine or tunnel should be divided into measurement zones to enable the systematic measurement, recording, and auditing of routine monitoring devices at the prescribed frequency. For example, widened roadways and other critical excavations may have specific monitoring frequencies, parameters and trigger levels. The relative risks may change during the life of the excavation opening (eg due to widening and/or stress changes associated with extraction).

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In coal mine roadways supported by rock bolts, accurate monitoring of roof displacements needs to be in place. Monitoring triggers should cover displacement magnitudes and displacement rates.

A monitoring plan or SOP also needs to cover:

> training and competency requirements for all aspects of monitoring instrumentation, including:
  – installation, use, inspection frequency, readings, recording, reporting, analysis, maintenance and replacement of monitoring instrumentation
  – criteria for the replacement, how and when the replacement occurs
  – who is appointed to what role and their responsibilities.
> adjustments of regular monitoring that should occur according to the varying site geology or conditions
> investigation of any abnormalities in the monitoring results, and procedures that apply where the potential for ground movement or failure is identified (eg changes which require immediate attention), or if the support design is changed.
> criteria for determining when the monitoring plan must be reviewed or changed; detail the requirements for communicating these changes to workers.

Monitoring results need to be analysed, interpreted and retained for future reference, and held onsite. Include information about any action required to remediate any unsafe areas. These records should be signed off when appropriate remedial work has been satisfactorily completed.

6.4 TRIGGER ACTION RESPONSE PLANS (TARPs)

Trigger action response plans (TARPs) for ground or strata instability specify the actions to be taken when:

> Workers observe ground conditions that have departed from normal (or from what is expected). Conditions may be more adverse or favourable. Changes in conditions could result in ground failure occurring.
> Planned controls are not in place, or operable, potentially leading to a major incident.

See the Appendix for an example of a TARP.

6.4.1 ROUTINE MONITORING USING TARPS

Routine monitoring checks the performance of support that has been installed. This can be supported by TARPs.

The SSE needs to ensure that:

> all relevant workers are trained in the content of monitoring TARPS, including trigger action levels and the appropriate remedial actions
> the results of remedial actions and continued requirements are provided to the mine manager until a position of stability is recorded.

The TARP should provide a list of triggers (usually three or four) observable at the operator level. The triggers range from normal to extremely abnormal. For each hazard level the appropriate support type, as defined in the manager's support rules, and actions are identified. The TARP may also detail when the equipment needs to be replaced.

Even in stable conditions where no excavation work is proposed (for example, at tourist mines) the mine or tunnel operator needs to have arrangements in place to provide assurance that any changes in the level of risks are detected and suitable measures are taken.

6.4.2 FACTORS TO CONSIDER WHEN DEVELOPING A GROUND CONTROL TARP

The SSE decides on the appropriate format of the TARP to use for the mining or tunnelling operation. Factors to consider include:

- simplicity
  - use simple visual triggers to detect any change or deterioration in ground conditions (eg roof/backs movement, sag, faults and joint swarms)
  - use commonly understood language
  - be brief and use colour coding. See the Appendix.
- significant items
  - TARPs should focus on the significant factors influencing ground or strata behaviour (behaviour is influenced by a number of factors)
- clear triggers
  - triggers that are easy for workers to identify and understand
- clear actions
  - actions to be taken should be relevant to the trigger that initiates the action
- clear accountability
  - actions should be assigned to someone who has the authority to take the appropriate actions and who is available in an appropriate timeframe to take those actions
- communication
  - there should be a clear line of communication between workers, supervisors and engineers, and between shifts
- monitoring frequency
  - risks may change during the mining or tunnelling cycle
  - any changes should be reflected in monitoring frequencies and triggers for each phase of the cycle
- empowering workers
  - depending on the ground conditions, the TARP should empower operators to install higher standards of support, install roof/backs monitoring, reassess conditions with a supervisor, and/or stop mining and evacuate the site
  - the TARP should also advise authority levels about any reduction in the level of support

TARPs should be displayed on underground noticeboards or in the control room.

Regular reviews of the risk assessments and research will ensure triggers and planned actions within the TARPs are appropriate.[18]

[18] Adapted from pages 33-34: NSW Government|Trade & Investment Mine Safety.(2015). NSW Code of Practice|WHS (Mines) Legislation: *Strata control in underground coal mines*. New South Wales, Australia: NSW Department of Trade and Investment, Regional Infrastructure and Services.

6.5 SELECTING SUITABLE MONITORING METHODS AND INSTRUMENTATION

Show the location of all monitoring equipment on the mine plan. The location of monitors depends on the monitoring instrument to be used and the installation and spacing requirements. Instruments need to be checked regularly to ensure they are correctly calibrated.

Some monitoring methods are shown in Table 3.

MONITORING METHOD	
Photography	> take photographs of walls, roof/backs, pillars, drawpoint conditions and fragmentation > record the date each image is captured
Convergence monitoring (see also section 6.10.2)	> measures displacement of exposed rock using tensioned wires across drive walls or 3D imaging > examples of when it can be used include: – in caving processing above stopes or extraction panels – changes in mine road movement because of nearby development – to assess the ability of stope walls to remain stable for a sufficient length of time to complete extraction and fill the stope)
Feeler gauge	> two steel rods that are pushed into a hole to measure gaps or separations in the roof of a mine > the steel rods can move independently and have small feelers that slide into a gap when pressed against the side of the hole > when a gap is located measure its size by moving the two rods independently > measure the gap or separation with a ruler or callipers after removing the feeler gauge from the hole
Real time seismic monitoring and associated data analysis methods (see also section 6.8)	> assists in understanding: – the cause-effect responses to blasting – mining in high stress conditions where potential for bump or burst conditions exists – performance monitoring of ground support reinforcement – site ground characteristics
Absolute and/or incremental rock stress measurement	> used at large, complex, or seismically active sites to determine the pre-mining rock stress field and changes in the rock stress field > particularly relevant where there is the potential for rock instability involving large volumes of rock at critical locations for example: – open stope crown pillars below filled stopes and barrier pillars – coal pillars in access drives and extraction panels
Laser surveying	> used to determine the extent of over-break, under-break and non-break in large open stopes > can also be used to determine the 3D void shape and volume where caving or collapse voids have formed > re-surveying on a regular basis may be required
Surface subsidence monitoring	> surveying of subsidence pegs and satellite imaging, for example

MONITORING METHOD	
Longitudinal projections	> used to summarise: – stope geometry changes during blasting – date and number of rings fired – estimates of tonnage broken – estimates of the extent and depth of wall sloughing (preferably using laser surveying techniques or by visual estimate – observations of ground conditions
Comparison of observed ground conditions and numerical modelling	> verifies model results against observed ground condition > compares ground conditions observed during monitoring with predictions from modelling > identifies discrepancies between stope and pillar dimensions > determines the reasons for discrepancies and identifies appropriate remedial actions

Table 3: Monitoring methods

6.6 MONITORING BOLT INTEGRITY

6.6.1 CABLE BOLT MONITORING

Various strategies have been used to try to measure the in situ performance of multi-strand cable bolts. However, the practical challenges and the high demands on the cable bolts have typically compromised the effectiveness of cable bolt monitoring.

6.6.2 MONITORING OF BOLT INTEGRITY – COAL MINES

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Falls of ground can occasionally occur following fracturing of installed rock bolts, due to overloading or corrosion or a combination of the two. Monitoring devices are available to detect fractured rock bolts where this is suspected. The main risk factors are the presence of highly saline or corrosive water in the roof, together with bolt loading by shear movements in the immediate roof. Depending on the corrosion chemistry, galvanised bolts are not necessarily effective in these circumstances.

Two types of monitoring bolts are available. They use an electrical resistance circuit or an optical fibre loop built in to the bolt:

> The electrical version incorporates the rock bolt steel into one or more electrical circuits which will be interrupted on bolt failure. The electrical bolt can be interrogated singly using an ohmmeter, or it can be connected in a chain and interrogated manually or by the mine's monitoring and control system. The position of any break can be found using a Time Domain Reflectance (TDR) meter.

> The optical fibre version incorporates a fibre optic strand inside the bolt. This can be checked manually from below by shining a cap lamp onto the end of the bolt. If no return is seen, the bolt is broken.

These monitoring bolts are intended to be installed on a systematic basis. For example, one row every 20 m along a rock bolted roadway in place of the standard rock bolts that indicate if in situ rock bolt failure is occurring.

6.6.3 VIBRATING WIRE STRAIN GAUGES

Vibrating wire strain gauges (VWSGs) are suited to mining applications as they are easy to use and relatively robust and reliable. The VWSG is composed of a tensioned wire attached to a diaphragm or other sensing element. An integrated vibration sensing coil is used to pluck the wire and sense the frequency at which the wire resonates.

These types of instruments are particularly suited to long-term monitoring because they have much greater stability than equivalent systems using electrical resistance strain gauges.

