Guideline for Managing the Risk of an Airblast in an Underground Mine

MDG 1031

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Produced by
Mine Safety Operations Division
New South Wales
Department of Primary Industries

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DISCLAIMER

FOREWORD

The NSW Department of Primary Industries document MDG 1031 TR – *Technical Reference Material for Managing the Risk of an Airblast* is attached to this Guideline. It provides supporting reference material.

This is a Published Guideline. Further information on the status of a Published Guideline in the range of OHS instruments is available through the NSW Department of Primary Industries Legislation Update Number 2/2001 which is included in this Guideline.

The range of instruments includes:

- Acts of Parliament
- Regulations made under the Act
- Conditions of Exemption or Approval *(Coal Mines)*
- Standards (AS, ISO, IEC)
- Approved Industry Codes of Practice (under the OHS Act)
- Applied Codes, Applied Guidelines or Standards (under clause 14 of the Coal Mines (General) Regulation 1999)
- Published Guidelines
- Guidance Notes
- Technical Reference documents
- Safety Alerts

The principles stated in this document are intended as general guidelines only for the assistance of owners and managers in devising safety standards for the working of mines. Owners and managers should rely upon their own advice, skills and experience in applying safety standards to be observed in individual workplaces.

The State of New South Wales and its officers or agents including individual authors or editors will not be held liable for any loss or damage whatsoever (including liability for negligence and consequential losses) suffered by any person acting in reliance or purported reliance upon this Guideline.

The MDG 1031 *Guideline for Managing the Risk of an Airblast in an Underground Mine,* has been distributed to industry for consultation and comment through a representative working group, the Metalliferous Industry Safety Advisory Committee and the Coal Safety Advisory Committee.

The NSW Department of Primary Industries has a review time set for each Guideline that it publishes. This can be brought forward if required. Input and comment from industry representatives would be much appreciated. The Feedback Sheet at the end of this document can be used to provide input and comment.

ROB REGAN
Director, Mine Safety Operations
Chief Inspector of Mines
Chief Inspector of Coal Mines

CONTENTS

Purpose and scope

This Guideline is intended to assist mine managers and contractors in the management of the risk of an airblast occurring in an underground mine.

The scope of this Guideline includes:

- an outline of the factors or elements that are necessary for an airblast to occur
- the safety considerations surrounding those factors
- matters for consideration that could assist in effectively eliminating or minimising the risk of an airblast occurring
- matters for consideration to mitigate the effects of an airblast are also provided.

An airblast is a major hazard. Should it occur it could cause many fatalities within a mine and extensive damage to equipment and infrastructure. For this reason it is very important to investigate the most appropriate means to prevent an airblast from occurring and possibly also plan to mitigate the consequences should an airblast still occur.

To assist in this process an example of a TARP (trigger action response plan) is provided in the appendix of this Guideline. This TARP itemises examples of issues that could be monitored to prevent or mitigate the effects of an airblast in a caving mine.

Note that:

- Adherence to Guidelines does not of itself assure compliance with the general Duty of Care.
- Mine operators deviating from Guidelines should document a risk assessment supporting the alternative arrangements. However, the risk assessment should always be current, relevant and be regularly reviewed.

References

NSW Legislation

- Occupational Health and Safety Act 2000, General Duty of Care.
- Clause 46 of the Mines Inspection Act 1901, General Rule 2000 requires the general manager to ensure that any foreseeable risks to the health and safety of persons at the mine are identified and assessed and that such risks are eliminated or minimised to the fullest extent that is reasonably practicable.
- Clause 9 of the Mines Inspection Act 1901, General Rule 2000 requires the general manager to prepare, communicate and regularly review a Mine Safety Management Plan.
- Clause 11 of the Mines Inspection Act 1901, General Rule 2000 requires the contractor to comply with a Mine Safety Management Plan which is approved by the general manager.
- Clause 19 of the Mines Inspection Act 1901, General Rule 2000 requires the general manager to deal with risk by eliminating the risk, controlling the risk at the source or minimise the risk and with the remaining risk provide personal protective equipment.
- Clause 37 Coal Mines Regulation Act 1982, requires the manager to have full charge and control of operations at a mine.

Note: The Mines Inspection Act 1901 and the Coal Mines Regulation Act 1982 will be replaced by new legislation in NSW soon after printing. However, similar clauses to those mentioned above will be in force.

NSW Department of Primary Industries publications

- MDG 1010 *Risk Management Handbook*
- *Minerals Industry Safety Handbook* – July 2002
- *Mine Safety Management Plan Workbook*

Standards Australia publications

- AS 4360 - Risk Management

Other references

- Australian Centre for Geomechanics. December 2004. *Monitoring cave-related seismicity at Ridgeway Gold Mine*, ACG Newsletter, Vol. 23.
- Brown, E.T. 2003. *Block Caving Geomechanics*, Brisbane: Julius Kruttschnitt Mineral Research Centre.
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- Logan A. 2004. *Air Inrush Risk Assessment for Caving Mines*, Paper Presented at MassMin 2004 Santaigo. Newcrest Mining Ltd, Melbourne, Australia.
- Potvin, Y, Thomas, E. and Fourie, A. 2005. *Handbook on Mine Fill.* Australian Centre for Geomechanics, Nedlands, Western Australia, Australia.
- Ross, I and van As, A. 2005. *Northparkes Mines —Design, Sudden Failure, Air-Blast and Hazard Management at the E26 Block Cave* Paper Presented at 9th AusIMM Underground Operator's Conference 2005, Perth, Western Australia.

Glossary of terms and abbreviations

For the purpose of this document the following terms and abbreviations apply:

Airblast
An airblast is a rapid displacement of large quantities of air, often under pressure, in a constrained underground environment caused by a fall of ground or other material. The extent of the consequences of such an airblast depends on the amount of air that is compressed and the rate of that compression. Note: An airblast in coal mines is called a windblast.

