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Department of Regional NSW

Guide

Managing risks of subsidence

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1. Introduction

1.1. Objective of the subsidence guide

This guide provides practical guidance to assist the mine operator of an underground coal mine in:

(1) complying with their obligations under the WHS laws[1] in relation to subsidence, and

(2) identifying and controlling hazards that may cause harm to people from subsidence through the development and implementation of a principal hazard management plan (PHMP) or risk management in accordance with a high-risk activity (HRA) notification.

1.2. The primary duty of care and ensuring health and safety

Under section 19 of the *Work Health and Safety Act 2011* , all persons conducting a business or undertaking (PCBUs), including mine operators, must ensure, so far as is reasonably practicable, the health and safety of workers they engage or cause to be engaged, or whose work activities they influence or direct.

PCBUs must also ensure, so far as is reasonably practicable, that the health and safety of other persons is not put at risk from work carried out as part of the conduct of the business or undertaking.

1.3. Definition of subsidence

The Work Health and Safety (Mines and Petroleum Sites) Regulation 2022 describes subsidence as the deformation or displacement of a part of the ground surface or subsurface strata caused by the extraction of minerals.

Such deformation or displacement has potential to cause hazardous conditions, which must be controlled to ensure, so far as is reasonably practicable, that the health and safety of workers and other people is not put at risk from subsidence.

1.4. How to use this guide

Note that:

(1) section 2 of this guide provides guidance notes that are common to risk management in relation to subsidence

(2) sections 3 and 4 of this guide provide guidance notes that are specific to a PHMP and the HRA notification, respectively, in relation to subsidence

(3) the mine operator should consider the guidance provided in sections 2 and 3 of this guide when identifying a principal hazard in relation to subsidence and developing and implementing a PHMP for subsidence, and

(4) the mine operator should consider the guidance provided in both sections 2 and 4 of this guide when developing and implementing risk management in relation to subsidence, as part of a HRA notification.

This guide includes references to both mandatory and non-mandatory actions. The references to legal requirements contained in the WHS laws are not exhaustive and are included for context only.

[1] It will sometimes be convenient to refer generally to WHS laws, as defined under section 5 of the WHS(MPS) Act, which includes:

- WHS(MPS) Act,
- WHS(MPS) Regulation,
- WHS Act
- WHA Regulation

This guide has been prepared to be consistent with the WHS laws as at the date of publication and should be interpreted, to the extent that if there is any ambiguity, in a manner that is consistent with the WHS laws.

To ensure you comply with your legal obligations you must refer to the latest legislation, which is available on the NSW legislation website (www.legislation.nsw.gov.au).

This publication does not represent a comprehensive statement of the law as it applies to particular problems or to individuals or as a substitute for legal advice. You should seek independent legal advice if you need assistance on the application of the law to your situation.

This guide does not cover all hazards or risks to health and safety, which may arise from subsidence, nor all aspects of risk management as documented in AS/NZS ISO 3100:2009 Risk management – Principles and guidelines. The WHS laws require mine operators to manage all aspects of risks to health and safety in relation to mining operations, not only those for which Regulations and guidelines exist.

The words 'must', 'requires' or 'mandatory' in this guide indicate there are legal requirements that must be complied with. The word 'should' indicates a recommended course of action, while 'may' indicates an optional course of action.

Lists of points in the guide should not be read as exhaustive unless this is specifically indicated in the text.

Despite any examples that may be provided as part of this guide, every process developed, or document prepared for a mine should be developed to suit the nature, complexity and location of the mining operation and the risks associated with that mining operation.

You should familiarise yourself with the terms in the glossary of this guide before reading or using this guide.

2. Managing risks of subsidence

2.1. Overview of subsidence risk management

Under section 14(1) of the WHS(MPS) Regulation, a PCBU at a mine, including the mine operator, must manage risks to health and safety associated with mining operations at the mine in accordance with Part 3.1 of the Work Health and Safety Regulation 2017.

Specifically, under section 70(1) of the WHS(MPS) Regulation, the mine operator of an underground coal mine must, in complying with section 14, manage risks to health and safety associated with subsidence at the mine. Section 70(2) sets out specific requirements in relation to subsidence.

Section 2.2 of this guide provides an outline of the scope of subsidence risk management.

Sections 2.3 to 2.7 of this guide provides guidance in relation to the following main steps of subsidence risk management:

(1) identification and understanding of subsidence hazards – refer to section 2.3 of this guide

(2) assessment of risks of subsidence - refer to section 2.4 of this guide

(3) development and selection of risk control measures - refer to section 2.5 of this guide

(4) implementation and maintenance of risk control measures - refer to section 2.6 of this guide, and

(5) continual improvement and change management - refer to section 2.7 of this guide.

Each of the above steps should be conducted together with the following processes:

(1) consultation, co-operation and co-ordination - refer to section 2.8 of this guide, and

(2) monitoring and review – refer to section 2.9 of this guide.

The mine operator should maintain a current and correct understanding of hazards and the effectiveness of risk management on an on-going basis by implementing the steps and processes

above. Consideration should be given as to how risk control measures will be identified, selected, or developed, implemented, maintained, monitored, and reviewed in a structured way to ensure effective management of all risks to health and safety associated with subsidence at the mine.

2.2. Scope of subsidence risk management

In defining the scope of subsidence risk management for a mining operation, the mine operator must consider all risks to health and safety associated with subsidence at the mine.

2.2.1. Mining operations where risk management is required

The mine operator of an underground coal mine must manage risks of subsidence due to:

(1) secondary extraction

(2) shallow depth of cover mining where the depth of cover is less than 50 metres, irrespective of first or secondary workings

(3) highwall mining, and

(4) any other circumstances where underground coal mining may lead to subsidence, for example, subsidence observed above first workings because of excessive settlement of pillars on weak claystone floor strata.

2.2.2. Surface and subsurface features where risk management is required

The surface and subsurface features refer to features that could give rise to risks to health and safety if the features are affected by subsidence. The surface and subsurface features include:

(1) public utilities (e.g. highways, railways, tunnels, bridges, air strips, electrical transmission infrastructure or pressurised gas pipelines)

(2) public amenities (e.g. shopping centres, hospitals, churches, sport facilities, childcare centres, or schools)

(3) built features other than public utilities and amenities (e.g. dwellings, factories, workshops, privately owned gas storages or surface mining voids or facilities), and

(4) natural features (e.g. cliffs, steep slopes, natural caves or dams or surface of land), where subsidence may result in hazardous conditions due to instability of rock or soil masses, rock falls, landslide, fractures, sinkholes, inundation, gas release or pollution of drinking water.

2.2.3. Area requiring risk management

The area requiring risk management is defined by the areal distribution of relevant and appropriate components of subsidence. For example, the use of the vertical displacement may not be relevant and appropriate to define an area if the risks from the development of horizontal displacement need to be managed. In practice, the areal distribution of horizontal displacement can be noticeably different from the vertical displacement.

When defining the area where risk management is required, consideration should be given to any factors that may cause the development of far-field subsidence, such as:

(1) overlying or underlying mine workings, in particular old pillar workings

(2) topographic characteristics of the land

(3) nature and magnitude of horizontal stress field

(4) geological structures, and

(5) complexities or anomalies in overburden geological or geotechnical conditions.

The intensity of risk management across the area may vary depending on the nature, likelihood, potential consequences, and complexity of subsidence hazards at any location within the area where risk management is required.

2.2.4. Period requiring risk management

The period requiring risk management is defined from the onset of subsidence to a time when risks of subsidence have become negligible to the health and safety of people.

The definition should be made based on relevant and appropriate components of subsidence. For example, the period requiring risk management for bridges affected by subsidence may need to be defined by considering valley closures and horizontal displacement, which may commence earlier and finish later than vertical subsidence.

When defining the period of risk management, consideration should be given to any factors that may cause the development of long-term subsidence or delayed subsidence, such as:

(1) overlying or underlying mine workings, in particular old pillar workings

(2) topographic characteristics of the land

(3) nature and magnitude of horizontal stress field

(4) geological structures

(5) climate conditions

(6) water in the mine workings, and

(7) complexities or anomalies in overburden, roof or floor geotechnical conditions, especially the nature and existence of claystone in the floor or roof strata, which have a potential for strength deterioration over time.

The intensity of risk management may vary depending on the nature, likelihood, potential consequences, and complexity of subsidence hazards at any time during the period requiring risk management.