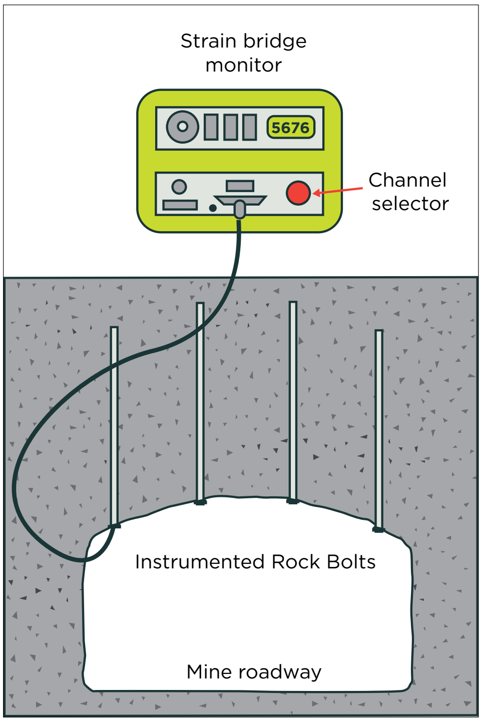
6.6.4 STRAIN GAUGED ROCK BOLTS

Strain gauged rock bolts are used to measure axial and bending strains imposed on the rock bolts when installed in a roadway. The strain gauged bolts replace some or all of the normal bolts in the bolting pattern. See Figure 8.

Strain gauged bolts are manufactured from actual rock bolts as used in the support system. Nine pairs of electrical resistance strain gauges are installed on each bolt in flat bottomed grooves machined along the full length of the bolt on opposite sides. The spacing of the strain gauges along the bolt varies with bolt length but typically ranges between 160 mm and 250 mm for the standard 1.8 m to 2.4 m range of bolts.

Strain gauged bolts are installed as part of the normal cycle of bolting operations, using the same equipment, consumables and bolting patterns, where practicable. A protective sleeve at the end of the bolt is used to cover and protect the connector during installation, with an extended installation dolly typically required. An initial set of readings is taken immediately prior to installation so that temperature effects are minimised. The strain gauges on each bolt are periodically recorded to measure strain changes in the bolts. Systems are available to monitor the bolts remotely from the surface.

The bolts are subjected to testing and quality control procedures during and after manufacture.



(Reproduced with permission from Strata Control Technology, NSW, Australia)

Figure 8: Strain gauge

6.7 GEOTECHNICAL HAZARD ZONES – HAZARD PLANS OR MAPS

Geotechnical hazards need to be systematically tracked and shown on geotechnical hazard plans or maps for existing and future areas of the underground mining or tunnelling operation. This includes areas of stoping, development, panel extraction, shafts or cross-cuts. Use the most up-to-date data available in compiling the hazard plans or maps. This information can come from the geotechnical assessment and the geological or geotechnical mapping.

Figure 9 shows an example of hazard zones on a hazard map and Figure 10 shows a hazard map from an underground metalliferous mine.

Hazard plans or maps should include the following, where applicable:

> existing and planned excavation openings
> drillhole or bore hole locations
> mapped and interpreted geological features (eg faults, shear zones, dykes). This includes features that have been mapped in excavated roadways and predicted features for future mining areas
> mapped roadway conditions (eg fretting, spall)
> geotechnical domains
> depth of cover (if applicable)
> location of monitoring devices
> lithology
> seam or ore body thickness
> seam or ore body split areas
> presence and nature of igneous intrusions
> seam or ore body dip
> horizontal stress direction.

Regularly update the hazard plans or maps to reflect any changes in the above information.

The mine or tunnel operator needs to ensure the hazard mapping process is undertaken by a geotechnical engineer or other competent person and includes:

> Systematic ground and support inspections carried out at suitable intervals at the site. The frequency of the inspections is based on how quickly visual conditions change or are expected to change. In active mining zones (eg areas affected by extraction taking place in close proximity), weekly or daily assessments may be appropriate.
> Priority areas for inspection, such as areas within the influence of nearby mining activity, and zones where higher risks have been previously identified.
> Inspection plans tailored to expected site conditions that provide a quantitative measure of risk for each underground roadway, and take into account other available information such as core logs, drill hole and monitoring data.
> Inspection plans supplemented with procedures for reporting and assessing problems and taking appropriate actions where required (ie TARPs).
> Visual inspection data (stored and updated each time hazard mapping is completed). Reports should be able to be generated highlighting the relative risk in each area and reasons for any increased risk.

The SSE needs to ensure workers are aware of any changes to geological hazards.

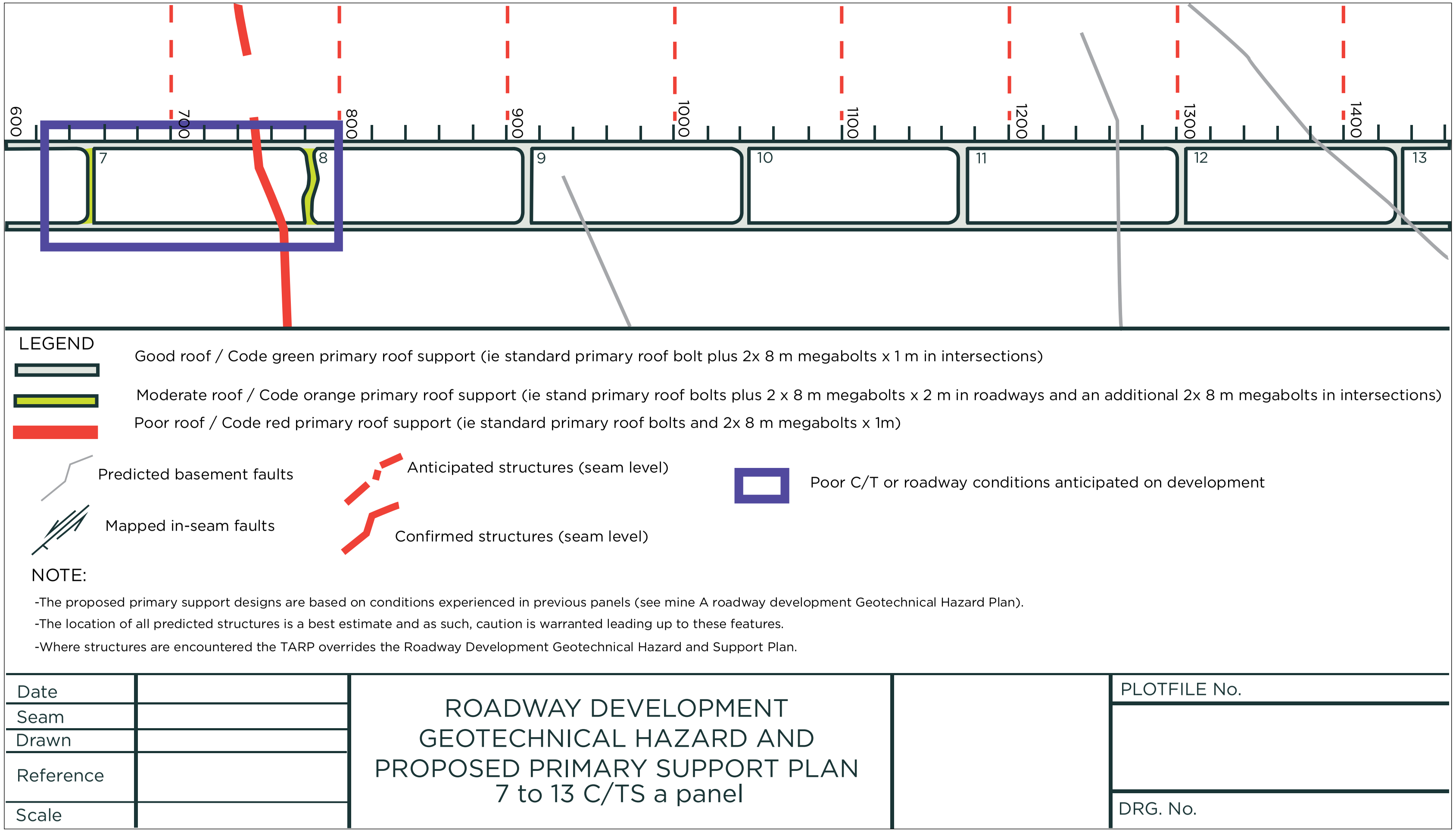


Figure 9: Example of hazard zones shown on a hazard map[19]

[19] NSW Government|Trade & Investment Mine Safety.(2015). NSW Code of Practice|WHS (Mines) Legislation: *Strata control in underground coal mines*. New South Wales, Australia: NSW Department of Trade and Investment, Regional Infrastructure and Services.