Bulkhead
A bulkhead is usually a solid structure built across a drive or opening that would seal the drive or opening from the effects of an airblast or mitigate the effects of such an airblast from the rest of the mine. A bulkhead can also be known as a stopping or plug.

CMS
Cavity monitoring systems

Drive
A drive is a tunnel or long excavation underground. Also known as a drift, especially in coal mines.

LEL
Lower explosives limit

MSMP
Mine Safety Management Plan

Seismogenic zone
The seismogenic zone is an active seismic front caused by failure of the rockmass primarily through shearing and intact rock fracturing (Duplancic, 2001).

TARP
Trigger Action Response Plan (see an example in Appendix 1).

TDR
Time domain reflectometer

The management system minimising the risk of an airblast

General

A management system for minimising the risk of an airblast should be part of a Major Hazard Management Plan and should be integrated with the overall Mine Safety Management Plan (MSMP). It should be based on a risk management approach to safety. Users of this Guideline should refer to MDG 1010 *Risk Management Handbook* for more information on this approach. Some Major Hazard Management Plans can include a Trigger Action Response Plan (TARP) as mentioned in more detail within these guidelines.

The technical reference document included within this Guideline provides detail on matters to consider in various areas such as planning, design, monitoring, and/or control measures to take as well as issues that could require further investigation. Each of these issues are suggested to be included when developing a management system to minimise the risk of an airblast occurring.

Any system and/or monitoring procedure being designed to correspond to any of the safety issues stated within this Guideline should, where appropriate, be developed in consultation with recognised competent specialists as well as those who will be or have been implementing similar actions such as managers, employees, contractors and any other representatives.

Record keeping and documentation

Records and documentation of investigations, planning, design, monitoring and any Triggered Action Response Plan (TARP) should be integrated within the MSMP document control system. Accurate records should be kept on how risk is managed at every stage. Particular documents that could be considered may include:

- Risk assessment and hazard management plans
- Specialists' advice and reports
- Investigation reports
- Assessments and investigations associated issues that could have an impact on design and planning such as geotechnical, groundwater, gas, monitoring decisions and planned responses if conditions change
- All mine design and planning matters
- Risk assessments carried out to minimise risk when performing various activities
- Design parameters and specifications of bulkheads or safe havens
- Safe Work Procedures
- Nominated responsibilities of personnel
- Further relevant geotechnical and geological mapping, drill logs and any resultant interpretations
- Monitoring records of water or gas as the risk could considerably increase if an airblast occurs
- Testing and maintenance of monitoring equipment
- Training records
- Workplace inspection records
- Hazard reporting and follow-up records

Training

The Mine Safety Management Plan should include a training plan and an assessment of training needs. Training and skill levels should be recorded on personnel files.

Particular attention should be given to ensuring all personnel are trained and fully aware of any potential airblast situation as well as their expected response should certain conditions change which may also include their part in any emergency response plan.

Monitoring, systems audit and review

There should be a monitoring and review process to ensure the safety management system is implemented as planned. This could include the management of the prevention of airblast contained in the Major Hazard Management Plan. This review process should be part of a continuous improvement program as contained within the Mine Safety Management Plan. This system review could include a review to ensure consideration has been given to relevant Australian Standards and industry guidelines in:

- Record keeping
- Procedural compliance
- Regular reviews to ensure that monitoring and responses to changes are occurring as planned
- Monitoring results are analysed, both routinely and after special occurrences or changed conditions or deviations identified
- Completing close-out actions resulting from monitoring and hazard identifications
- Documenting outcomes from these analyses and actions completed on any operational changes that require improvement as well as fed back for future safety management planning
- Auditing of the system by an independent review team external to the mine management, the results of which are communicated to senior management and appropriate action taken to correct identified deficiencies.

Risk identification and assessment

The following section lists considerations when identifying hazards and other issues that could contribute towards an airblast occurring underground.

These lists are not exhaustive. There may be other hazards or issues, including ones that are site-specific that may require identification, monitoring and the establishment of more control measures.

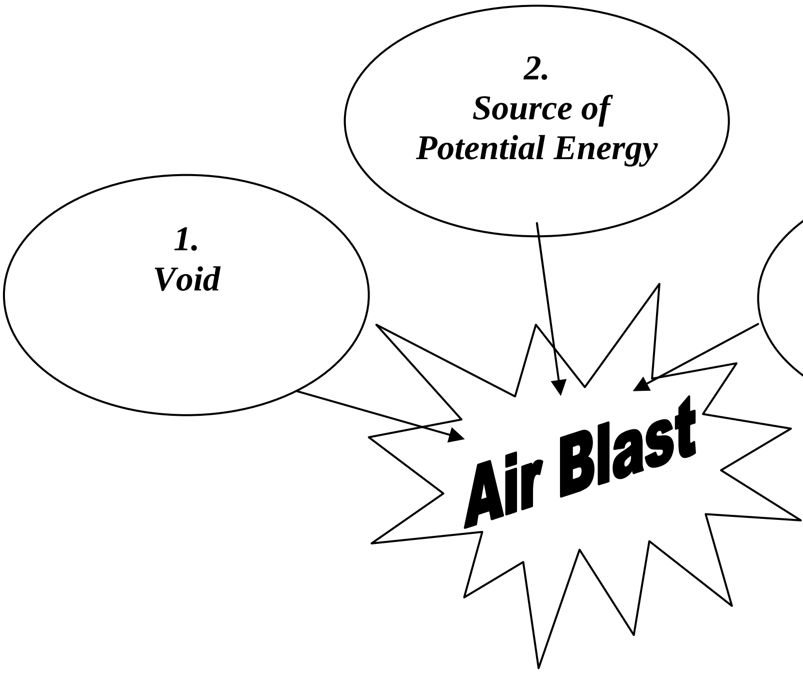
The *Technical Reference Material for Managing the Risk of an Airblast* - MDG 1031 TR is documented within this Guideline. This material provides supporting reference material and tables key issues in detail to be considered.