2.3. Identification and understanding of subsidence hazards

Under clause 34 of the WHS Regulation, a duty holder, including the mine operator, must identify all reasonably foreseeable hazards that could give rise to risks to health and safety.

To understand the identified subsidence hazards, the scope of investigation and analysis should include:

(1) the nature of the hazards, including their magnitude, location, distribution, timing and duration

(2) the likelihood of the hazards affecting the health or safety of a person, and

(3) the severity of the potential health and safety consequences.

When identifying, investigating and analysing subsidence hazards, the mine operator should consider the matters set out in sections 2.3.1 to 2.3.4 below.

2.3.1. Factors affecting subsidence hazards

The following factors should be considered when identifying, investigating and analysing subsidence hazards:

(1) the characteristics of all relevant surface and subsurface features as set out in section 2.2.2 above, including any known future developments (e.g. sub-divisions or other improvements) within the area where risk management is required

(2) the characteristics of the mining operation, including the rate, method, layout, schedule and sequence of mining operations, the thickness of the seam to be mined, extraction height and cover depth

(3) the characteristics of any previously excavated or abandoned workings that may interact with any proposed or existing mine workings

(4) the existence, distribution, geometry, and stability of significant voids, standing pillars or remnants within any old pillar workings that may interact with any proposed or existing mine workings (for further details, refer to section 2.3.3.2 below)

(5) the characteristics of all relevant geological, hydrogeological, hydrological, geotechnical, topographical, and climatic conditions of the area where risk management is required, including the structural, lithological, and geotechnical characteristics of the overburden, inter-burden, floor and roof strata

(6) the characteristics of any conditions that may cause elevated or abnormal subsidence or formation of sinkholes (for further details, refer to section 2.3.3 below), and

(7) the predicted and actual nature, magnitude, location, distribution, timing and duration of subsidence.

2.3.2. Uncertainty

Uncertainty could potentially lead to an incomplete, inaccurate, inappropriate or a lack of understanding of subsidence hazards. Consequently, this may affect the basis on which risk control measures will be developed and selected.

Generally, uncertainty occurs because of:

(1) the inherent variations and complexities of the environment within which subsidence risk management takes place. This is often the case where a large volume of heterogeneous rock/soil masses containing numerous geological structures and other discontinuities are deformed due to underground coal mining operations

(2) the assumptions used during investigations, analysis or risk assessments, or

(3) available information that:

a. is partial

b. is vague

c. consists of an unknown level of accuracy or reliability

d. is variable or subject to different interpretations

e. is conflicting or inconsistent

f. involves factors whose relationship or interaction is unknown

g. involves a range of possibilities, or

h. changes over time.

The characteristics of the information above are due to the inherent variations and complexities described above and the nature of subsidence engineering, which often requires input from:

(1) multiple engineering or science disciplines

(2) multiple organisations or stakeholders, or

(3) multiple phases of investigations with varying qualities.

Uncertainty is a significant matter when managing risks to health and safety associated with subsidence. It is important to specifically address any uncertainties when managing risks to health and safety associated with subsidence. For further guidance, refer to sections 2.5.3 and 2.7 of this guide.

2.3.3. Specific subsidence issues

The specific subsidence issues refer to conditions that may cause elevated or abnormal subsidence, which may result in an unplanned event that causes harm to people. For example, subsidence that occurs earlier or later than predicted could result in a hazardous condition where no risk control measures have been implemented.

Abnormal subsidence means the development of subsidence that is:

(1) different from the predicted nature (e.g. tension or compression), magnitude, location, distribution, timing or duration of subsidence, or

(2) difficult to predict or unexpected in terms of the nature (e.g. tension or compression), magnitude, location, distribution, timing or duration of subsidence.

Based on the industry experience and knowledge at the time of writing, sections 2.3.3.1 to 2.3.3.9 of this guide provide a non-exhaustive list of situations in which there is a potential for the development of abnormal subsidence.

The mine operator should ensure that hazard identification, investigation and analysis consider any situations (including the situations set out in sections 2.3.3.1 to 2.3.3.9 below, if relevant), where there is a potential for the development of abnormal subsidence.

Specific considerations in risk control (see sections 2.5.3 and 2.7 below) are also necessary in these situations (including those set out in sections 2.3.3.1 to 2.3.3.9 below, if relevant) to ensure that the risk management system can respond to any changes in an adequate and timely manner.

2.3.3.1. Long-term subsidence or delayed subsidence

Risk management of long-term subsidence or delayed subsidence is difficult due to uncertainty in the timing and duration of the risks. This is one of the key factors causing the unplanned subsidence impacts previously observed in NSW.

The occurrence of either long-term or delayed subsidence is determined by the long-term stability of first workings or partially extracted workings if these workings are not properly designed taking into consideration the site conditions.

Where the long-term stability of first workings or partially extracted workings is required for the protection of surface or subsurface features, the mine operator should ensure the hazards of long-term subsidence or delayed subsidence are identified and assessed taking into consideration:

(1) the relevant mine design parameters, such as the layout of mine workings and the geometry and strengths of pillars

(2) the presence and characteristics of water affecting the strata surrounding the mine workings

(3) the structural, lithological, and geotechnical characteristics of the overburden, inter-burden, floor and roof strata, particularly the presence of claystone, and

(4) any conditions that may cause increased loading on the pillars or changes to the stress environment surrounding the mine workings, for example, interactions with the adjacent old workings or the presence of any spanning massive strata in the roof or overburden.

2.3.3.2. Multi-seam mining involving old pillar workings

In the context of managing the risks of subsidence old pillar workings refers to:

(1) any overlying old pillar workings, and

(2) certain underlying old pillar workings, which are within the influence of the stresses induced by any proposed or existing mine workings.

The interactions of the old pillar workings with any proposed or existing mine workings have a potential to cause:

(1) far-field subsidence

(2) elevated subsidence

(3) irregular distribution of subsidence, or

(4) elevated strains, tilts and curvature resulting from the above-mentioned irregular distribution of subsidence.

The hazard identification, investigation and analysis should consider the existence, distribution, geometry and stability of significant voids, standing pillars or remnants within any old pillar workings that may interact with any proposed or existing mine workings.

2.3.3.3. Multi-seam mining involving previously extracted longwalls

In the context of managing the risks of subsidence, the previously extracted longwalls refer to:

(1) any overlying extracted longwalls, and

(2) certain underlying extracted longwalls that are within the influence of the stresses induced by any proposed or existing mine workings.

The interactions of the previously extracted longwalls with any proposed or existing mine workings have a potential to cause:

(1) far-field subsidence

(2) elevated subsidence

(3) elevated strains, tilts and curvature, or

(4) distribution of strains, tilts and curvature, which may differ from that caused by single seam extraction.

The hazard identification, investigation and analysis should consider:

(1) the spatial relationship between the layouts of the mine workings at different seam levels

(2) the geological and geotechnical characteristics of the overburden and inter-burden strata, and

(3) any other factors that affect the interactions between the proposed or existing mine workings and the previously extracted longwalls.

2.3.3.4. Massive strata

Depending on the mechanical strengths and geometrical attributes of the massive strata in relation to the characteristics of the mine layout design, the presence of the massive strata in the roof or overburden has a potential to cause:

(1) reduced subsidence

(2) far-field subsidence

(3) complicated loading conditions on pillars

(4) irregular or abrupt distribution of subsidence, or

(5) elevated strains, tilts and curvature resulting from the irregular or abrupt distribution of subsidence.

The reduced subsidence may be of benefit if the mine layout can be appropriately designed in relation to the mechanical and geometrical attributes of the massive strata in the roof or overburden. However, the other above-mentioned effects will cause difficulty or uncertainty in risk management. For example, it will be difficult or impossible to predict the strains or tilts associated with the irregular or abrupt distribution of subsidence.

2.3.3.5. Creek crossings, valleys or gorges

Underground coal mining beneath or in the vicinity of creek crossings, valleys or gorges, irrespective of their steepness, has a potential to cause:

(1) valley closure, and

(2) upsidence of the valley floor.

Valley closure and upsidence may develop outside the normal distribution limit of the vertical displacement.

Any built features or public utilities (e.g. bridges or high pressurised gas pipelines) that are located across or on the floor of these topographic features may be subject to elevated and complicated stress conditions that may exceed their design capacities for managing risks to health and safety.