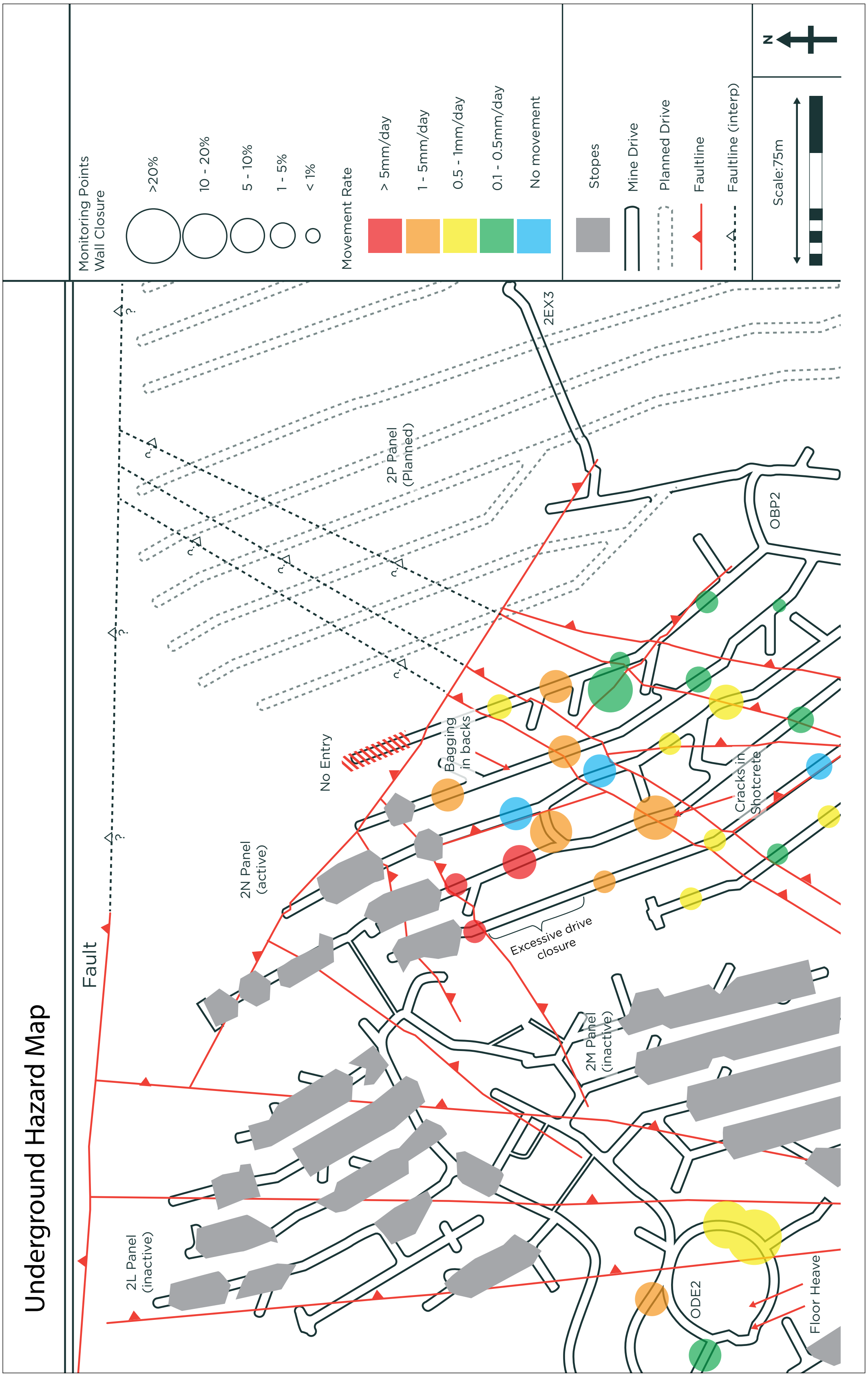


Figure 10: Example of a hazard map from an underground metalliferous mine

6.8 SEISMIC MONITORING

Seismic monitoring data assists in understanding:

> the cause-effect responses to blasting
> mining in high stress conditions where potential for bump or burst conditions exists
> performance monitoring of ground support reinforcement
> site ground characteristics.

This is useful for mining or tunnelling operations in close proximity to buildings or people (eg tunnelling projects within towns and cities, or underground mining operations located close to residential areas).

Consider the following factors when designing an appropriate seismic monitoring plan:

> the capability of sensors to determine magnitude and source parameters
> the orientation of sensors within the mine or tunnel and expected sources of seismicity
> locating seismic event noise filtration and sensors away from ore passes and other sources of background mine 'noise' (eg vibration from ore passes, ventilation fans and crushers)
> locating the digitiser/communications computer close to the sensors for cleaner waveforms
> the potential need for far field monitoring and redundancy in the system (ie for situations where sensor saturation/overload occurs)
> developing a template for seismic damage investigations
> the triggers to activate the emergency management plan
> the need for suitably qualified people to operate the system and to undertake the monitoring
> the need for monthly reporting to enable comparison of periods of excavation/blasting activities, expected behaviour and assessment of trends
> the need for power/UPS backup systems for full seismic monitoring coverage.

6.9 MEASUREMENT OF LOADS AND DEFORMATION

Monitoring tests assumptions made in the geotechnical assessment about the stress environment (level of stress changes), such as displacements of the roof/backs or of large blocks that will occur at the mine.

If there are differences between assumptions and the results on the ground then the design, specified as part of the geotechnical assessment, will need to be reviewed and updated accordingly. The controls implemented will need to be checked to ensure they are consistent with the reviewed geotechnical assessment.

The stress environment is defined using 3D stress measurement or a monitoring programme.

6.9.1 MEASURING IN SITU STRESS

For underground mining or tunnelling operations, information on the in situ stress is a key design consideration. It is directly relevant to mine and extraction planning, particularly with respect to stress concentration effects during both development and extraction. Two stress measurement techniques are:

> in situ stress measurements to define the state of stress at a particular point in time
> stress change monitoring to define the mining-induced changes in the stress field over a period of time.

6.9.2 METHODS OF IN SITU STRESS MEASUREMENT IN ROCK

Methods used to determine in situ stress in rock include:

> relief methods (overcoring)
> compensation methods (flatjack)
> fracture induction methods (hydraulic fracturing)
> acoustic emission.

The overcoring method is the most common technique currently used in underground mining or tunnelling operations. It is based on the fact that the stress in rock cannot transmit through a void. Stresses in a rock mass can therefore be relaxed to zero by cutting (coring) around the rock. If a stress cell is glued within the overcored rock, the amount of stress existing in the rock prior to relaxation can be calculated from the measured rock strain changes that occur during relaxation (overcoring).

6.9.3 LOCATION TO MEASURE IN SITU STRESS

Measuring the in situ stress gives the magnitude and direction of in situ stress in a specific area where the stress field has not been significantly disturbed by mining or tunnelling activities. The results of the measurement can be used in the ground reinforcement design for excavations that will be developed away from extraction/stoping activities and previously extracted areas.

A suitable representative stress measurement site will have the following features:

> no major geological structures or abnormalities in the vicinity of the site
> no mining or tunnelling activity taking place near the site
> no major changes in depth of cover
> lithology that is representative for the area.

6.9.4 STRESS CHANGE MONITORING

Some roadways will be subject to excavation-induced stress changes during their lifetime (eg entry roadways during extraction/stoping). Stress change monitoring readings should be taken while mining is in progress nearby and adjacent to the instrumentation site.

The frequency of the readings needs to be determined by the competent person in charge of the monitoring programme. The type of mining and the rate of mining advance influence the required frequency of readings.

A stress change monitoring programme typically includes 3D stress cells installed in a line across a pillar, and roof and pillar extensometers. It may include instrumented roof bolts or shear strips.

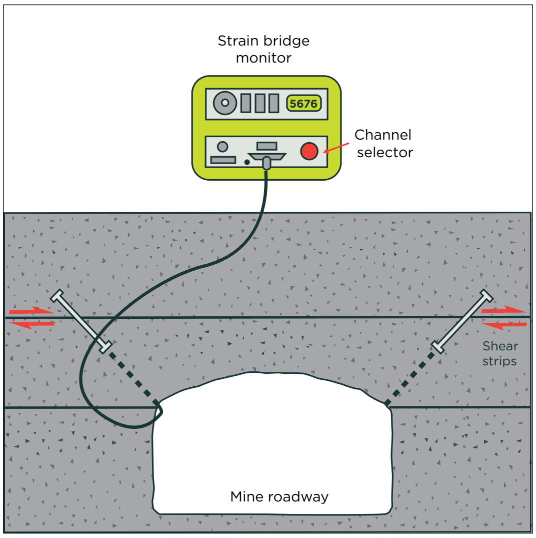
SHEAR INDICATORS

Shear indicators are used to determine the location, displacement and direction of bedding plane shears. They can be used in boreholes or simply attached to the side of the tunnel or roadway.