For more information on how to conduct a risk assessment refer to MDG 1010 *Risk Management Handbook*.

Guideline Content

Part A

The three headings considered in part A to manage the risk of an airblast are: *Void, Source of Potential Energy, and Openings into a Void from the Mine.*



These three elements are contributing factors that need to exist for an airblast to occur.

Part B

The one element considered in part B is mitigating the effects of an airblast under the heading: *Mitigating the potential effects of an airblast.*

Airblast – elements and considerations

Part A

1. Void or underground opening

Required outcomes

- Plan and manage the shape and dimensions of a void or underground opening so as not to contribute to an increased risk of releasing potential energy above the opening or in providing a potential linkage to the rest of the mine and then lead to an airblast occurring. A second outcome is to control the content of the air within the void to minimise any risk of an explosion should an airblast occur. It is recommended that management consider using Trigger Action Response Plans to systematically manage the monitoring and control of all elements that could otherwise gradually lead to an unacceptable level of risk of an airblast occurring.

Main risks

- The dimensions of a void can affect potential energy and linkage to mine workings that can combine to lead to an airblast occurring
- A void's dimensions can inadvertently change, thereby creating an unacceptable risk of an airblast occurring.
- The content of the air within voids or in a goaf may be conducive to causing an explosion after an airblast occurs, creating an even worse incident.

Main risk considerations

- When seeking to fulfil the required outcomes, consider carrying out documented risk assessments and communicate the results and resultant controls to all persons involved.
- Plan to minimise the size and dimensions of a void.
- Investigate and assess the risk of an airblast by determining the dimensions and volume of any voids underground.
- It is difficult to obtain accurate dimensions of a void due to restrictions of access
- Regularly monitor the size and dimensions of a void to detect any changes that may alter the risk of an airblast occurring or its consequences if one did occur
- Determine the amount of broken material and its swell factor which may impact on the size of the void and the resultant risks associated with the void.

2. Source of potential energy

Required outcomes

Rock or material above a void or underground opening is a source of potential energy. The main outcome is to understand the risk level of this energy being released and to control this risk.

Main risks

- Potentially unstable rock or material that could result in a mass failure into a void or any underground opening causing a piston effect compressing the air which then travels through a mine as an airblast.
- Larger than necessary spans of openings can expose more joints and geological structures than necessary creating unacceptable levels of risk of unstable ground. This would not apply to caving operations which deliberately aim for unstable spans to cave.
- Voids or openings in close proximity to the surface or close to other underground openings may have the potential for the surrounding rock to become unstable.
- The proximity of voids or openings to inherently weaker layers of rock can create unstable ground.
- The higher the potential fall the greater the potential energy and its consequences, even within a small area.

Main risk considerations

- When seeking to fulfil the required outcomes, consider carrying out documented risk assessments and communicate the results and resultant controls to all persons involved.
- The risk of an airblast should be understood and controlled.
- Have sufficient geological, geotechnical and hydrological information to accurately assess the potential instability of ground around voids and to develop predictive models.
- Excavate underground openings to inherently stable shapes in situations that may apply and that require this stability.
- Understand and monitor static loads above and alongside voids or openings.
- Investigate caveability of roof strata and pillar failures in coal mines.
- Assess caveability of ground taking into account varied rock types and occurrences of dominant structures.
- To minimise massive failure, induced caving could be an option at certain stages so failure is controlled.
- Monitor for early warning signs on status of selected mine openings or voids.

- Certain triggers such as blasting, seismic events, water accumulation and changed ground conditions can add to the instability of rock surrounding voids.
- Ineffective ground support.
- Any caving of backfilling material underground can be a source of potential energy for an airblast unless its potential is effectively controlled.
- Inflow of groundwater or mud can also become a source of potential energy for an airblast unless managed and controlled effectively.

3. Openings into a void from the mine

Required outcomes

It is ideal if there are no openings from the rest of the mine into a void which may be a source of an airblast. However if there are openings from the mine into such a void then a desired outcome would be for that void to be effectively closed off or isolated from the rest of the mine. Otherwise openings that could become an airblast pathway should be managed to eliminate or minimise any effects of an airblast.

Main risks

- Any opening(s) connecting a void to the rest of a mine have potential to be a pathway for an airblast.

Main risk considerations

- When seeking to fulfil the required outcomes, consider carrying out documented risk assessments and communicate the results and resultant controls to all persons involved.
- If an airblast could occur from a void, plan for, if possible, no openings to connect the void to the rest of a mine.
- Effectively isolate the void using bulkheads engineered to withstand the worse case scenario wind velocity.
- Plan openings from the mine into a void so that the air pathways lead to ventilation shafts or other exits from the mine and not where personnel or infrastructure are located.
- An airblast will vent to the atmosphere mostly along paths of least resistance. This is likely to be where the effects of an airblast will be concentrated. Return airways are likely paths as they offer negative pressure.
- Consider the possibility of a void having connections to the rest of the mine via unplanned connections due to falls of ground.

Part B

Mitigating the potential effects of an airblast

Required outcomes

To mitigate the effects of an airblast if there is a potential risk of exposure of personnel and/or infrastructure.

Main risks

- Exposure of personnel and/or infrastructure to the effects of an airblast.