Creek crossings, valleys or gorges are sometimes surface expressions of geological structures (e.g. faults). In these cases, specific considerations in risk control (see sections 2.5.3 and 2.7 below) are important as it may be difficult to understand the nature of the risks before the development of subsidence.

2.3.3.6. Steep topography

Underground coal mining in areas with steep topography has a potential to:

(1) cause tensile strains on the hill tops or along the valley sides, resulting in hazardous conditions such as damage to built features, rock falls or slope instability

(2) contribute to the development of valley closure, or

(3) contribute to the development of upsidence of the valley floor.

The complex effects of steep topography on subsidence development are not always considered subsidence assessments. As a result, there is a potential for unplanned events when undertaking underground coal mining in areas with steep topography. The effects of steep topography on subsidence development should be considered by the mine operator as part of the hazard identification, investigation, and analysis.

2.3.3.7. Geological structures

Geological structures, such as folds sills or dykes, are one of the most important factors causing the development of abnormal subsidence. The hazard identification, investigation and analysis should consider the geological structures on both regional and local scales, as relevant.

2.3.3.8. Sinkhole formations

Sinkholes, or potholes, are the most hazardous form of subsidence because:

(1) their impacts on any affected surface or subsurface features are likely to occur rapidly or abruptly

(2) any surface or subsurface features located within the areas affected by a sinkhole are likely to be severely damaged resulting in hazardous conditions, and

(3) it is difficult to predict or monitor the timing of the impact of sinkhole formation.

In NSW, sinkholes have generally been observed above partially extracted workings, including first workings, under the depth of cover generally less than 50 metres. The geological, geotechnical, hydrogeological, and climatic conditions are known to be the important factors for sinkhole formation, which should be considered as part of the hazard identification, investigation and analysis.

2.3.3.9. Shear strain

Shear strain is one of the components of deformation. However, shear strain has not been recognised in the conventional subsidence engineering theory and the coal mining industry has not commonly considered it when managing risks of subsidence.

Despite this, investigations by the Resources Regulator have found evidence which suggests that shear strain is an inherent component of subsidence. The investigations have also shown that shear strain was a significant factor that caused damage to dwellings or other built structures in areas with deep cover depths, where the conventional horizontal strains may otherwise indicate a low level of risk. Shear strain should be considered as part of the hazard identification, investigation, and analysis.

2.3.4. Procedures and outcomes

The mine operator of an underground coal mine should identify, investigate, and analyse all reasonably foreseeable subsidence hazards by considering the matters set out in sections 2.3.1 to 2.3.3 above (as relevant), as well as any other relevant site-specific factors associated with subsidence at the mine.

Under section 70(2)(c) of the WHS(MPS) Regulation, the mine operator of an underground coal mine must ensure that investigation and interpretation of subsidence information is carried out only by a competent person.

The outcomes of the subsidence hazard identification, investigation and analysis should detail:

(1) the mine operator's understanding of all identified subsidence hazards, including:
   a. the nature of the hazards, including their magnitude, location, distribution, timing and duration
   b. the likelihood of the hazards affecting the health or safety of a person, and
   c. the severity of the potential health and safety consequences.

(2) any limitations and assumptions used in the investigation and analysis

(3) any identified site-specific factors that have a potential to cause the development of abnormal subsidence, and

(4) any identified site-specific factors that may cause uncertainty that may potentially lead to incomplete, inaccurate, inappropriate, or even a lack of understanding of subsidence hazards.

Importantly, the mine operator should consider the above-mentioned details (see items (1) to (4) above) when:

(1) developing risk scenarios to manage uncertainty (refer to section 2.5.3 below)

(2) managing change and continual improvement to risk management (refer to section 2.7 below), or

(3) designing the subsidence monitoring program (refer to section 2.9 below).

2.4. Assessing the risks of subsidence

Under section 14(2) of the WHS(MPS) Regulation, a PCBU at a mine, including the mine operator, must ensure that a risk assessment is conducted in accordance with section 14 by a person who is competent to conduct the particular risk assessment having regard to the nature of the hazard.

In conducting a risk assessment, the mine operator should have regard to the outcomes of subsidence hazard identification, investigation and analysis as set out in section 2.3.4 above.

The participation in subsidence risk assessment by the stakeholders, such as authorities or operators of public utilities or amenities, is essential to ensure the validity and adequacy of the risk assessment. Further guidance on consultation, co-operation and co-ordination is provided in section 2.8 of this guide.

In undertaking a risk assessment, the mine operator may refer to the relevant publications, such as AS/NZS ISO 31000:2009 and SA/SNZ HB 436:2013, and specific standards adopted by stakeholders.

Under section 14(5) of the WHS(MPS) Regulation, the mine operator (or a PCBU at a mine, who is a contractor) must keep a record of the following:

a. each risk assessment conducted under this section and the name and competency of the person who conducted the risk assessment

b. the control measures implemented to eliminate or minimise a risk that was identified by the risk assessment.

However, under section 14(6) of the WHS(MPS) Regulation, a PCBU at a mine is not required to keep a record of the risk assessment if:

a. the risk assessment is required to be carried out by an individual before the worker commences a task that forms part of an activity, and

b. the person keeps a record of risk assessments that addresses the overall activity being undertaken, of which the task forms a part.

2.5. Development and selection of risk control measures

2.5.1. General

In complying with Part 3.1 of the WHS Regulation, the mine operator must develop and implement risk control measures that:

(1) eliminate risks to health and safety so far as is reasonably practicable, and

(2) if it is not reasonably practicable to eliminate risks to health and safety - minimise those risks so far as is reasonably practicable.

The various ways of controlling risks can be ranked from the highest level of protection and reliability to the lowest. This is referred to as the hierarchy of control measures.

The mine operator must apply the hierarchy of control measures to manage the risks to health and safety in accordance with clause 36 of the WHS Regulation.

When applying the hierarchy of control measures to manage the risks of subsidence, the mine operator should consider:

(1) all possible risk control measures for the identified subsidence hazards (refer to sections 2.3 and 2.4 above), and

(2) the underground coal mine, including the rate, method, layout, schedule and sequence of mining operations, as one of the available risk control measures pursuant to section 70(2)(a) of the WHS(MPS) Regulation. For more information, refer to section 3.5.1 and Appendix A of this guide.

The mine operator should work through the hierarchy to ensure that the most effective and reliable risk control measures are developed and selected for implementation.

2.5.2. Selection of risk control measures to be implemented before or during subsidence development

There are 2 different methods to control the risks of subsidence:

Method A – Selection of risk control measures to be implemented before the development of subsidence, and

Method B – Selection of risk control measures to be implemented during the development of subsidence. The risk control measures should be implemented in a timely manner in response to the results of monitoring and consultation with stakeholders. A trigger action response plan (TARP) is commonly used by the underground coal mining industry for this method.

Not all risk control measures for subsidence will be suitable for Method B. Control measures requiring substantial planning, designing, consultation, time and resources to complete the implementation, e.g. relocation or re-routing of major infrastructure or construction of cruciform for a high voltage transmission tower, will only be suitable for Method A.

The implementation of Method B is more likely to be affected by site-specific factors or uncertainties such as adverse weather conditions or land access restrictions affecting the implementation of risk control measures.

When applying the hierarchy of control measures to ensure the most effective and reliable risk control measures are implemented, the mine operator should investigate whether Method B is

feasible and effective for the site-specific conditions. If it is not, Method A or a combination of Methods A and B should be selected and implemented.

Note: The implementation of certain risk control measures for managing the risks of subsidence may require substantial planning, designing, consultation, scheduling, time and resources, as well as prior environmental impact assessments and associated approvals under other legislation.

2.5.3. Control measures for risk scenarios

Where there is uncertainty about a subsidence hazard with potentially severe health and safety consequences, it is important to prepare for potential variations in the nature and likelihood of the hazard. The mine operator should establish relevant risk scenarios so that there is preparedness for change, instead of adopting a single management strategy. Effective and reliable risk control measures should be developed and selected for each of the risk scenarios in accordance with section 2.5.1 of this guide.

A contingency plan should be developed and used to implement the risk control measures selected for the risk scenarios if changes identified by monitoring and stakeholder consultation warrant such implementation.