The borehole system typically involves a 2 m long stainless steel strip with pairs of electrical resistance strain gauges bonded on opposite sides at intervals of about 50 mm. To cover sections of borehole more than 2 m long, it is common to drill multiple holes with overlapping shear strips, one in each hole.

The shear strips are commonly encapsulated in larger diameter tubes to provide shear tolerance and extend the effective range of the instruments. These tubes are then fully grouted in place in the borehole, typically to depths less than about 10-15 m.

These instruments provide an indication of the location, magnitude, and direction of any shear movements. The multiple strain gauges are typically read individually and then downloaded to a programme that can provide interpretation of the results. See Figure 11. Logging systems are available to remote monitor shear strips from the surface.



(Reproduced with permission from Strata Control Technology, NSW, Australia)

Figure 11: Shear indicator

6.10 GROUND OR STRATA MOVEMENT INDICATORS

6.10.1 EXTENSOMETERS

Extensometers are used to measure the profile of deformation (expansion) in the rock around an excavation as the rock deforms and dilates (expands) in response to the stresses acting in the rock. Extensometers are widely used to obtain support design information and as the basis of safety monitoring systems.

Extensometers normally comprise a series of anchors located at set intervals along the borehole. Extensometers can be installed in different locations in the same hole to determine differential movements in layered rocks. There may be up to 20 intermediate anchor positions to determine the pattern of strain along the hole. The change in distance between these anchors with respect to a datum point is measured using an appropriate readout device(s). The datum point will typically be the last anchor:

> in an uphole, a stable reference anchor position at the far end of the borehole

> in a downhole, a stable reference anchor position at the collar of the hole.

Typically the deepest anchor is assumed not to move so that movement of the collar and all the other anchors are referenced to this deepest anchor.

Ground deformation tends to occur in close proximity to the face of an excavation or in an area under the influence of adjacent extraction. Extensometers are therefore usually placed as close as possible to the face in order to capture as much of this deformation as possible.

Note: Extensometers can only measure movement in the direction of the borehole in which they are installed. Borehole orientation is therefore very important in designing a monitoring array.

If movement within the bolted horizon occurs beyond pre-defined trigger levels, additional cables may need to be installed to control failure occurring higher into the roof. A TARP can be used with these instruments to trigger the installation of additional support wherever it may be required.

Multi-point wire extensometers tend to be used for routine monitoring of roadway deformation because most systems provide a visual indication that can be easily read by underground personnel. Some systems require a specific readout system and some systems can be configured to be read remotely from the surface.

Sonic probe extensometers provide a means of measuring up to 20 anchor points to a much higher resolution than wire extensometers, but the cost and availability of the readout systems and the more complex analysis and interpretation required tends to limit their use to specialist monitoring applications.

Ground deformations around underground excavations often involve a component of shear across the borehole and occasionally borehole instability. These processes can compromise the operation of extensometers by pinching the wires that leads to false and under-registered indications of ground movement. External influences such as nearby grouting of cable bolts, corrosion of wires, and stone dusting (in coal mines) can also compromise the effective operation of extensometers.

The SSE must ensure a regular inspection and maintenance programme is implemented to confirm the effective operation of these instruments.

A wide range of instruments are available, Table 4 shows the most commonly used.

INSTRUMENT	
Sonic probe extensometers	> monitor movement in the roof/backs, floor and sides/ribs > use standardised anchor spacing on all extensometer installations that allow comparisons of strains generated in the roof/backs at different horizons > anchors can be placed up to 20 locations along a 9.5 m length hole and can be measured to accuracy of 0.1 mm > can be installed at the excavation face, and movement can be monitored as the roadway advances
Dual or multiple height tell tales	> provide visual indication of roof/backs condition > can be installed by ground support workers as they progress > provide early indication of changing conditions, which allows for earlier action and therefore reduced risk and downtime > can show roof strata movement within two or more horizons in both the bolted horizon and the strata above, giving total displacement to an accuracy of 1 mm
Strain gauges	> measure strains generated in a localised area > commonly installed as strain gauge bolts that measure the strain along the length of the bolt at up to nine locations

Table 4: Commonly used instruments

6.10.2 CONVERGENCE MONITORING

Drive closure, or convergence, is most effectively measured with a series of convergent points located on the surface of a drive. A convergent point is a fixed reflective surface or point that can be accurately measured repeatedly with either a survey laser or a tape extensometer. The fixed points can be as simple as two points on each wall or a more complex multi-point arrangement. Figure 12 shows a segmented tunnel lining and an underground tunnel or roadway, and the measuring points installed to measure convergence.

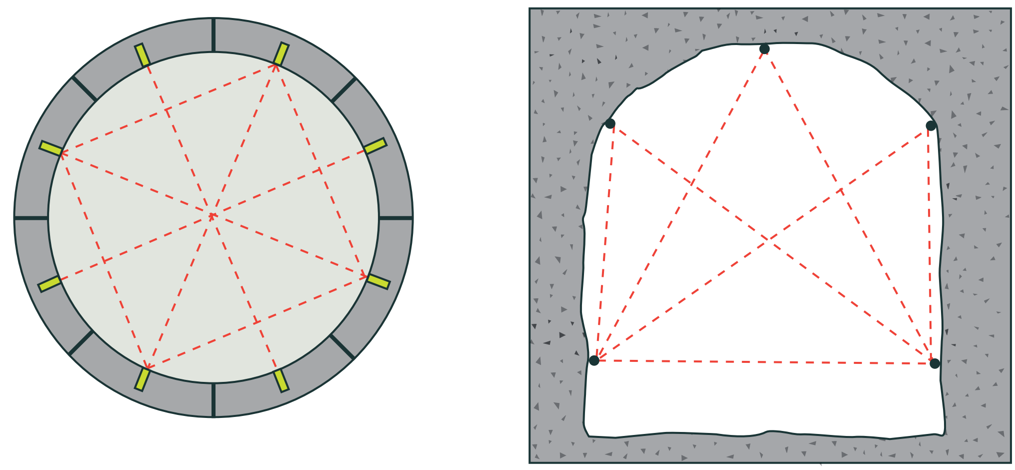


Figure 12: Examples of convergence monitoring and measuring locations in a segmented tunnel lining and underground tunnel or roadway

6.11 CRACK MONITORING

A number of techniques are available for monitoring the movement of rock blocks bounded by joints or other discontinuities in harder rock. To monitor the movement of individual blocks, crack monitoring devices can be used to identify any widening of discontinuities. Techniques range from simple manual measurements, using calipers or a dial gauge between reference points either side of the discontinuity, to automatic monitoring using electronic sensors and data loggers. See section 6.10 for more information on ground or strata movement indicators.

Crack monitors consisting of graduated polycarbonate slides can be used to measure rotation as well as transverse and longitudinal displacement.

Monitoring across multiple discontinuities can be achieved using a tensioned wire installed across them and attached to a suitable sensor.

Installing wooden wedges with a piece of reflective material attached to them into cracks can provide a simple visual alert. When the wedge falls out of the crack this could lead to the implementation of a TARP response. For the wedges to work effectively they should be stored in a conditioned environment close to where they will be used to either take on or lose moisture.

6.12 MONITORING PILLAR AND EXTRACTION SEQUENCE DESIGN – COAL MINING

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Pillar extraction is a relatively high risk procedure. The appropriate extraction design, equipment, and working methods need to be used to manage the risks of harm to workers and others.

Remote monitoring of selected pillars during extraction using load cells, extensometry and convergence measurements confirms pillar behaviour and is an effective method for verifying pillar and extraction sequence designs.

Where monitoring is used to verify mine pillar and extraction sequence design, the mine operator should ensure:

> All monitoring instruments are remote reading with cabling fed back to a monitoring point located in a safe position away from the pillar extraction line.
> Changes in vertical load are monitored using a uniaxial vibrating wire stress cell or similar device installed into horizontal boreholes within the pillars. The pillar load and deformation measurements should be combined with pillar convergence readings to determine effective pillar strength and failure behaviour. These cells should be placed in contact with the borehole walls in the correct orientation to measure any increase in vertical loading.
> Extensometers installed in horizontal boreholes are used to give information on lateral deformation of pillars and ribs under increasing load. For pillar extraction, the rate of build-up of load within a pillar, as the extraction line draws near, should also indicate if full caving is occurring and if the pillar is behaving as expected.
> Roof extensometers are installed close to selected pillars to warn of any unusual roof movement. Very little roof movement is generally expected prior to pillar extraction.
> Floor heave is indicated using wooden props set between the roof and floor and the collection of roof-to-floor convergence data. The development of floor heave may indicate pillars are punching into the floor.

6.12.1 MONITORING DURING PILLAR EXTRACTION

Monitoring of roof and pillar behaviour during extraction should be supported by a monitoring plan tailored to site conditions. There should be a separate TARP developed for use during pillar extraction which is specific to the extraction phase.