Main risk considerations

- Determine the potential pathways, air velocity, and secondary effects in the vicinity of persons or infrastructure should an airblast occur.
- Consider any effect on ingress and egress from a mine should an airblast occur in various locations.
- Consider planning for safe haven and stockpile locations should the potential risk level of an airblast become unacceptable as mining progresses.
- Restrict access ways to potential airblast locations.
- Consider establishing bulkheads or rock barriers as a precaution to protect persons and/or infrastructure.
- A dead end cross cut or heading could provide a safe haven in the event of an airblast if there is any warning that one is imminent.
- Personnel should be fully aware of any signs that might indicate an airblast is possible and be fully trained in what action to take if one appears to be imminent.
- Areas within a coal mine which could have been thought to be outside the Hazardous Zone (HZ) may become part of the HZ due to an airblast occurring, thus creating additional potential for an explosion to occur.
- In coal mines, assess the risk of poor roof conditions in the proximity of the breakthrough position. Bedding separation may be caused by ingress of groundwater from the hole or release of accumulated gas.
- Consider planning good housekeeping to minimise secondary impacts from an airblast from loose material left along drives (or drifts).
- Consider developing a model of potential airblast situations to predict velocities and potential risk to personnel and/or infrastructure.

- Ensure that any installed services adjacent to, or at, the planned breakthrough position are either removed or effectively isolated.

Feedback sheet

Your comment on this Guideline for Managing the Risk of an Airblast in an Underground Mine will be very helpful in reviewing and improving the document.

Please copy and complete the Feedback Sheet and return it to:

Regional Inspector of Mines - Orange
Mine Safety Operations
NSW Department of Primary Industries
Locked Bag 21
Orange NSW 2800
Australia
Fax: 61-2-6360 5363

How did you use, or intend to use, this Guideline?

What do you find most useful about the Guideline?

What do you find least useful?

Do you have any suggested changes to the Guideline?

Thank you for completing and returning this Feedback Sheet

Appendix I

A Trigger Action Response Plan

Following a detailed risk assessment of potential hazards within a mine, a list of major hazards can be developed. Possible changed conditions that could trigger a major hazard event should also be identified. This would form the basis for a Major Hazard Management Plan (MHMP). A Trigger Action Response Plan (TARP) could be a summary of that plan. A TARP can provide the following advantages by:

- Clearly summarising the overall system for managing major hazards for the mine.
- Summarising the major hazards within the mine which can make a more effective review particularly if additional hazards begin to emerge.
- Summarising the proposed monitoring and the systematic approach that is required to monitor the major hazards.
- Providing planned trigger responses if early trends indicate changes in risk levels. Note that key personnel should be made aware of the specific trends that may indicate the risk of a major hazard has increased and what response it may trigger from management.
- Providing for early responses if the risk levels become unacceptable. The main advantage of this is that the hazard is always kept under control.
- Summarising actions that have been well planned and require implementation when specific circumstances occur. These circumstances are generally well before any situation worsens and risk levels become unacceptable.
- Each planned response has been researched and determined from a tangible and scientific basis and not merely from opinion based solely on experience.
- Enabling corporate memory to be continuous despite changes in management. The TARP remains a live document and the planned responses and actions are summarised within the table. These will be known by future management and will be known to have been documented for sound reasons.
- Providing a notification system with the Government that has been agreed upon. This may be over and above legislative requirements. This enables Government authorities to be kept informed of trends developing with major hazards at the site and knowing the actions that would be implemented well before a situation becomes unmanageable.
- Providing a summary that allows a regular but simple and effective review by Government. This review can include the latest results of monitoring and resulting actions as trends develop. This ensures that there is continual vigilance in managing major hazards at the mine. Following this review the Government may then endorse the approach taken.
- As conditions change in the mine new major hazards may be identified early and be added to the TARP.
- Providing a sense of control of major hazards. It can provide a sense of confidence that the mine is safe from a major incident occurring.

Note: Major hazards in this table are those that could result in multiple fatalities. Also it only includes those hazards that can be monitored for any changes of conditions that may lead to a major incident occurring. These are operational hazards that have been identified and are not to ensure planning and design objectives are achieved. It also does not include major hazards that do not require monitoring if hard barriers can be established and would be sufficient to control the hazard, such as preventing mobile equipment fires and electrical hazards.
Note also: The original risk assessment and MHMP should be regularly reviewed. This may prompt more detailed risk assessments or research to ensure triggers and planned actions within the TARP have remained appropriate.

THIS IS AN EXAMPLE ONLY OF A TARP

(This TARP table includes all hazards identified in a caving operation of which an airblast is just one)

MAJOR HAZARD MONITORING & TRIGGER LEVELS AT A MINE CAVING OPERATION

HAZARD	FORM OF REVIEW	REVIEW PERIOD	TRIGGER LEVELS	PLANNED RESPONSE	AGGREED TRIGGER REPORTING TO THE GOVT	COMMENT (Can be for corporate memory)
Identify any voids within cave that could develop and allow conditions that potentially could result in an airblast	Bulking factor changes using (1) Open hole plumbing, (2) Fly-over surveying surface subsidence, (3) Volume calculations of surface subsidence	Quarterly	Bulking factor 1.24 to 1.30	Continuously track the trend. Should numbers deviate from 1.24 then seek outside expert's opinion to examine process and possible reasons for change.		Original estimate of caved muck pile = 1.30.
			Bulking factor +1.3 to 1.4	Identify the source of greater than historical bulking factor eg oxide products	When over 1.3 then notify Government of density.	

MAJOR HAZARD MONITORING & TRIGGER LEVELS AT A MINE CAVING OPERATION						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE GOVT**	**COMMENT (Can be for corporate memory)**
			Bulking factor 1.4 and more	Identify void space within the cave. If associated in-situ material on the edge of the cave, then use hydro-fracturing or drill and blast techniques to break the in-situ material.	When over 1.4 notify Government with details of planned response.	
			Bulking factor +1.4	If the factor continues to rise above 1.4, then stop production until the void has been successfully caved.		
Static load that could impact on main crown pillar	(1) Number of cracks in shotcrete	Monthly	Double the number of cracks in previous month.	Increase frequency of crack and convergence monitoring of the area to fortnightly reviews.		Measurement of width and position is also catalogued.