2.6. Implementation and maintenance of risk control measures

2.6.1. General

Under clause 37 of the WHS Regulation, a duty holder, including a mine operator, who implements a control measure to eliminate or minimise risks to health and safety must ensure that the control measure is, and is maintained so that it remains, effective, including by ensuring that the control measure is and remains:

(1) fit for purpose, and

(2) suitable for the nature and duration of the work, and

(3) installed, set up and used correctly.

When implementing and maintaining the risk control measures developed in accordance with sections 2.5.1 to 2.5.3 above, the mine operator should:

(1) ensure that the risk control measures are installed, set up and used correctly in terms of:
   a. their design specification
   b. operational requirements, and
   c. location, timing and duration of implementation or maintenance,

(2) ensure that it is feasible to implement and maintain the risk control measures having regard to:
   a. site-specific conditions (e.g. land access to implement and maintain the risk control measures)
   b. weather conditions
   c. availability of technologies
   d. availability of resources, and
   e. availability of time to complete the implementation and maintenance,

(3) have a defined schedule to implement and maintain the risk control measures

(4) define the accountability of the competent person who implements and maintains the risk control measures

(5) measure the progress of implementation and maintenance against the development of subsidence to ensure timely completion of the implementation and maintenance of risk control measures

(6) ensure that the implementation and maintenance of one group of risk control measures do not adversely affect the functionality and effectiveness of other groups of risk control measures

(7) monitor the risk control measures to ensure that they remain effective (refer to section 2.9.1 below)

(8) maintain the risk control measures so that they remain effective

(9) rectify any failures, malfunctions, defects, or deterioration of the implemented risk control measures, and

(10) ensure preparedness for change through the implementation of a contingency plan (refer to section 2.5.3 above) so that the risk control remains effective on an on-going basis.

2.6.2. Trigger action response plan (TARP)

A TARP is a risk management tool that triggers a planned response to a change in conditions such as the development of a hazard.

A TARP summarises the monitoring arrangements and includes planned actions ready for implementation when certain trigger points are detected by the monitoring. It should be put in place only after a risk assessment has verified the selection of the most effective control measures.

In managing the risks of subsidence, a TARP may be used where:

(1) there is a gradual and slow deteriorating trend in the development of subsidence

(2) the surface and subsurface features have defined tolerances for subsidence, against which certain triggers can be established and used, and

(3) it is feasible to implement the selected risk control measures in a timely manner to control the risks during the development of subsidence.

Note: A TARP may not apply to every situation of subsidence risk management (refer to section 2.5.2 above).

When implementing a TARP, it is important to consider the following factors:

(1) simplicity - easily understood triggers designed for people who use them

(2) clear linkage - the management actions are linked to, and appropriate for, the triggers

(3) clear accountability - the management actions are assigned to a competent person who has the authority and is available to take the triggered actions

(4) communication - there is clear communication between all affected people including stakeholders, and

(5) escalation - there are escalating actions linked to deteriorating conditions (e.g. restricting or suspending mining).

2.7. Continual improvement and change management

This section of the guide is particularly relevant where there is a high level of uncertainty about the nature and likelihood of a subsidence hazard with potentially severe health and safety consequences.

In managing the risks of subsidence, it is important to:

(1) continually improve the risk management system, and

(2) manage changes in the nature, likelihood, and consequence of subsidence hazards.

This is because it is often difficult to achieve an adequate understanding of the subsidence hazards prior to the development of subsidence, because of the effects of uncertainty (refer to section 2.3.2 above) and abnormal subsidence (refer to section 2.3.3 above).

During the development of subsidence, the mine operator should:

(1) gain an improved understanding of subsidence hazards through:
   a. on-going subsidence monitoring and reviews (refer to section 2.9 below)
   b. additional investigations and assessments, as necessary
   c. on-going verification of the risk assessments previously conducted
   d. on-going verification of the assumptions used during the subsidence hazard identification, investigation, analysis, and risk assessment previously conducted, and
   e. on-going update of the relevant subsidence and geological database for the underground coal mine,

(2) revise risk control measures in response to an improved understanding of subsidence hazards through:
   a. on-going testing and verification of the effectiveness and reliability of the implemented risk control measures
   b. applying the hierarchy of control measures to select the most effective risk control measures, as necessary
   c. implementing additional risk control measures or modifications to the existing risk control measures, as necessary, and
   d. modifying the rate, method, layout, schedule and sequence of mining operations, as necessary,

(3) regularly consult with stakeholders in relation to managing the risks of subsidence (refer to section 2.8 below),

(4) ensure on-going detection of early warnings of changes from the results of risk assessments to facilitate corrective or proactive management actions or the commencement of emergency procedures in a timely manner, and

(5) ensure timely implementation of a contingency plan if the implemented risk control measures are not effective. This contingency plan needs to be established taking into consideration the risk scenarios as discussed in section 2.5.3 of this guide.

2.8. Consultation, co-operation and co-ordination

Under section 70(2)(e) of the WHS(MPS) Regulation, 'the mine operator must ensure as far as is reasonably practicable, procedures are implemented for the effective consultation, co-operation and co-ordination of action in relation to subsidence between the mine operator and relevant persons conducting business or an undertaking that is, or is likely to be, affected by subsidence'.

The procedures for consultation, co-operation and co-ordination of action with respect to subsidence should include:

(1) a process for identifying stakeholders, such as authorities or operators responsible for public utilities or amenities or owners or operators of an industrial or commercial establishment, who may be affected by subsidence,

(2) a mechanism to undertake and record regular consultation between the mine operator and stakeholders during subsidence risk management. The following questions should be addressed during the consultation:
   a. have all subsidence hazards been identified?
   b. is the mine operator's understanding of subsidence hazards still current and correct?
   c. have the implemented risk control measures been working effectively?
   d. are the risks of subsidence being adequately managed?

e. have there been any early warnings of changes from the results of risk assessments, which warrant corrective or proactive management actions or the commencement of emergency procedures?

f. have any incidents of subsidence occurred and what is the learning from the investigations of these incidents?

g. should the implemented risk control measures be revised according to the results of subsidence monitoring and review?

Note: Appendix B provides an example of a management status report that has been used in the mining industry to assist with regulator consultation, co-operation and co-ordination between the mine operator and stakeholders.

(3) a mechanism to ensure effective communication between the mine operator and stakeholders, and

Note: The observations of subsidence impacts by one stakeholder may be relevant to the other stakeholders.

(4) a process for obtaining stakeholder endorsement of the relevant risk management plans.

Note: When managing risks to health and safety associated with subsidence, the stakeholders' expertise and resources often form a fundamental part of the risk management system.

2.9. Monitoring and review

2.9.1. Subsidence monitoring

The mine operator of an underground coal mine must ensure that:

(1) monitoring of subsidence is conducted, including monitoring of its effects on relevant surface and subsurface features (section 70(2)(b) of the WHS(MPS) Regulation), and

(2) all subsidence monitoring data is provided to the regulator in the approved way and form and at the times required by the regulator (section 70(2)(d) of the WHS(MPS) Regulation).

2.9.1.1. Objective of subsidence monitoring

In undertaking subsidence monitoring, the mine operator should determine how the monitoring data is to be captured, recorded, communicated and, importantly, acted upon, for:

(1) ensuring that the mine operator has a current and correct understanding of the hazards of subsidence

(2) ensuring that the risk control measures are maintained so that they remain effective

(3) avoiding unplanned events

(4) detecting early warnings of changes from the results of risk assessments to facilitate corrective or proactive management actions or the commencement of emergency procedures

(5) identifying emerging new risks of subsidence, and

(6) informing the continual improvement and change management (refer to section 2.7 above).

2.9.1.2. Scope of subsidence monitoring

The scope of subsidence monitoring must include monitoring of:

(1) subsidence

(2) the effects of subsidence on relevant surface or subsurface features, and

(3) the effectiveness of risk control measures to ensure that they remain effective.

Refer to section 2.2.2 above for the guidance notes regarding the surface and subsurface features.

2.9.1.3. Design, implementation and maintenance of subsidence monitoring

When designing, implementing and maintaining a subsidence monitoring program, the mine operator of an underground coal mine should:

(1) address the objective and scope of the subsidence monitoring program (refer to sections 2.9.1.1 and 2.9.1.2 above)

(2) consider the outcomes of subsidence hazard identification, investigation and analysis (refer to section 2.3.4 above). In particular, the subsidence monitoring program should be designed and implemented to assist with:

   a. the verification of the risk assessments previously conducted

   b. the verification of the assumptions used during the investigations, analyses or risk assessments previously conducted, and

   c. the management of uncertainty and abnormal subsidence,

(3) consider the results of stakeholder consultation (refer to section 2.8 above), and

(4) ensure that the monitoring activities are carried out by a competent person.