Use tell tales in working areas to monitor the onset of roof movement. Other warning signs, incorporated into any monitoring scheme, include deteriorating visual conditions, rock noise and breakage of wooden props set between the roof and floor.

M C

6.13 MONITORING TO DETECT GOAF/WASTE FALL PRECURSORS[20]

Goaf/waste falls are generally preceded by audible cracking and bumping as the rock fractures. Microseismic monitoring may be used to help detect potential goaf/waste falls. This form of monitoring uses the build-up of microseismic activity as an indicator of the onset of large-scale rock failures which might ultimately result in failure of the roof/backs and possible wind blast. It comprises a combination of seismic detectors (geophones), seismic processes, data links and computers that enable an operator to interpret seismic activity and issue a warning of an impending collapse.

The interpreted response provides details of the magnitude, frequency and location of seismic events.

These parameters form the basis of a set of criteria for the prediction of major seismic events with which a wind blast may be associated. When any of the criteria is met, an alarm is issued.

T

6.14 MONITORING FOR MOVEMENT CAUSED BY TUNNEL DEVELOPMENT

When constructing tunnels, adjacent infrastructure below and above the ground should be monitored to ensure the tunnelling activities are not causing any movement that may disturb or cause damage to the infrastructure. The monitoring requirements are often dictated by the asset owner of the infrastructure. A baseline survey is usually required before any tunnelling activities commence.

6.15 REGULAR EXAMINATIONS AND SHIFT REPORTS

The mine or tunnel operator must ensure that regular examinations of the mining or tunneling operation are undertaken at specified intervals according to the procedures in the HSMS. These are in addition to the inspection requirements in section 6.7.

6.15.1 REGULAR EXAMINATION OF MINING OR TUNNELLING OPERATIONS

Regular inspections of the mining or tunnelling operation must be undertaken by a competent person as determined by the mine or tunnel operator. Table 3 lists some of the examinations required; for a full list of matters requiring regular examination see MOQO Regulation 222.

If any ground or strata hazards are identified during inspections they need to be communicated to the geotechnical engineer (or other competent person) and the supervisor or underviewer, and documented on the shift report. Then – so far as is reasonably practicable – these hazards need to be eliminated or minimised.

[20] Fowler J.C. & Hebblewhite, B. (2003, November). *Managing the Hazards of Wind Blast/Air Blast in Caving Operations in Australian Underground Mines*. Paper presented at the first Australian Ground Control in Mining Conference, Sydney, Australia.

WHAT NEEDS TO BE EXAMINED	WHEN
Every part of the mining or tunnelling operation where a worker is or will be present.	Before the start of each shift (and at suitable times during each working shift)
Every accessible area of the mining or tunnelling operation, including every area containing, barriers, machinery, seals, underground or surface infrastructure, and ventilation stoppings.	At least weekly

Table 5: Some of the regular examinations required to be completed at mining or tunnelling operations

All work environments should be inspected at the start of each shift by the workers operating in that location.

6.15.2 SHIFT INSPECTIONS AND REPORTS

Shift inspections must be undertaken by the underviewer at an underground coal mining operation and the supervisor at any underground metalliferous mining or tunnelling operation.

At each shift, the shift supervisor or underviewer must identify any hazards or potential hazards (including those related to ground or strata instability), the state of the workings and plant at the mining or tunnelling operation, any material matters that might affect the health and safety of workers, and the controls (if any) put in place during the shift to manage those hazards.

Written shift reports must be completed at underground mining operations or tunnelling operations. Report the contents to the underviewer or supervisor of the following shift and the workers.

At the end of the inspection official's shift, include the following information in the inspection report:

> defects or abnormalities affecting roadway stability

> defects in the monitoring system

> tell tales replaced during the shift

> remedial work carried out

> remedial work required

> changes in roadway conditions

> who has been informed of these matters.

Inform the relevant people as soon as possible if the inspection identifies any defect or abnormalities. Discuss the relevant actions with the incoming shift of workers.

PART C

07/

GROUND OR STRATA FAILURE AND ACTIONS REQUIRED

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

***Regulation 61** Maintenance of records of health and safety management system*

***Regulation 131** Steps to be taken following ground or strata failure*

7.1 REPORT ACTUAL OR SUSPECTED GROUND OR STRATA FAILURE

The mine or tunnel operator must ensure that the underviewer or supervisor is notified of any actual or suspected unplanned fall of rock or coal at an underground mining operation or tunnelling operation. See section 9.1 for more information about notifiable events.

The mine or tunnel operator must ensure that every report by a worker about an unplanned fall of rock or coal is assessed to determine whether it could have resulted in serious harm to a worker or any other person. If the fall of rock or coal could have resulted in serious harm to a worker or any other person, an investigation must be carried out by the mine or tunnel operator.

If the investigation finds the cause of the rock or strata instability was due to a ground or strata support design fault, in part or in full, the mine or tunnel operator must ensure that the design is reviewed by a competent person. The competent person must:

- be independent of the operation, and
- not have been involved in the development of the original ground or strata design.

Keep records of any ground or strata failure that caused or had the potential to cause serious injury to any person (including records of the investigation into the causes of the failure).

PART C

08/

EMERGENCY PREPAREDNESS

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

Regulation 71 *Principal hazard management plans for ground or strata instability*

Regulation 92 *Site senior executive responsible for having principal control plans*

Regulation 105 *Emergency management control plan*

8.1 PREPARE FOR GROUND OR STRATA INSTABILITY EMERGENCIES

The SSE needs to identify and describe the potential emergencies that can arise from the failing of the ground or strata instability controls that have been implemented at the mining or tunnelling operation. For example, mesh and bolts failing that may lead to roadway collapses.

The mine or tunnel emergency management PCP describes the preparation and response to the risks from the potential ground or strata instability controls failing. Workers need to be trained to implement the emergency management PCP.

See WorkSafe's code *Emergency Preparedness in Mining and Tunnelling Operations* for more detailed information.

PART D

IN THIS PART:

PART D

09/

NOTIFIABLE EVENTS

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work Act 2015

***Section 23** Meaning of notifiable injury or illness*

***Section 24** Meaning of notifiable incident*

***Section 25** Meaning of notifiable event*

***Section 55** Duty to preserve sites*

***Section 56** Duty to notify notifiable event*

***Section 57** Requirement to keep records*

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

***Regulation 225** Declaration of notifiable injury or illness and notifiable incidents*

***Regulation 226** Record of notifiable events*

***Regulation 228** Investigation of notifiable events*

***Regulation 229** Notification of high-risk activities*

***Schedule 5** Injuries, illnesses, and incidents declared to be notifiable events under Act*

***Schedule 6** Particulars of notifiable events*

9.1 NOTIFIABLE EVENTS

The mine or tunnel operator must notify WorkSafe as soon as possible after becoming aware that a notifiable event arising out of the conduct of the mining or tunnelling operation has occurred. See section 56 of HSWA.

A notifiable event is when a person dies, a notifiable injury or illness occurs, or a notifiable incident occurs, as defined in sections 23 and 24 of HSWA. In addition, the MOQO Regulations declare certain injuries, illnesses, and incidents that relate to mining and tunnelling operations as notifiable. See www.worksafe.govt.nz for details on how to notify WorkSafe and the forms to use.

See WorkSafe's special guide *Introduction to the Health and Safety at Work Act 2015* and fact sheet *What Events Need to be Notified?* for more information about:

> notifiable illness, injuries and incidents
> how to notify WorkSafe
> what to do after a notifiable event, including not disturbing the site
> record keeping.

Schedule 5 of the MOQO Regulations lists notifiable events specific to ground or strata instability:

> any failure of ground control that prevents persons from passing through the area or otherwise exposes them to danger

> any ground movement of a surface slope, face, bench, or haul road that has the potential to cause injury or death

> any movement of a surface slope or face that adversely affects any building, footpath, waterway, public utility, or other area of public access

> in relation to the surface of a mining operation, the structural failure of any gantry, storage bunker, tower, or other elevated structure, and

The collapse or failure of an excavation or any shoring supporting an excavation is included as a notifiable incident within the list under section 24(i) of HSWA.

PART D

10/

REVIEW AND AUDIT

IN THIS SECTION:

The legislation that applies to this section is:

Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

Regulation 61 *Maintenance of records of health and safety management system*

Regulation 62 *Providing health and safety management system documentation to mine workers*

Regulation 63 *Providing health and safety management system documentation to contractor*

Regulation 69 *Review and revision of principal hazard management plans*

Regulation 70 *Audits of principal hazard management plans*

10.1 WHEN TO REVIEW THE PHMP

The SSE must ensure the PHMP is reviewed at least once every two years after it was made. The review determines whether the controls continue to be suitable and effective in managing the risks associated with ground or strata instability.

The PHMP must also be reviewed after:

> an accident involving ground or strata instability at the mining or tunnelling operation
> a material change in the management structure that may affect the PHMP
> a material change in plant used or installed at the mining or tunnelling operation that may affect ground or strata instability
> the occurrence of any event specified in the PHMP as requiring a review of the PHMP.