MAJOR HAZARD MONITORING & TRIGGER LEVELS AT A MINE CAVING OPERATION

HAZARD	FORM OF REVIEW	REVIEW PERIOD	TRIGGER LEVELS	PLANNED RESPONSE	AGGREED TRIGGER REPORTING TO THE GOVT	COMMENT (Can be for corporate memory)
Static load that could impact on main crown pillar (cont.)	(2) Convergence modelling. Plotting of convergence trends – looking for acceleration in convergence. Hot / cold spot contouring.	Monthly	50 mm drive convergence in one month or total.	Increase monitoring frequency to fortnightly. Where shotcrete appears to have failed, inspection is to be made by Geotechnical engineer and repair identified where required		Over a 12 month period of reviews +/- 1mm on average per fortnight across the extraction level. Level responding to draw control plan. Monitoring of cracks ongoing. Any increase in cracking will result in increased monitoring. Note: However that fibrecrete becomes ineffective at deformations at this level.

MAJOR HAZARD MONITORING & TRIGGER LEVELS AT A MINE CAVING OPERATION						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE GOVT**	**COMMENT (Can be for corporate memory)**
Static load that could impact on main crown pillar (cont.)			200 mm drive convergence.	Barring down. Re-support with bolts, mesh and fibrecrete.	Notify Government when convergence reaches 200 mm.	200 mm has been recorded without structural support damage in other caving mines. Note: However that support tendons become ineffective at deformations of this level.
Mud rush risk	(1) Shift supervisor inspections of drawpoints	Daily	Visual observation of suspected “damp” Drawpoints”.	Inform line management of any concern and raise Hazard Report.	Nil	

MAJOR HAZARD MONITORING & TRIGGER LEVELS AT A MINE CAVING OPERATION						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE GOVT**	**COMMENT (Can be for corporate memory)**
Mud rush risk (cont.)	(2) Take sample from LHD bucket/s away from 'damp' drawpoint for fines and test for moisture content.	When hazard report is submitted.	Fine Damp or Fine Wet material present at drawpoint(s). Moisture Content (MC) is measured by moisture weight/total mass	Remote loading procedures apply on fine damp and fine wet drawpoints.	Notify Government if remote loading commences	Fine Damp or Fine Wet Based on latest test work, defined in mud rush study as: Fine >30% (-50mm). Dry < 10%MC. Damp 10%-15%MC Wet> 15%MC.
	(3) Drawpoint observations for fines & moisture content by Technical Services Group. Moisture content sampling of wettest drawpoints.	Fortnightly	Fine Damp or Fine Wet material present at drawpoint(s).	Remote loading procedures apply on fine damp and fine wet drawpoints.	Continue to notify Government of results	.

MAJOR HAZARD MONITORING & TRIGGER LEVELS AT A MINE CAVING OPERATION						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE GOVT**	**COMMENT (Can be for corporate memory)**
Water inrush risk	Monitor rainfall so that rainfall events producing more than 100mm over eight days can be identified.	Monthly	Rainfall event generating greater than 4.3 ML per day percolated into the cave catchment. ie >50 l/s.	Inform Production Superintendent to monitor pump usage on a shift by shift basis.		50 litres per second is two-thirds of pumping capacity.

MAJOR HAZARD MONITORING & TRIGGER LEVELS AT A MINE CAVING OPERATION						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE GOVT**	**COMMENT (Can be for corporate memory)**
Water inrush risk (cont.)	Shift by shift monitoring of pump usage.	Continual – shift by shift.	If levels are forecast to exceed 2/3 of mine pump capacity at 50l/s.	Pump out the water using existing main pumps. Continuous monitoring of pump usage.	Notify Government if continues to be over 50 litres per second for two shifts.	Wetting of the cave dirt expected to take some weeks / months. Only 9 events in 100yrs over 2ML per day in catchment. Probability of exceeding 50l/s is 1 in 1000 if the maximum rainfall event was to occur. Even the maximum events recorded of 5.53ML and 14.1ML can be pumped from 2 to 4 days respectively.

MAJOR HAZARD MONITORING & TRIGGER LEVELS AT A MINE CAVING OPERATION						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE GOVT**	**COMMENT (Can be for corporate memory)**
Water inrush risk (cont.)	Continuous monitoring of pump usage.	Continual	Pumping capacity exceeded (>75 l/s).	Extra take up water storage can be placed in lower level and lower decline. Commission separate pump system as back up.	Continue to notify Government of results	
	Continuous monitoring of pump usage.	Continual	Pumping and storage capacity exceeded.	Evacuate Mine.	Continue to notify Government of results	This will allow organised steady evacuation of the mine – unlikely to result in sudden engulfment.

Appendix II

DEPARTMENT OF MINERAL RESOURCES – MINE SAFETY AND ENVIRONMENT DIVISION

LEGISLATION UPDATE

No. 2/2001 **27 November** 2001

RANGE OF OHS SUPPORTING MATERIAL WITH LEGAL STATUS

Occupational health and safety (OHS) laws aim to promote and secure the health and safety of persons at work.

As well as having strict requirements under Acts and Regulations, the legal framework has developed in a way that recognises the need for some flexibility for industry to address individual circumstances.

Over time, a range of supporting material has been developed. This material takes the form of codes, standards or guidelines, which may collectively be called OHS supporting material.

Although it is not strictly speaking the law, this material usually has some legal status. This status will vary with the nature of the material and its relationship to the law.

The following table summarises the range of instruments which may influence OHS from a legal perspective. This includes not only Acts and Regulations themselves but also examples of the supporting material.

The content of this Table is intended for general guidance only and should not be relied upon as a source of legal advice.

(Note: The Department of Mineral Resources, Mine Safety and Environment Division changed on 1 November 2004 and became Mine Safety Operations Division of the NSW Department of Primary Industries).