The subsidence monitoring program should specify:

(1) the individual monitoring activities of the subsidence monitoring program

(2) the information to be captured from each of the individual monitoring activities

(3) the locations and area where each of the individual monitoring activities will be undertaken, including the layout and/or locations of instrumentation, monitoring points and inspections

(4) the timing, frequency and duration of monitoring activities and reporting

(5) the monitoring methods, technologies, industry standards and codes of practice that apply when undertaking the monitoring activities

(6) the measures and procedures for quality assurance

(7) the measures and procedures for detecting emerging new risks or early warnings of changes from the results of risk assessments

(8) the measures and procedures for recording and reporting monitoring results to the regulator and stakeholders

(9) the measures and procedures for rectifying any disturbances to or malfunctions of the implemented monitoring device in a timely manner so that the subsidence monitoring program remains effective

(10) a set of criteria, which if satisfied, enables a competent person to vary the implemented subsidence monitoring program (e.g. timing, frequency or duration of subsidence monitoring or reporting), and

(11) any necessary ‘redundancies’, that is, different monitoring technologies or procedures that are to be used to monitor the same subsidence hazard. Redundancies should be considered where the subsidence hazard may have potentially severe health and safety consequences.

Relevant details of a proposed subsidence monitoring program should be demonstrated on a graphical plan (i.e. Plan 7) that is part of the HRA notification (refer to the NSW Resource Regulator’s guide Notifying the regulator of a high-risk activity).

2.9.1.4. Base-line subsidence data

Base-line subsidence data, which is collected prior to the commencement of subsidence, is fundamentally important as this information is required for the calculation of subsidence parameters or for the assessment of effects of subsidence on relevant surface and subsurface features.

If subsidence starts and the base-line subsidence data is inadequate or inaccurate, then the validity of the subsidence monitoring data will be questionable. Importantly, it will be difficult to rectify any flaws in the implemented subsidence monitoring program due to the permanent loss of correct or adequate base-line subsidence data.

Prior to the development of subsidence, the mine operator should complete:

(1) the design and implementation of the subsidence monitoring program in accordance with section 2.9.1.3 above, and

(2) the collection of base-line subsidence data in accordance with the subsidence monitoring program.

2.9.1.5. Submission of subsidence monitoring data to the NSW Resources Regulator

Section 70(2)(d) of the WHS(MPS) Regulation requires the mine operator of an underground coal mine to ensure that all subsidence monitoring data is provided to the regulator in the approved way and form and at the times required by the Regulator.

For guidance notes on how to submit subsidence monitoring data to the Regulator, refer to the NSW Resources Regulator's form Providing subsidence monitoring data.

2.9.2. Review

The mine operator must review and as necessary revise the risk control measures implemented for subsidence in accordance with section 15 of the WHS(MPS) Regulation.

In the case of subsidence, where the level of uncertainty is often high and risks may change over time, both monitoring and review are essential for:

(1) detecting changes

(2) verifying the risk assessments previously conducted

(3) ensuring the effectiveness and reliability of risk control measures, and

(4) supporting continual improvement and change management.

In undertaking the reviews, the stakeholders must, so far as is reasonably practicable, be consulted and the following questions should be addressed:

(1) have all subsidence hazards been identified?

(2) is the mine operator's understanding of subsidence hazards still current and correct?

(3) have the implemented risk control measures been working effectively?

(4) are the risks of subsidence being adequately managed?

(5) have there been any early warnings of changes from the results of risk assessments, which warrant corrective or proactive management actions or the commencement of emergency procedures?

(6) have any incidents of subsidence occurred and what is the learning from the investigations of these incidents?

(7) should the implemented risk control measures be revised according to the results of subsidence monitoring and review?

Note: Appendix B provides an example of a management status report that has been used in the mining industry to assist with regular consultation, co-operation and co-ordination between the mine operator and stakeholders.

Risk control for subsidence should be reviewed and revised as necessary when:

(1) a significant change from the assumptions used or the results of risk assessments, is detected

Note: A change (from the assumptions used or the results of risk assessments) is significant if the implemented risk controls may become less effective or ineffective as a result of this change.

(2) a significant change in the site-specific conditions is identified

Note: A change in the site-specific conditions is significant if the implemented risk controls may become less effective or ineffective because of this change (e.g., identification of geological structures that may cause abnormal subsidence).

(3) there are early warnings of abnormal subsidence where significant surface or subsurface features exist

Note: In the context of subsidence risk management, the significance of surface or subsurface features is determined by the severity of the potential health and safety consequences if these features are adversely affected by subsidence.

(4) the control measure does not control the risk it was implemented to control so far as is reasonably practicable

(5) a new relevant hazard or risk is identified

(6) the results of consultation (refer to section 2.8 above) indicate that a review is necessary

(7) an incident or notifiable incident has occurred, or

(8) the results of an audit indicate that a review is necessary.

The mine operator must ensure that any interpretation of subsidence information (e.g. reviewing the risk control measures for subsidence) is carried out only by a competent person.

3. Principal hazard management plan (PHMP) for subsidence

3.1. Overview

Section 4 of the WHS(MPS) Regulation defines a principal hazard as:

'... an activity, process, procedure, plant, structure, substance, situation or other circumstance relating to the carrying out of mining operations or petroleum operations that has a reasonable potential to result in multiple deaths in a single incident or a series of recurring incidents in relation to —

a. for mining operations — one or more of the following —

i. ground or strata failure,

ii. inundation or inrush of any substance,

...

iii. subsidence,...'

The NSW code of practice - Safety management systems in mines states that:

Principal mining hazards are singled out for special consideration because they are hazards with specific relevance to mining that have the potential to cause an incident with very serious consequences, even though the probability may be low.

As the risks associated with principal mining hazards are not always obvious, they must be identified and then assessed separately and in combination in case there are interactions flowing from one to the other.

According to observations made across NSW coalfields, a principal hazard in relation to subsidence:

(1) can have very serious potential health and safety consequences

(2) may require risk control measures which can be very significant in terms of the planning, consultation, design, implementation, time and resources. These control measures usually need to be determined and implemented prior to the development of subsidence, and

(3) can be difficult to understand due to uncertainty, prior to the development of subsidence.

The guidance notes provided for the development and selection of risk control measures (refer to sections 2.5.1 to 2.5.3 above) and management of uncertainty, abnormal subsidence and changes (refer to sections 2.3 and 2.7 above) are particularly relevant to a PHMP for subsidence.

Sections 2 and 3 of this guide should be considered when identifying a principal hazard and developing and implementing a PHMP for subsidence.

3.2. Identifying principal hazards in relation to subsidence

Under section 27(1) of the WHS(MPS) Regulation, the mine operator must identify all principal hazards associated with mining operations at the mine.

To identify principal hazards in relation to subsidence, the mine operator should conduct a comprehensive and systematic investigation and analysis of all relevant matters set out in section 2 of this guide, in particular sections 2.2, 2.3 and 2.8 above.

Section 27(3)(a) of the WHS(MPS) Regulation requires the mine operator to use investigation and analysis methods that are appropriate to the principal hazard being considered (refer to section 3.3 below), when conducting a risk assessment.

3.3. Risk assessment

Under section 27(2) of the WHS(MPS) Regulation, the mine operator must conduct, in relation to each principal hazard identified, a risk assessment that involves a comprehensive and systematic investigation and analysis of all aspects of risk to health and safety associated with the principal hazard.

The mine operator, in undertaking a risk assessment for a principal hazard of subsidence, must:

(1) ensure that the risk assessment involves a comprehensive and systematic investigation and analysis of all aspects of risk to health and safety associated with the principal hazard

(2) use investigation and analysis methods that are appropriate to the principal hazard being considered. For example:

   a. a historical mine layout plan is not appropriate for assessing the stability of overlying or underlying old pillar workings underneath a major public utility if the accuracy of the layout plan cannot be verified

   b. any structural conditions of a dwelling that may become hazardous when affected by subsidence should be identified and assessed by a competent person prior to the development of subsidence. The results of the investigation should be used for the development and implementation of appropriate risk control measures, or

   c. it is not appropriate to assess the stability of embankments supporting critical transport infrastructure based on assumed mechanical parameters for the embankments. These parameters should be obtained through site-specific investigations, and

(3) consider the principal hazard individually and also cumulatively with other hazards at the mine (e.g. inflow or inrush of water).