A PHMP should also be reviewed after:

> each audit, if any non-conformances are identified
> any significant changes to the roof conditions, the geotechnical environment, or depth of cover
> any inadequacies are found in the ground control system, or any part of it
> changes to the mine or tunnel operating system which may affect the PHMP (eg changes proposed to roadway dimensions or methods of working)
> any significant change to the mine or tunnel layout, and/or its systems
> operations or personnel, production methods, or systems (including natural changes, extensions or conversions)
> moving an activity and/or plant and equipment from one area of the mine or tunnel to another
> changes being made to core systems such as bolting type.

10.1.1 INPUTS FOR THE REVIEW

When reviewing the PHMP also review the risk assessment used and referred to within it. There could be new risks for which controls are needed, or existing risks that have changed meaning controls could need changing.

The SSE should consider any other relevant information gathered during:

> routine risk appraisals and assessments
> geotechnical assessments
> monitoring and results of inspections by the mine or tunnel operator or WorkSafe
> review of TARPs
> incidents or near misses
> feedback from workers, industry health and safety representatives or other health and safety representatives
> reviews of industry safety alerts.

After the review is completed, the PHMP and supporting documents may need to be revised and re-issued. Workers will need to be informed of any updated documents. Ensure training or retraining is provided to workers, where required.

The mine or tunnel operator must keep records relating to the PHMP (including any reviews and revisions as required under MOQO Regulation 61) for at least 12 months from the date the mine or tunnel is abandoned.

Records about the PHMP and any reviews must be provided, on request, to an inspector or a health and safety representative under clause 69 (5) of the MOQO Regulations.

10.2 AUDITING THE PHMP

Internal audits of the PHMP may be undertaken, from time to time, as required, by the mine or tunnel operator.

Independent external audits of the PHMP must be undertaken at least once every three years from the date the plan was made. The external audit should examine the adequacy, implementation, and compliance with the PHMP. The following areas may be audited:

> quality and supply of consumables
> suitability and operation of drilling equipment
> selection of support regime
> knowledge and application of manager's support rules
> knowledge and application of TARPs
> strata support installation
> deformation monitoring and interpretation
> ground condition observation skills and application.

The final audit report will include the findings of the audit, recommendations for corrective action, review mechanisms and who is responsible. The mine or tunnel operator should act on the findings of the audit report, as required, to ensure the health and safety of workers.

If the operator does not fully comply with the audit recommendations, the operator should record why the recommendation(s) have not been implemented.

Keep records of the audit of the PHMP for at least 12 months from the date the mine or tunnel is abandoned. Records of any risk appraisals carried out to identify principal hazards must also be kept. Ensure details of audits and the risk appraisals are available to:

- WorkSafe
- health and safety representatives
- industry health and safety representatives.

10.3 COMMUNICATING CHANGES FROM REVIEWS OR AUDITS

After a review or audit of the PHMP, communicate any changes to workers. Ensure the workers can readily access a current version of the PHMP and any other plans or documented processes for the management of hazards that are relevant to their work.

PART E

IN THIS PART:

PART E

11/

GLOSSARY

TERM	EXPLANATION
Abutment	The areas of unmined rock at the edges of mining excavations that may carry elevated loads resulting from redistributions of stress. Abutment is also used to refer to abutment stress, being the mining-induced stress build-up located in the abutment region of the mine, adjacent to an excavation.
Backs	The roof or upper part of any underground mining excavation. In coal mines it is called the roof.
Bedding planes	Planes of weakness in the rock that usually occur at the interface of parallel beds or laminae of material within the rock mass.
Cable bolts	A device or method for reinforcing ground. Cable bolts can be installed as primary or secondary support elements. Cable bolts are installed using either pumpable cement grout or polyester resin cartridges, depending on the cable type and stiffness. They can be either fully or partially anchored by grout/resin.
Competent person	Competent person means a person who: a. has the relevant knowledge, experience, and skill to carry out a task required or permitted by the MOQO Regulations to be carried out by a competent person; and b. has a relevant qualification evidencing the person's possession of that knowledge, experience, and skill or – if the person is an employee – a certificate issued by the person's employer evidencing that the person has that knowledge, experience, and skill.
Continuous	In this code, continuous means over the life of the mine or tunnel. The frequency (eg daily, weekly, or monthly intervals) will be determined by the risk assessment and the design.
Controlled drilling and blasting	The art of minimising rock damage during blasting. It requires the accurate drilling and placement and initiation of appropriate explosive charges in the perimeter holes to achieve efficient rock breakage with least damage to the remaining rock around an excavation.
Dip	The angle a plane or stratum is inclined from the horizontal.
Discontinuity	A plane of weakness in the rock mass (of comparatively low tensile strength) that separates blocks of rock from the general rock mass.
Dowel	An untensioned rock bolt, anchored by full column or point anchor grouting, generally with a face plate in contact with the rock surface.
Earthquake	Groups of elastic waves propagating within the earth that cause local shaking/trembling of ground. The seismic energy radiated during earthquakes is caused most commonly by sudden fault slip, volcanic activity or other sudden stress changes in the Earth's crust.
Elastic	The early stage of rock movement (strain) resulting from an applied stress which does not give permanent deformation of the rock – where the rock mass returns to its original shape or state when the applied stress is removed.
Fault	A naturally occurring plane or zone of weakness in the rock along which there has been movement. The amount of movement can vary widely.
Factor of Safety (FoS)	The ratio of the average ground support strength (S) to the average stress applied to that part of the excavation (σp). It can be expressed as $FoS = S/\sigma p$

TERM	EXPLANATION
Fill	Waste sand or rock, uncemented or cemented in any way, used either for support, to fill stope voids underground, or to provide a working platform or floor.
Geology	The scientific study of the Earth, the rock of which it is composed, and the changes which it has undergone or is undergoing.
Geological structure	A general term that describes the arrangement of rock formations. Also refers to the folds, joints, faults, foliation, schistosity, bedding planes and other planes of weakness in rock.
Geotechnical engineering	The application of engineering geology, structural geology, hydrogeology, soil mechanics, rock mechanics and mining seismology to establish practical solutions to ground control challenges.
Ground	Coal, rock and soil in all possible forms, from a fresh, high-strength material to a weathered, low-strength material. It also includes all fill materials, both cemented in any way or uncemented.[21]
Ground control	The ability to predict and influence the behaviour of rock in a mining environment to eliminate or manage the risks of injury or ill-health to workers, so far as reasonably practicable, whilst having due regard for the required serviceability and design life of the mine.
Health and safety representative (HSR)	A health and safety representative (HSR) is a worker elected by the members of their work group to represent them in health and safety matters, in accordance with subpart 2 of Part 3 of HSWA.
Induced stress	The stress that is due to the presence of an excavation. The level of induced stress developed depends on the level of the in situ stress and the shape and size of the excavation.
Industry health and safety representative	An industry health and safety representative (industry HSR) may be appointed to represent underground coal mine workers. The representative is appointed by a union or by a group of underground coal mine workers. An industry HSR must meet the competency and experience requirements for an HSR at a mining operation prescribed by or under regulations made under HSWA (see MOQO Regulation 110). In addition to the functions and powers conferred on other HSRs, an industry HSR has additional functions and powers. See HSWA Schedule 3, Part 1.
In situ stress	The stress or pressure that exists within the rock mass before any mining has altered the stress field.
Instability	Condition resulting from failure of the intact rock material or geological structure in the rock mass.
Joint	A naturally occurring plane of weakness or break in the rock (generally aligned sub vertically or transverse to bedding), along which there has been no visible movement parallel to the plane.
Load in support units	The load that a support unit is carrying is monitored by means of load cells. This load is compared to the load bearing capacity of a support unit. If an elongate is designed to yield at 20 tonnes, a load cell can be used to check on the actual yield load.
Loose (rock)	Rock that visually has potential to become detached and fall. In critical areas, loose rocks must be scaled to make the workplace safe.

[21] Adapted from page 10: Government of Western Australia, Department of Industry and Resources & Mines Occupational Safety and Health Advisory Board (MOSHAB). (1997). Guideline: *Geotechnical considerations in underground mines*. Western Australia, Australia: Government of Western Australia.