INSTRUMENT	GENERAL PURPOSE	APPLICATION	LEGAL STATUS
Act of Parliament	Creates powers, authorities, duties or rights (including power to make regulations)	Binding – requirements must be complied with (unless a valid exemption is held).	Acts are statutory law.
Regulation made under an Act	To give expression to an Act – to say what is to be done or achieved.	Binding – requirements must be complied with (unless a valid exemption is held).	Regulations are subordinate legislation.
Condition of Exemption or Approval	To allow imposition of conditions.	Binding – requirements must be complied with.	Delegated administrative law.
Standard (AS ISO IEC)	To define accepted practice or minimum standard.	Depends on relationship with regulation – may be binding (if called up by regulation) or persuasive (by existence of the Standard itself).	Depends on relationship with regulation – may be binding (if called up by regulation) or informative (by existence of the standard itself).
Approved Industry Code of Practice under the Occupational Health and Safety Act	To provide practical guidance on how to meet general OHS requirements.	Persuasive – indicates what to do but does not mean it has to be done. Alternative measures may be used.	Admissible in support of allegation that general duty of care has been breached.
Applied Code, Standard or Guideline [1]	To provide practical guidance on how to do or achieve requirements of regulations.	Persuasive – indicates what to do but does not mean it has to be done. Alternative measures may be used.	Most likely admissible in support of allegation that general duty of care has been breached.
Published Guideline	To provide guidance on how to assess and manage a particular risk or set of risks.	Advisory – provides advice on how to manage the relevant risk(s).	May be admissible in support of allegation that general duty of care has been breached.
Guidance Note	To provide background information that may be used in developing risk controls.	Informative	Could be admissible in support of allegation that general duty of care has been breached.
Technical Reference Document	To convey technical information.	Informative	May support expert evidence.
Safety Alert	To make industry aware that something has happened.	Informative	May provide evidence of the 'forseeability' of risk of injury.

[1] Under clause 14 of the Coal Mines (General) Regulation 1999.

Technical Reference Material

for

Managing the Risk of an Airblast in An Underground Mine

MDG 1031 TR

Prepared for:	Chief Inspector of Mines Chief Inspector of Coal Mines Mine Safety Operations NSW Department of Primary Industries
Date:	June 2006

PREFACE

Unsupported rock spans are excavated within most underground mines. The resulting risk associated with the collapse of those spans needs to be assessed. Included in such a risk assessment can be an assessment of the risk of an airblast occurring.

The sudden collapse of a large volume of rock into a void can create an airblast that could travel throughout the mine. Such an airblast in a mine can have devastating consequences. It is often characterised by significant overpressures and air velocities which can result in fatal injuries to persons and cause severe damage to equipment and infrastructure.

This Technical Report Material (TRM) 1031 may be used as fundamental input into any risk assessment process associated with identifying hazards or risk of an airblast as well as planning, designing, investigating or maintaining control measures to prevent or mitigate airblasts underground.

This TRM is in two parts - Parts A and B.

Part A examines three elements which have been derived from the three key contributing factors that need to exist for an airblast to occur. These three elements are:

- *void*
- *source of potential energy*
- *openings into a void from the mine. Note: This opening into the void is one that would connect the void to the rest of the mine through which an airblast could travel.*

Conversely, if any one of these three contributing factors (or elements) in Part A is not present or is totally controlled, then an airblast would be prevented from occurring.

Part B examines issues surrounding one element only; namely *mitigating the effects of a potential airblast* or minimising the risk of exposure of persons and infrastructure to an airblast should an airblast occur.

Parts A and B include suggestions on issues that may warrant consideration. These may include:

- general issues to consider
- investigation work that may be necessary
- planning or design suggestions
- controls that may be put in place
- monitoring suggestions that may help to indicate if further action is necessary.

WORKING GROUP MEMBERS

The NSW Chief Inspector of Mines set up a working group to develop this guidance material. Their contribution is appreciated and acknowledged with thanks.