To conduct the risk assessment for a principal hazard of subsidence, the mine operator should conduct a comprehensive and systematic investigation and analysis of all relevant matters set out in section 2 of this guide, in particular sections 2.2 to 2.5 and section 2.8 above.

3.4. Preparing for a PHMP for subsidence

Under section 28 of the WHS(MPS) Regulation, the mine operator must prepare a PHMP for each principal hazard associated with mining operations at the mine in accordance with section 28 and Schedule 1.

Section 6 of Schedule 1 of the WHS(MPS) Regulation states that:

'The following matters must be considered in developing the control measures to manage the risks of subsidence:

a. the characteristics of all relevant surface and subsurface features
b. the characteristics of all relevant geological, hydrogeological, hydrological, geotechnical, topographic and climatic conditions, including any conditions that may cause elevated or abnormal subsidence or the formation of sinkholes
c. the characteristics of any previously excavated or abandoned workings that may interact with any proposed or existing mine workings
d. the existence, distribution, geometry and stability of significant voids, standing pillars or remnants within any old pillar workings that may interact with any proposed or existing mine workings
e. the predicted and actual nature, magnitude, distribution, timing and duration of subsidence
f. the rate, method, layout, schedule and sequence of mining operations.'

In addition to the requirements of section 6 of Schedule 1, the mine operator should prepare the PHMP for subsidence by comprehensively and systematically considering all relevant matters set out in section 2 of this guide.

The PHMP for subsidence is part of the SMS for a mine (see section 19(2)(c)(i)) of the WHS(MPS) Regulation, which must be implemented so far as is reasonably practicable under section 18(2) of the WHS(MPS) Regulation). For guidance notes on SMS, refer to NSW code of practice - Safety management systems in mines.

Under section 28(3) of the WHSMP Regulation, the PHMP for subsidence must:

(1) describe the nature of the principal hazard of subsidence. The descriptions should be based on the results of investigations and analyses undertaken in accordance with the relevant matters set out in section 2 of this guideline, in particular sections 2.2 to 2.4 and 2.8 above
(2) describe how the principal hazard of subsidence relates to other hazards associated with mining operations at the mine
(3) describe the analysis methods used in identifying the principal hazard of subsidence
(4) include a record of the most recent risk assessment conducted in relation to the principal hazard of subsidence
(5) describe the investigation and analysis methods used in determining the control measures to be implemented
(6) describe all control measures to be implemented to manage risks to health and safety associated with the principal hazard of subsidence. The descriptions should be provided in accordance with all relevant matters set out in section 2 of this guideline, in particular sections 2.5 to 2.9 above
(7) refer to any design principles, engineering standards and technical standards relied on for control measures for the principal hazard of subsidence, and
(8) set out the reasons for adopting or rejecting each control measure considered.

Under section 28(5) of the WHSMP Regulation, the mine operator must ensure that no mining operations are carried out at the mine that may give rise to a principal hazard before the PHMP for

that hazard has been prepared. A PHMP for subsidence should be prepared and implemented prior to the development of subsidence that may give rise to the principal hazard of subsidence.

3.5. Other matters relevant to managing risks associated with a principal hazard in relation to subsidence

Under section 28(4)(b) of the WHS(MPS) Regulation, when preparing a PHMP, the mine operator must consider any 'other matters relevant to managing the risks associated with the principal hazard'.

The objective of this section is to assist the mine operator in developing and implementing PHMPs for subsidence following the best industry practices.

At this stage, only a limited number of examples of such industry practices are provided in this section. This guide will be updated in due course to provide additional examples of best industry practices in managing health and safety risks in relation to PHMP for subsidence.

Note: industry practices that are highly site-specific are not covered in this guide.

3.5.1. Mining operations as a risk control measure

When applying the hierarchy of control measures (refer to section 2.5 above), the mine operator should consider the underground coal mine, including its rate, method, layout, schedule, and sequence of mining operations, as one of the available risk control measures in accordance with section 70(2)(a) of the WHS(MPS) Regulation.

It is important that a PHMP for subsidence incorporates a procedure that activates and implements 'controlled mining operation' as a risk control measure. While using the mining operation to control subsidence hazards can be effective, the implementation of this control measure may require specific and significant planning and preparation.

Appendix A provides an example of the best industry practices in relation to the implementation of 'controlled mining operation' as one of the control measures to manage risks to health and safety associated with subsidence. This example has been summarised from cases involving risk management for major public utilities affected by subsidence.

3.5.2. Management status reporting to assist with regular consultation

Appendix B provides an example of a management status report that has been used in the industry to assist with regular consultation, cooperation and co-ordination between the mine operator and stakeholders.

The frequency for providing the management status report to stakeholders may vary depending on the nature of risk at a particular site. For major public utilities and amenities affected by subsidence, a weekly reporting frequency is common.

3.5.3. Other examples of best industry practices relevant to a PHMP

Appendix C provides an example of managing health and safety risks of subsidence in relation to dwellings and other similar civil structures. This example outlines the essential information and procedures necessary for the development and implementation of effective risk control measures.

3.6. Review, audit and maintenance

3.6.1. Review and maintenance of a PHMP

The mine operator must ensure that the PHMP for subsidence is reviewed and as necessary revised in accordance with section 29 of the WHS(MPS) Regulation.

If the PHMP for subsidence is revised, the mine operator must record the revision, including any revision of a risk assessment, by amending the plan in writing.

A PHMP is part of the SMS for a mine (see section 19(2)(c)(i)), which must be audited under section 20, maintained under section 21 and reviewed, and as necessary revised, under section 22 of the WHS(MPS) Regulation.

For further guidance notes in relation to maintenance and review, refer to sections 2.6 and 2.9 of this guide.

3.6.2. Audit

The mine operator must audit a PHMP for subsidence as part of auditing the effectiveness of the SMS in accordance with section 20 of the WHS(MPS) Regulation.

The primary purpose of audits should be to determine whether risk controls for subsidence are in place and effective.

Under section 20(c) of the WHS(MPS) Regulation, the system for auditing the effectiveness of the SMS must be set against the performance standards for measuring the effectiveness of all aspects of the SMS, including the methods, frequency, and results of the audit process. The audit should also consider the following matters:

(1) competency of the auditor

(2) the person responsible for ensuring the audit is conducted, and

(3) the person responsible for implementing the results of the audit.

When setting the performance standards, the following publications should be considered and as necessary referred to:

(1) section 5.1 of the NSW code of practice – Safety management systems in mines

(2) Annex A of Risk management – Principles and guidelines (AS/NZS ISO 31000:2009), and

(3) section 6 of Risk management guidelines – Companion to AS/NZS ISO 31000:2009 (SA/SNZ HB 436:2013).

4. High risk activity (HRA) notification in relation to subsidence

A mine operator must give notice of a HRA to the NSW Resources Regulator and ensure that the requirements of section 35 and Schedule 3 of the WHS(MPS) Regulation are complied with.

In Schedule 3 of the WHS(MPS) Regulation, there are three HRAs that relate to subsidence:

(1) section 17 - Secondary extraction

(2) section 18 - Shallow depth of cover mining, and

(3) section 30 - Highwall mining.

Specifically, when submitting a HRA notification that involves subsidence, the mine operator must provide:

(1) details of how the risks to the health and safety of workers and other persons from subsidence caused by the activity will be managed - refer to section 17, Schedule 3 - Secondary extraction

(2) information on how the risks to the health and safety of workers and other persons from the potential formation of sinkholes will be managed - refer to section 18(3)(d), Schedule 3 - Shallow depth of cover mining, or

(3) information on how the risks to the health and safety of workers and other persons from subsidence caused by the activity will be managed - refer to section 30(3)(c), Schedule 3 - Highwall mining.

The HRA notification should consider and address all relevant matters set out in section 2 of this guide, in particular sections 2.2 to 2.9 above.

The level of detail required for all the relevant matters set out in section 2 of this guide should be commensurate with the nature, likelihood, potential consequences, and complexity of subsidence hazards identified.

For guidance notes on how to provide a HRA notification in accordance with section 35 and Schedule 3, refer to the NSW Resources Regulator's guide Notifying the Regulator of a high-risk activity.