TERM	EXPLANATION
Manager's support rules	The details about the ground support that should be installed at specified places in specific circumstances at the mining or tunnelling operation. See also Support plans.
Mine worker	A worker in a mining operation. Note that this includes a worker in a tunnelling operation.
Mining-induced seismicity	The occurrence of seismic events in close proximity to underground mining operations or tunnelling operations. During and following blast times there is a significant increase in the amount of seismic activity in a mine. Mining-induced seismicity is commonly associated with volumes of highly stressed rock, sudden movement on faults, or intact failure of the rock mass.
Mining operation	Under HSWA, a mining operation means: (a) the extraction of coal and minerals and the place at which the extraction is carried out; and (b) includes any of the following activities and the place at which they are carried out: (i) exploring for coal: (ii) mining for coal or minerals: (iii) processing coal or minerals associated with a mine: (iv) producing or maintaining tailings, spoil heaps, and waste dumps: (v) the excavation, removal, handling, transport, and storage of coal, minerals, substances, contaminants, and wastes at the place where the activities described in subparagraphs (i) to (iv) are carried out: (vi) the construction, operation, maintenance, and removal of plant and buildings at the place where the activities described in subparagraphs (i) to (iv) are carried out: (vii) preparatory, maintenance, and repair activities associated with the activities described in subparagraphs (i) to (iv); and (c) includes— (i) a tourist mining operation: (ii) a tunnelling operation.
Old workings	Workings, or any part of workings, of an abandoned or suspended mine operation that are above, below or within 200 m of a mining operation, including roadways, voids and goafs created as part of the abandoned or suspended operation.
Ore	A mineral deposit that is mined in metalliferous mining operations.
Pillar	An area of ground (usually ore) left within an underground mine to support the overlying rock mass or hanging wall. Pillars can be the key load bearing components of an underground mine.
PCP	See Principal control plan.
PHMP	See Principal hazard management plan.
Plane of weakness	A naturally occurring crack or break in the rock mass along which movement can occur.
Plastic	The deformation of rock under applied stress once the elastic limit is exceeded. Plastic deformation results in a permanent change in the shape of the rock mass.

TERM	EXPLANATION
Principal control plan (PCP)	A plan required under MOQO Regulation 92. The plan documents systems and processes in place at the mining or tunnelling operation to manage hazards at the operation, and the measures that are necessary to manage principal hazards at the mining or tunnelling operation. See MOQO Regulation 93.
Principal hazard	Any hazard arising at any mining operation (including a tunnelling operation) that could create a risk of multiple fatalities in a single accident or a series of recurring accidents at the mining operation in relation to any of the following: i. ground or strata instability: ii. inundation and inrush of any substance: iii. mine shafts and winding systems: iv. roads and other vehicle operating areas: v. tips, ponds, and voids: vi. air quality: vii. fire or explosion: viii. explosives: ix. gas outbursts: x. spontaneous combustion in underground coal mining operations. It also includes any other hazard at the mining operation (including a tunnelling operation) that has been identified by the site senior executive under MOQO Regulation 66 as a hazard that could create a risk of multiple fatalities in a single accident, or a series of recurring accidents at the mining operation. See MOQO Regulation 65.
Principal hazard management plan (PHMP)	A plan required under MOQO Regulation 66. The PHMP describes a principal hazard and sets out the controls used to manage it. A PHMP must be prepared for each principal hazard identified at the mining or tunnelling operation. MOQO Regulations 68, 69 and 70 cover what needs to be included in a PHMP, and requirements for reviews, revisions and audits. MOQO Regulation 71 specifies what must be included in a PHMP for ground or strata instability.
Reinforcement	The use of tensioned rock bolts, cable bolts, split sets and dowels placed inside the rock to apply large stabilising forces to the rock surface or across a joint tending to open. The aim of reinforcement is to develop the inherent strength of the rock and make it self-supporting. Reinforcement is primarily applied internally to the rock mass.
Release of load	Excavation of rock during mining removes or releases the load that the rock was carrying. This allows the rock remaining to expand slightly due to the elastic properties of the rock.
Rib	The sides of a roadway typically associated with coal mines.
Roadways	The formed underground excavations that – once supported – provide access through an underground environment for people, equipment or services. Roadways can be a simple excavation forming one roadway, or multiple excavations forming a network of roadways. See also Tunnel.
Rock bolt	A tensioned bar or hollow cylinder, usually steel, that is inserted into the rock mass, via a drill hole, and anchored either by friction or grout/polyester resin along its length and a steel face plate and a nut at the other end. The steel face plate is in contact with the rock surface.

TERM	EXPLANATION
Rock mass	The sum total of the rock as it exists in place, taking into account the intact rock material, and groundwater, as well as joints, faults and other natural planes of weakness that can divide the rock into interlocking blocks of varying sizes and shapes.
Rock mass classification	Provides a means of determining the quality of the rock mass and is a way of assessing support requirements. A rock mass is generally weaker and more deformable than the constituent rock material as it contains structural weakness planes, such as joints and faults. The stability of an excavation in a jointed rock mass is influenced by many factors including the: > strength and weathering of rock material > frequency and orientation of jointing > joint strength, condition and persistence > confining stress > presence of water.
Rock mass strength	The overall physical and mechanical properties of a large volume of rock which is controlled by the intact rock material properties, groundwater and any joints or other planes of weakness present. One of the least well-understood aspects of geotechnical engineering.
Rock mechanics	The scientific study of the mechanical behaviour of rock and rock masses under the influence of stress.
Rock noise	Sounds emitted by the rock during failure, may be described as cracking, popping, tearing and banging.
Roof	The roof or upper part of any coal mine operation. See Backs.
Seismic event	Earthquakes or vibrations caused by sudden failure of rock. Not all seismic events produce damage to the mine.
Seismicity	The geographic and historical distribution of earthquakes.
Seismology	The scientific study of earthquakes by the analysis of vibrations transmitted through rock and soil materials. The study includes the dynamic analysis of forces, energy, stress, duration, location, orientation, periodicity and other characteristics.
Shear	A mode of failure where two pieces of rock tend to slide past each other. The interface of the two surfaces of failed rock may represent a plane of weakness, or a line of fracture through intact rock.
Shotcrete	Cement, water, sand and fine aggregate mix that is sprayed at high velocity on the rock surface at pressure and is compacted dynamically. Tends to inhibit blocks ravelling from the exposed faces of an excavation.
Standard operating procedures (SOPs)	Documented standard operating procedures for installation, maintenance, removal and quality control.
Strain	The change in length per unit length of a body resulting from an applied force. Within the elastic limit, strain is proportional to stress.
Strength	The maximum stress that can be carried prior to failure.

TERM	EXPLANATION
Stress	The internal resistance of an object to an applied load. When an external load is applied to an object, a force inside the object resists the external load. The terms stress and pressure refer to the same thing. Stress is calculated by dividing the force acting by the original area over which it acts. Stress has both magnitude and orientation.
Stress field	A descriptive term to indicate the pattern of the rock stress (magnitude and orientation) in a particular area.
Stress shadow	An area of low stress level due to the flow of stress around a nearby excavation, eg a large stope. May result in joints opening up causing rock falls.
Strike	The bearing of a horizontal line in a plane or a joint.
Stope	An excavation where ore is extracted on a large scale.
Support	Steel or timber sets, concrete lining, steel liners, etc that are placed in contact with the rock surface to limit rock movement. The rock mass must move on to the support before large stabilizing forces are generated. Support is applied externally to the rock mass (although untensioned cables can be classified as ground support).
Support plans	Plans detailing the support to be installed at specified places in specified circumstances at the mining or tunnelling operation. See also Manager's support rules.
TARP	See Trigger action response plan.
TBM	Tunnel boring machine.
Tectonic forces	Forces acting in the earth's crust over very large areas to produce high horizontal stresses which cause can earthquakes. Tectonic forces are associated with the rock deforming processes in the Earth's crust.
Tensile	Reflects the ability of the rock or strata to stretch without breaking or fracturing.
Trigger action response plan (TARP)	A plan setting out the response required when observed conditions changes. See the Appendix.
Tunnel	An excavation usually associated with civil works that – once supported – creates an underground passage for transportation, services or people.
Tunnelling operation	An operation (including the place that it occurs) involving extraction of fill with the purpose of creating a tunnel or shaft, or enlarging or extending any tunnel or shaft. It excludes certain tunnelling operations set out in MOQO Regulation 6.
Wedge	A block of rock bounded by joints on three or more sides that can fall or slide out under the action of gravity, unless supported.