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CONTENTS

GUIDANCE MATERIAL FOR MANAGING THE RISK OF AN AIRBLAST IN AN UNDERGROUND MINE

PART A	**ELEMENT**	
	(1) VOID	**A void needs to be present for an airblast to occur. Therefore, the risk of an airblast is lowered if the dimensions of a void are minimised. However, if a medium to large void is part of the mine design or there is a potential for a larger void to be created then the following should be considered.**
Sub- element	Issues to be considered	Additional notes, controls and monitoring
Geometry	1. Volume of void	*General* There needs to be in place a system to measure or accurately estimate the changing dimensions of a void so that the risk of an airblast can be estimated. *Coal or tabular deposits* In tabular deposits, especially coal mines, the presence of a massive stratum in the immediate roof area is critical to estimating the potential for an airblast. Factors to consider could include the following: • Where a massive stratum lies within the caving height of a goaf, a void or air gap may develop. The size of the void can be very difficult to estimate. • Where a massive stratum lies directly on top of the seam the volume of the open goaf is critical in estimating the potential for an airblast. In this case the total dimensions of the uncollapsed goaf or void would be important to readily estimate the risk. *Caving operations* An airblast can be substantially prevented in a caving operation by designing the void geometry to provide for continuous caving. Planning and designing for a minimal air gap and void throughout a caving operation is an important design objective.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Geometry (cont.)	1. Volume of void (cont.)	*Caving operations* A primary control in preventing an airblast from occurring is to inhibit or minimise the development of an air gap. Consider only pulling the swell until the cave back has broken through to its limit to prevent a significant void being developed. Also, to minimise an air gap one could consider blasting or hydro-fracturing of the stope or cave back to induce a fall of ground. Where inducement of the back is not practical then a muckpile of broken material below the cave back and in the potential fall area could be provided. This muckpile should be kept as large as possible to reduce the volume of the void and cushion the energy from any fall of ground. This stockpile of material could also reduce the air pressure should an airblast occur as air flows through it, thus minimising the effects of an airblast to the rest of the mine. *Monitoring controls* Consider establishing a void monitoring system to monitor the void's dimensions and any changes to those dimensions. Some monitoring systems have included: • time domain reflectometers (TDR's), • mass balance calculations, • open hole cameras, • cavity monitoring systems, • depth plumbing via drill holes, and • microseismic sensors (at various depths) to identify seismogenic zones. Information, such as above, should be obtained from a number of sources to cross check the data. If safe access exists to the void and information can be obtained on its dimensions, then it can be compared to the void design and an additional assessment of the risk of airblast could be made.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Geometry (cont.)	2. Plan area of void	*Coal or tabular deposits* Where a goaf is overlain by a massive stratum the plan area of an open goaf void and in particular the width of the goaf would be important in determining the risk of an airblast occurring. *Controls* A primary control to prevent airblast is to minimise the plan area of a void thus minimising a fall of ground. It may be appropriate following a geotechnical assessment to induce a fall of ground and manage the fall. This may be appropriate in caving operations and could be achieved by increasing the area of the footprint. However, consideration should be given for additional controls to minimise the effects of an airblast if one did occur. *Planning and monitoring* The void plan area should not exceed engineering design specifications. If the risk is high of this happening due to geotechnical or other reasons, then a monitoring system should be in place. Cavity monitoring system (CMS) or survey pickups may facilitate the identification of over-breaks within a stope or mined out void. If an increase in the plan area is detected it may contribute to an uncontrolled failure of ground and therefore an airblast. Further control measures may be considered to reduce this risk.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Geometry (cont.)	3. Height of void	*General* It would appear that the potential energy and therefore the magnitude of the consequence of an airblast increases proportionally with the height of the void. *Coal or tabular deposits* The height of an open goaf void, overlain by a massive stratum, would be important in assessing the consequence of an airblast should it occur. *Controls* A primary control is to leave blasted or fallen material in the mined out area to reduce the height of the void to cushion or dissipate the energy from an airblast should it occur. If there is potential for the void height to increase in time then a monitoring system could be set up to monitor changes in height. Planned responses could then be established when certain trigger points are reached that would minimise the risk of an airblast from occurring. A Trigger Action Response Plan (TARP) can be arranged in a table form to summarize this response plan, refer to Appendix I for an example. Planned responses to consider include: • initially more regular monitoring of the void height, • adopting a very strict draw control strategy, • increasing the stockpile of rock material below the void, • securing escape pathways, • establishing controls, such as safe havens and partly or fully restricting an airblast pathway. For details see Part B *Mitigating the potential effects of an airblast.*

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Geometry (cont.)	4. Shape of void opening and hydraulic radius	*General* Shape can influence the stability of a void. Hydraulic radius (area divided by perimeter) is a commonly used measure of the geometry of the undercut in caving operations. Both Laubscher's Stability Graph and the Extended Matthew's method use hydraulic radius of the undercut for determining whether a rock mass will cave. *Planning and controls* The stope shape design process should take into consideration the stability of all stope surfaces, not only the stability of the backs. Hanging wall and rib pillar failures in steep to moderately dipping orebodies should be considered. Empirical design methods may be used to determine the maximum stable hydraulic radius for each surface. The principal controls include: • mine design (taking into account the footprint shape and hydraulic radius), • variations in the draw of material below and • understanding the ground's caveability through geotechnical data.
Geometry	5. Changes in geometry of void	*Planning and monitoring* The potential for an airblast to occur increases if any unplanned over-break of ground occurs in any mined out areas or stope. A geotechnical assessment should be carried out to determine the level of risk should any over-break occur. If considered necessary, monitoring of the void and surrounding ground may be required; which may then trigger the need for further control measures to minimise the risk of an airblast. See controls mentioned above under Part A, (1) Void, Geometry, 3. Height of void.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Content	1. Gas Note: Coal Mines – the risk level significantly increases with the presence of flammable gases should an airblast occur	*Coal –General* An airblast in a coal mine will expel a mixture of methane, coal dust and air from the goaf. This expelled mixture may also raise deposited coal dust, in the active workings, into suspension. Ignition of this gas and dust cloud is likely to result in a major explosion. *Coal – Controls* It is worth noting that in coal mines the lower explosive limit (LEL) for methane gas and suspended coal dust air cloud is lower than the LEL for either separately. Therefore, serious consideration needs to be given to effectively ventilate the void area or goaf to eliminate explosive methane levels if the potential fro an airblast develops. *Coal – Monitoring* Gas detection equipment may need to be installed to monitor for changes in methane levels. Further planning may be necessary to have the ability to provide additional ventilation to dilute air or to prevent gas from accumulating.
Content	2. Dust Note: Coal Mines – the risk significantly increases with the presence of flammable dust should an airblast occur	*Coal - Minimise risk with controls* In coal mines the real lower explosive limit (LEL) for methane gas and suspended coal dust air cloud is lower than the LEL for either separately. Consideration needs to be given to the application of stonedust into the void or goaf area to reduce the coal dust explosion hazard.