To notify the Regulator of a high risk activity, log into the Regulator Portal and complete and submit the high risk activity notification form.

Should you require a user account for the portal or to add a mine you operate to your existing user account then please submit a request to add a PCBU or operator.

5. Engineering plans and drawings

Engineering plans and drawings are part of the results of the mine operator's investigation, assessment and consideration. The mine operator should refer to the NSW Resource Regulator's guide Notifying the Regulator of a high-risk activity for guidance notes on how to prepare and submit the engineering plans and drawings in relation to:

(1) secondary extraction

(2) shallow depth of cover mining, or

(3) highwall mining.

6. Notification of an incident or injury

For guidance notes on how to notify subsidence-related incidents or injuries, refer to the NSW Resource Regulator's guide Notification of incident and injury.

7. Notification of reportable events

For guidance notes on how to notify reportable events relevant to subsidence, e.g. commencement of mining operations or proposed material changes in relation a PHMP, refer to the NSW Resources Regulator's fact sheet Notifying the Regulator of reportable events.

8. References

- AS/NZS ISO 31000:2009: Risk management – Principles and guidelines, Standards Australia
- SA/SNZ HB 436:2013: Risk management guidelines – Companion to AS/NZS ISO 31000:2009, Standards Australia
- NSW code of practice: Safety management systems in mines
- Notification of incident and injury (guide)
- Notifying the Regulator of reportable events fact sheet
- Providing subsidence monitoring data (form)

Acronyms

HRA – High risk activity

PCBU – Person conducting a business or undertaking

PHMP – Principal hazard management plan

SMS – Safety management system

TARP – Trigger action response plan

WHS – Work health and safety

Glossary

This glossary includes terms used in this guide. Definitions, where indicated, have been sourced from WHS laws. Elsewhere, the terms have been defined according to the relevant literature or practices.

Angle of draw – the angle between the vertical and the line joining the edge of the mining void with the limit of vertical subsidence, usually taken as 20mm.

Base-line subsidence data – subsidence monitoring data collected prior to the commencement of subsidence. This data is required for the calculation of various subsidence parameters or the assessment of effects of subsidence on relevant surface and subsurface features.

Competent person – a person who has acquired through training, qualification or experience the knowledge and skills to carry out the task (other than in respect of work for which a particular competency is prescribed, for example clause 5(1) definition of 'competent person' paragraphs (a)-(f) of the WHS Regulation, or in clause 3(1) of the WHSMP Regulation).

Components of subsidence – in conventional subsidence engineering theories, these components include mining-induced vertical displacement (or vertical subsidence), horizontal displacement, tilt, horizontal strain and curvature, which are used for various engineering or risk management purposes. In recent years, additional components of subsidence have been identified including mining-induced valley closure, upsidence and shear strain.

Control measure – in relation to a risk to health and safety, means a measure to eliminate or minimise risks.

Cover depth – the depth of coal seam from the ground surface (metre).

Curvature – the radius of curvature of the ground surface or subsurface strata induced by underground coal mining. The curvature of deformed ground can be either concave or convex.

Delayed subsidence – a noticeable increase in subsidence that occurs rapidly or within a relatively short period in an area where underground coal mining ceased many months or even many years ago.

Discontinuity – a general term for natural or mining-induced planes of weakness or breaks in a rockmass.

Far-field subsidence – subsidence that occurs outside the conventional limit of subsidence. The limit is defined based on 35 degrees of angle of draw for the Southern Coalfield or 26.5 degrees of angle of draw for the other Coalfields in NSW.

Far-field horizontal displacement – mining-induced horizontal displacement that occurs outside the conventional limit of subsidence. The limit is defined based on 35 degrees of angle of draw for the Southern Coalfield or 26.5 degrees of angle of draw for the other Coalfields in NSW.

First workings – the formation of two sets of roadways (i.e. headings and cut-through) in a coal seam. The two sets of roadways are at an angle to each other (e.g. 90 degrees) forming pillars or blocks of coal that may be extracted at a later stage. First workings are primarily used for the development of coal resources prior to the extraction of the above-mentioned pillars or blocks of coal. First workings can also be the only type of mine workings in some mines or parts of mines.

Geological structures – natural planes of weakness in the rockmass that pre-date any mining activity. Geological structures include faults, folds, igneous intrusions, joints, bedding planes or any other type of geological discontinuities or disturbances within the rockmass.

Horizontal displacement – mining-induced change in the horizontal position of any part of the ground surface or subsurface strata.

Horizontal strain – mining-induced change in the horizontal distance between 2 points relative to their original horizontal distance. The strain can be shortening (i.e. compressive) or lengthening (i.e. tensile).

Improvement – any building or work erected or constructed on land; any formed road, street, path, walk or driveway; any pipeline, water, sewer, telephone, gas, or other service main, whether above or below the surface of the land (as defined in section 4(1) of the Mine Subsidence Compensation Act 1961).

Long-term subsidence – on-going development of subsidence after the completion of underground coal mining.

Massive strata – a rockmass that has a paucity of well-developed bedding planes. In the underground coal mining sector, the term 'massive' is often used to refer to the strata that are strong and have a capacity to span across the mine workings.

Pillar – an area of coal left to support the overlying rock.

Reasonably practicable - has the same meaning as it has in section 18 of the WHS Act.

Secondary working – underground coal mining (e.g. longwall mining or pillar extraction) to remove the pillars or blocks of coal delineated by the first workings.

Shear strain – a component of deformation that is defined by an angular change between two lines within an object.

Stakeholders – relevant persons conducting any business or undertaking that is, or is likely to be, affected by subsidence.

Strain – refers to changes in configuration of an object, which is measured by 'normal strain' and 'shear strain'.

Surface or subsurface features – refer to section 2.2.2 of this guide.

Tilt – mining-induced slope of a line between two points at the ground surface or within the subsurface strata.

Upsidence – mining-induced relative upward vertical displacement of the ground surface or subsurface strata, generally observable at the bottom of valleys.

Valley closure – mining-induced relative horizontal movement of the two sides of a valley towards each other.

Vertical displacement (or vertical subsidence) – mining-induced change in the vertical position of any part of the ground surface or subsurface strata.

Vertical subsidence – refer to vertical displacement.

WHS Act means the *Work Health and Safety Act 2011*.

WHS laws means the WHS Act, WHS Regulation, WHSMP Act and WHSMP Regulation.

WHS(MPS) Act means Work Health and Safety (Mines and Petroleum Sites) Act 2013.

WHS(MPS) Regulation means Work Health and Safety (Mines and Petroleum Sites) Regulation 2022.

WHS Regulation means Work Health and Safety Regulation 2017.

Appendix A – An example of governance arrangement to coordinate the implementation of different risk control measures including mining operation

This example is a highly summarised form of similar governance arrangements used in the industry. It provides the essential aspects of the management process without site-specific details.

1. Objectives

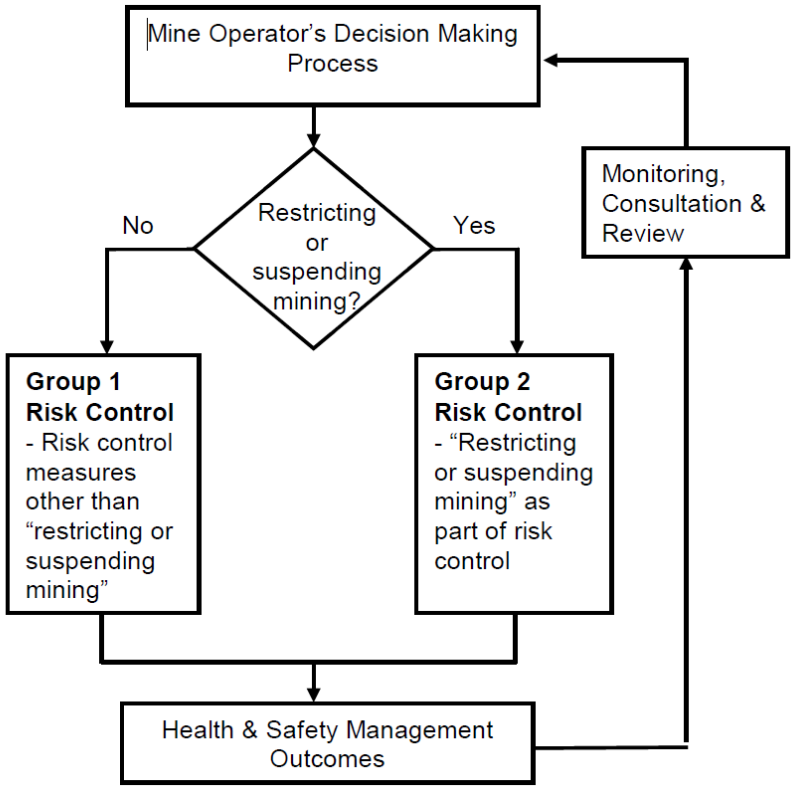
The overall objective of the governance arrangement is to ensure that the mine operator delivers risk management outcomes in compliance with the requirements under WHS laws, that is, the health and safety of workers and other persons is not put at risk from the mine or work carried out as part of mining operations so far as is reasonably practicable.