PART E

12/

APPENDIX

IN THIS SECTION:

12.1 EXAMPLE OF A TRIGGER ACTION RESPONSE PLAN (TARP)

TRIGGER		CODE GREEN	CODE YELLOW	CODE RED
	Visible Deterioration	> Generally flat roof. > Roof slabbing < **300 mm**. > No roof bolt plate loading (flattening of plates) or mesh deformation. > < **200 mm** guttering. > No tensile cracking. > Generally dry roof (minor drippers from roof). > Occasional joints crossing the roadway at > **2 m** spacing. > Faulting throw < **300 mm**. > No dykes or sills.	**Any of the following:** > Roof slabbing > **300 mm** for a distance greater than **4 m** across full roadway width. > > **200 mm** and < **300 m** guttering. > Visible roof sag. > Increased water inflow from boltholes and/or structures. > Faulting throw ≥ **300 mm** but < **1 m**. > High intensity near vertical tight joints at less than or equal to **2 m** spacing. > Open joints, joints dipping in different directions, joints crossing. > Any geological structure at intersections. > Any geological structure running at a shallow angle to the roadway (< 30 degrees). > Dyke and/or sill present. > Any 4-way intersection.	**Any of the following:** > Roof slabbing > **500 mm** for a distance greater than **4 m** across full roadway width. > > **300 mm** guttering. > Faulting throw ≥ **1 m**. > High intensity near vertical tight joints at ≤ **1 m** spacing. > Roof fall.
	Roadway Width	≤ 5.5 m	> 5.5 m but ≤ 6 m	> 6 m
	Intersection Span	≤ 10 m	> 10 m but ≤ 11 m	> 11 m, but less than 12 m Intersection span must not exceed 12 m.
	Roof Bolt Encapsulation	< 300 mm unencapsulated length.	≥ 300 mm unencapsulated length.	
	Monitoring	Total tell tale displacement < 20 mm. Upper tell tale displacement < 5 mm.	Total tell tale displacement: ≥ 20 mm, but < 30 mm. Upper tell tale displacement: ≥ 5 mm, but < 10 mm.	Total tell tale displacement: ≥ 30 mm Upper tell tale displacement: ≥ 10 mm **If total tell tale displacement > 40 mm after TG bolt installation: Stop mining.**

		CODE GREEN	CODE YELLOW	CODE RED
ACTION	**Headings and Cut-throughs**	6 x 2.1 m roof bolts per 1 m. **Support Plan XXX-1.**	6 x 2.1 m roof bolts per 1 m. Plus 2 x 4 m point anchored cable bolts per 2 m. **Support Plan XXX-2.**	6 x 2.1 m roof bolts per 1 m. Plus 2 x 8 m post groutable cable bolts per 2 m. Cable bolts to be grouted within one week of installation, or immediately if upper tell tale displacement ≥ 10 mm. **Support Plan XXX-3.**
	Intersections	6 x 2.1 m roof bolts per 1 m. Plus breakaway bolts. **Support Plan XXX-4.**	6 x 2.1 m roof bolts per 1 m. Plus 2 x 4 m point anchored cable bolts per 2 m. **Support Plan XXX-2.**	6 x 2.1 m roof bolts per 1 m. Plus 2 x 8 m post groutable cable bolts per 2 m. Cable bolts to be grouted within one week of installation, or immediately if upper tell tale displacement ≥ 10 mm. **Support Plan XXX-6.**
	Roof Monitoring Instrumentation	1 x tell tale at the intersection – hole drilled to 8 m depth (installed prior to intersection formation, with anchors at 8 m and 2 m). **AND** 1 x tell tale at intervals of ≤ 25 m – hole drilled to 8 m depth (with anchors at 8 m and 2 m).	1 x tell tale at the intersection – hole drilled to 8 m depth (installed prior to intersection formation with anchors at 8 m and 2 m). **AND** 1 x tell tale at intervals of ≤ 25 m – hole drilled to 8 m depth (installed within 4 m of the face with anchors at 8 m and 2 m). **AND** 1 x tell tale within 5 m of the start of Code Yellow – hole drilled to 8 m depth (installed within 4 m of the face, with anchors at 8 m and 2 m).	1 x 4-way tell tale at the intersection – hole drilled to 8 m depth (installed prior to intersection formation with anchors at 8 m, 6 m, 4 m and 2 m). **AND** 1 x 4-way tell tale at intervals of ≤ 25 m – hole drilled to 8 m depth (installed within 4 m of the face with anchors at 8 m, 6 m, 4 m and 2 m). **AND** 1 x 4-way tell tale within 5 m of the start of Code Red (installed within 4 m of the face with anchors at 8 m, 6 m, 4 m and 2 m).

RESPONSE		CODE GREEN	CODE YELLOW	CODE RED
	Mine worker	> Mining cycle tasks and ground support installation as per SOPs. > Check and record encapsulation once per shift or every 10 m. > Drill tell tale hole at required locations.	> Mining cycle tasks and ground support installation as per SOPs. > Install and tension 4 m cables on advance as per support plans. > Check and record encapsulation twice per shift or every 5 m. > Install tell tales at all intersections and in roadways at intervals of ≤ 25 m within 4 m of face.	> Mining cycle tasks and ground support installation as per SOPs. > Install and tension 8 m cable bolts on advance, as per support plan. > Check and record encapsulation twice per shift or every 5 m.
	Deputy/ Supervisor	> Install tell tales at required locations. > Read and record the tell tales at each shift within their section or as directed. > Review bolt installation method and ensure encapsulation tests are performed and recorded at each shift. > In shift report, record mining conditions (including roof composition and any bolting issues), as well as tell tale monitoring results and any actions taken. > Ensure that the support is installed as per support plans.	> Notify underviewer/supervisor when ground conditions first deteriorate from Code Green to Code Yellow. > Read and record the tell tales twice a shift within their section, or as directed. > Review primary bolt and cable bolt installation method and encapsulation twice at each shift. > In shift report, record mining conditions (including roof composition and any bolting issues), as well as tell tale monitoring results and any actions taken. > Ensure that the support is installed as per support plans.	> Notify underviewer/supervisor when ground conditions first deteriorate from Code Yellow to Code Red. > Read and record the tell tales twice a shift within their section, or as directed. > Review primary bolt and cable bolt installation method and encapsulation twice at each shift. > In shift report, record mining conditions (including roof composition and any bolting issues), as well as tell tale monitoring results and any actions taken. **If total tell tale displacement exceeds 40 mm post TG bolt installation: Stop mining, withdraw crew and notify underviewer/ supervisor.** > Ensure that the support is installed as per support plans.

RESPONSE	CODE GREEN	CODE YELLOW	CODE RED
Underviewer/ Supervisor	> Ensure compliance with this TARP and support rules and investigate any non-compliance. > Ensure all tell tale monitoring results are being recorded as necessary.	> Inspect area when first notified by the deputy/supervisor of Code Yellow. Note condition in shift report and any action taken. > Notify geotechnical engineer of change to Code Yellow on next available shift. > Ensure compliance with this TARP and support rules and investigate any non-compliance. > Inspect and verify roadway conditions before support level is decreased. Make note of any decision to decrease support in the shift report. Ensure all tell tale monitoring results are being recorded as necessary.	> Inspect area when first notified by the deputy/supervisor of Code Red. Note condition in shift report and any action taken. > Notify geotechnical engineer of change to Code Red on next available shift. > Ensure compliance with this TARP and support rules. Investigate any non-compliance. > Inspect and verify roadway conditions before the support level is decreased. Note any decision to decrease support in shift report. **If total tell tale displacement exceeds 40 mm post TG bolt installation:** Notify geotechnical engineer.
Geotechnical Engineer	> Oversee all monitoring results. > Analyse monitoring results and report to mine management in the monthly Strata Compliance Meetings or as required. > Geotechnical mapping as per Geotechnical Mapping of Roadways SOP_XXXX. > Compliance audits to check that the support and monitoring devices are installed as per support plans.	> Inspect area and confirm roof condition classification. > Geotechnical mapping as per Geotechnical Mapping of Roadways SOP_XXXX. > Analyse monitoring results and report to mine management in the monthly Strata Compliance Meetings or as required. > Compliance audits to check that the support and monitoring devices are installed as per support plans.	> Inspect area and confirm roof condition classification. > Inspect area as required to confirm/ determine additional monitoring and support requirements. > Draft support plans for additional support requirements. > Geotechnical mapping as per Geotechnical Mapping of Roadways SOP_XXXX. **If total tell tale displacement exceeds 40 mm after TG bolt installation:** Instigate a Strata Management Team Review. Investigate within 24hrs. Analyse monitoring results and report to mine management.
Mine Manager	> Ensure adequate resources for this TARP. > Approve support plans and TARPs. > Chair monthly Strata Compliance Meetings.	> Approve support plans and TARPs. > Chair Strata Monthly Strata Compliance Meetings.	> Chair Strata Management Team reviews. > Approve support plans and TARPs.

PART E

13/

REFERENCES

LEGISLATION

Health and Safety at Work Act 2015
Health and Safety at Work (Mining Operations and Quarrying Operations) Regulations 2016

These are available at: www.legislation.govt.nz

WORKSAFE DOCUMENTS

Approved code of practice *Emergency Preparedness in Mining and Tunnelling Operations* (2016)

Fact sheet *What Events Need to be Notified?* (2016)

Good practice guidelines *Worker Engagement, Participation and Representation* (2016)

Interpretive guidelines *Developing a Ground or Strata Instability Principal Hazard Management Plan* (2015)

Interpretive guidelines *Worker Representation through Health and Safety Representatives and Health and Safety Committees* (2016)

Special guide *Introduction to the Health and Safety at Work Act 2015* (2016)

These are available at WorkSafe's website: www.worksafe.govt.nz

FURTHER INFORMATION

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Notes

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