In applying the hierarchy of control measures (refer to section 2.5 of this guideline), the mine operator must consider the underground coal mine itself, including its rate, method, layout, schedule or sequence of the mining operations, as one of the available risk control measures in accordance with clause 67(2)(a) of the WHSMP Regulation.

The specific objective of the governance arrangement is to provide a process, which co-ordinates the implementation of different risk control measures including mining operation, to achieve the above-mentioned overall objective.

2. Important aspects of governance arrangement

Mine operator's decision making criteria – outcomes of risk management to be in compliance with the requirements under WHS laws.



The diagram above demonstrates a number of important aspects of a governance arrangement, including:

(1) The mine operator's obligation to deliver risk management outcomes in compliance with the requirements under WHS laws, that is, the health and safety of workers and other persons is not put at risk from the mine or work carried out as part of mining operations so far as is reasonably practicable,

(2) Governance arrangement as an overarching high level process to ensure timely and balanced implementation of the following two groups of risk control measures:

Group 1 – risk control measures other than 'restricting or suspending mining operation', and

Group 2 – 'restricting or suspending mining operation' as part of risk control. The restriction or suspension may be either temporary or on-going depending on the circumstances.

If the Group 1 risk control measures are found to be ineffective or likely to be ineffective, based on the results of monitoring, review or consultation, the mine operator needs to implement the Group 2 risk control measures to ensure compliance in a timely manner.

It follows that by making efforts to improve the effectiveness of the Group 1 control measures, the mine operator may avoid or minimise interruptions to mining in a planned and organised manner.

Observations have shown that a combination of the two groups of control measures can be very effective, when this is warranted, e.g. adequate and timely implementation of an improvement to Group 1 control measures may require mining to be temporarily restricted or suspended,

(3) The need to establish a decision making process to authorise mining operation on a regular basis by the mine operator. The decision making process needs to have a focus on the timing, duration, frequency, triggers and procedures to undertake the authorisation to mine so that timely restriction or suspension of mining can be carried out to ensure compliance with the requirements under WHS laws,

(4) Defined accountability of the mine operator's senior management to authorise mining operation following the above-mentioned decision making process,

(5) Defined communication system and consultation procedures as part of the governance arrangement, including a process for the mine operator's senior management to confer with relevant senior management of the authorities or operators of the major public utilities (or major amenities) affected by subsidence, and

(6) Record of mine operator's authorisation in the management status reports (refer to Appendix B).

Note:

- Governance arrangement, as discussed in this Appendix, has been used in the industry to manage health and safety risks associated with principal hazards related to major public utilities affected by subsidence. It may be suitable for management of risks associated with principal hazards related to major public amenities affected by subsidence,
- The frequency of authorisation to mine has generally been weekly during active subsidence period affecting major public utilities, and
- The decision making process has included specific procedures based on which to decide the commencement and cessation of mine operator's authorisation, subject to the nature/magnitude of risk development.

Appendix B – An example of management status report as part of ongoing consultation with stakeholders

ABC Colliery

Management status report No 15 - mining of Longwall 6 beneath Infrastructure Item No. A

Note:

- Status reports used in the industry have generally been very brief, not exceeding two pages per report, and
- The frequency to provide the management status report to the stakeholders varies depending on the nature of risk at a particular site. For major public utilities and amenities affected by subsidence, the frequency has generally been weekly during active subsidence.

General status

Reporting period	*from 29 April 2015 to 12 May 2015*
Length of extraction LW6	*600m as at 12 May 2015*
Distance travelled by LW6 face since previous report	*65m as at 12 May 2015*
Closest horizontal distance of LW6 face to the infrastructure	*-120m*[2]
Maximum subsidence observed at Infrastructure Item No. A	*110mm*
Increase in subsidence observed since previous report	*25mm*
Safety incident	*Not observed during this reporting period*

Management status

Monitoring activity	Date of monitoring	Monitoring frequency	Triggers reached since previous report	Management actions undertaken in response to triggers reached
Activity 1	*N/A*	*Every 5 minutes*	*No*	*N/A*
Activity 2	*8 May 2015*	*Monthly*	*No*	*N/A*
Activity 3	*8 May 2015*	*Weekly*	*No*	*N/A*
Activity 4	*Daily*	*Daily*	*No*	*N/A*
Any other management actions that have been undertaken since previous report? • *Implementation of all planned risk control measures, except certain monitoring activities, has been completed during this reporting period.*				
Any new subsidence hazards or early warnings of abnormal subsidence or deviations/changes from the results of risk assessment, which have been identified since previous report? • *Not during this reporting period.*				
Any outstanding or necessary additional or revised management actions to be undertaken?				

[2] Negative sign suggests that Infrastructure Item No A has not yet been directly undermined whereas positive sign suggests LW face has passed the infrastructure

Monitoring activity	Date of monitoring	Monitoring frequency	Triggers reached since previous report	Management actions undertaken in response to triggers reached
• *No, based on the results of consultation, monitoring and reviews to date.*				
Results of consultation with stakeholder since previous report regarding the effectiveness and adequacy of risk control. • *The current management process is considered to be effective.* • *Noting the expected active subsidence and need to review for preparedness.*				
Mine operator's comment regarding the effectiveness and adequacy of risk control • *Based on the results of consultation, monitoring and reviews to date, risk control is considered to be effective and adequate.*				
Forecast whether continued mining is likely to cause any hazardous conditions • *Based on the results of engineering analyses, consultation, monitoring and reviews to date, no triggers under the risk management plan are expected to be exceeded in the next reporting period. Accordingly continued longwall mining is not expected to cause hazardous conditions due to subsidence effects on Infrastructure Item No A in the next reporting period.*				
Authorisation to mime • if applicable (see Appendix A of this guideline).				

Status report by ABC Colliery: Signature _____ Date of submission _____

Position _____

Copy of report to: *(Appropriate detail)*

Appendix C – An example of current best practice risk management

- Dwellings and other similar built features

ABC Colliery

For mining of Longwall 6 beneath dwellings and other similar built features

Property Identification	Property owner's consent to allow engineers' access	Brief description of property	Findings and recommendations by civil engineer[1]	Findings and recommendations by geotechnical engineer[2]	Expected active subsidence period affecting the property	Mine operator's management actions in response to engineers' recommendations
A	Yes	1 house 1 gas storage 3 farm dams	• Engineer's finding & recommendation AC1 • Engineer's finding & recommendation AC2 • Engineer's finding & recommendation AC3	• Engineer's finding & recommendation AG1 • Engineer's finding & recommendation AG2	July 2015 to November 2015	• Summary of monitoring activities by the mine operator in response to engineers' findings and recommendations AC1 to AG2. • Summary of risk control measures to be implemented by the mine operator in response to engineers' findings and recommendations AC1 to AG2. • Implementation schedule for each of the above risk control measures and monitoring activities in relation to the development of subsidence. • Status of completion for each of the risk control measures and monitoring activities at time of risk review or end of subsidence caused by LW6 or prior to be commencement of the next longwall.

Notes:

1. Civil engineers' work refers to the identification and assessment of any structures that may become hazardous when affected by subsidence,

2. Geotechnical engineer's work refers to the assessment of stability of sloping ground, cliff formations, farm dams, etc., which may pose safety risks to dwellings or other similar built features if the sloping ground, cliff formations, farm dams, etc., become unstable when affected by subsidence, and

3. The above-mentioned engineers' work is to be carried out:

- by entering the land/property if the owner has provided consent to enter, or
- by obtaining information that is available without access to the relevant private land/property, if the property owner does not allow access. In this case, it may not be practicable for the engineers to develop detailed recommendations.