PART A	**ELEMENT**	
	(2) A SOURCE OF POTENTIAL ENERGY	**There needs to be a source of potential energy or "piston" for an airblast to occur. Rock or other material above or adjacent to a void has potential energy to fall. If this source of potential energy is minimised then the risk of an airblast is also minimised. The following issues may be considered when a source of potential energy that could contribute to an airblast occurring in an underground mine.**
Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock	1. Span	*Assessment, planning and design* It is generally accepted that larger spans expose a greater number of joints in a rock mass than smaller spans. Consider identifying dominant joint sets and controlling structures such as faults or geological contact zones. Stope designs may need modification or require additional ground support prior to mining and as part of the ongoing mining method. Empirical design methods may be used to estimate maximum stable spans and stand up times. Detailed geotechnical assessment may be necessary to assist in estimating the ground's caveability with its hydraulic radius. Openings may then need to be carefully designed to minimise the risk of unplanned ground movement. A potential large scale massive failure would pose a greater risk than a progressive failure in sheared rock material. *Planning - Coal* In coal mines planning of the goaf width could be critical to ensure either:- 1. Caving will not occur, or 2. Regular systemic caving is controlled leaving limited goaf hang-up.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	2. Shape	*Planning and design* The design shape may influence the stability of an open void. For example, arched stope backs may exhibit better stability than the equivalent span of a flat back. Consideration should be given to mining only inherently stable shapes following geotechnical assessment. Consider alternate stope designs and apply risk assessment principles to potential failure mechanisms.
Potential for instability of in-situ rock	3. Mass	*General* Consider induced stresses that could cause rock mass to shear. For example an excavated stope may affect the stability of crown pillars. *Monitoring* Consider monitoring the loading in the backs or roof of the open void. And, if applicable, monitor the effects of static loading on bridge or crown pillars by the filling of stopes at levels above especially but also any adjacent stope. Recognise that arching can develop in a fill mass such that some of the vertical load is transferred to surrounding walls.
Potential for instability of in-situ rock	4. Height	*General* The higher the potential fall the greater the potential energy and its consequences even within a small area. For instance an airblast could occur at a drawpoint if there is sufficient height and a plug or slab of material falls.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	5. Proximity to the surface	*Coal and all other shallow mines* In coal mines and or other shallow mines at depths of 50m or less, a plug failure may occur in the strata above the goaf or stope to the surface, creating a risk of an airblast by a mass fall of ground in otherwise readily caving strata. Under these conditions the entire goaf area formed can suddenly collapse resulting in a massive airblast. The term 'suddenly' means with no practical warning. Experience has been that a goaf can collapse with no warning in less than two seconds. However, in 1999, a large plug failure occurred at Parkes (NSW) at about 110m from the surface in weaker layers of rock. When this plug failure occurred it resulted in a massive airblast travelling through some of the underground workings. *Investigation* Rock masses close to surface can have varied properties due to weathering, oxidation, geological structure and the presence of aquifers. A pre-strip as part of open pit development may be necessary. And this may provide an opportunity to investigate near-surface geotechnical conditions. Also, there may be the potential for migration of a stope through or into a crown pillar by unraveling of weathered zones in proximity to the surface. Exposure of the stope back in a rock mass with different engineering qualities to the design may potentially accelerate failure as the rock mass conditions change. Monitoring may therefore be considered and changes reviewed against the design criteria.
Potential for instability of in-situ rock	6. Proximity to other voids	*Planning and design* Consider design stoping sequences and the location of excavations in relation to other openings with a view to minimising ground stresses to the other openings. If for instance a pillar was designed between two open stopes, it can result in the creation of a very large void volume and span should the pillar collapse. This emphasizes the importance of adequate pillar design.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	7. Geotechnical conditions (a) General	*Investigation* Consider using appropriate site investigation techniques based on the topographical, geological, geotechnical and hydro-geological conditions of the area and its surroundings. Also consider geophysical techniques being applied to investigate and understand the regional geology of the mine and its surroundings. Experience has shown that understanding the ground conditions and identifying changes can greatly assist in developing predictive methods. In particular, major geological structures need to be identified and taken into account. Other geotechnical information could include stress modelling and stress measurement. *Monitoring* Identifying and monitoring of geotechnical conditions can provide systematic measurements and new knowledge regarding void changes and rock movement on various geological structures. Monitoring of changes can include the use of microseismic monitoring, extensometers and open borehole plumbing.

<u>Sub-element</u>	<u>Issues to be considered</u>	<u>Additional notes, controls and monitoring</u>
Potential for instability of in-situ rock (cont.)	7. Geotechnical conditions (cont.) (b) Rock Mass Quality	*Investigation* Rock Mass Quality data may be used as a basis for empirical design of stable stopes or mined areas. Having accurate and extensive rock mass quality data can lead to enough understanding to be able to reduce the possibility of failure due to unidentified structures. As stated previously, rock masses close to the surface can have variable properties due to weathering, oxidation, geological structures and the presence of aquifers. *General* According to Brown (2003:32-125), rock mass quality is primarily determined by (1) Geotechnical diamond drilling and core logging, and (2) Geotechnical exposure mapping of the rock mass. (1) Geotechnical diamond drilling and core logging. Consider the following: • Representative sampling of the rock mass conditions – minimum of 25% of all resource drilled metres being logged for geotechnical information. • Driller's remuneration to include a component which is based on the percentage of core recovered and not just the metres drilled. • Multi-directional hole orientations. • Hole size being NQ triple tube core barrels or larger. • Holes surveyed with multi-shot equipment over the full depth of the hole. • Orientation of drill core using a suitable core orientation device with every core barrel run. • Prompt and detailed geotechnical logging of drill core in a dedicated core logging, layout, preparation, handling and storage area.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Potential for instability of in-situ rock (cont.)	7. Geotechnical conditions (cont.) (b) Rock Mass Quality (cont.)	• All geotechnical core being logged before any sampling or splitting is done. • Selected geotechnical core kept intact with the complete hole length. • Sections of low strength core (eg high clay content) to be sealed to preserve in-situ conditions including moisture content immediately on recovery. • Colour photography of all drill core under controlled conditions. • Logging of core to follow discontinuity parameters; such as orientation, spacing, roughness, wall strength, filling and number of sets. • All logging data recorded promptly into a suitable geotechnical database using appropriate manual or electronic techniques, recognizing the potential for data loss. • Full extent and location of core loss to be represented in core trays. • Down hole rock mass permeability testing may be necessary in water bearing or highly broken ground. • Groundwater levels being monitored in “observation” bore holes. • Down hole geophysical methods are useful to determine discontinuity; such as orientation, spacing, aperture and filling.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Potential for instability of in-situ rock (cont.)	7. Geotechnical conditions (cont.) (b) Rock Mass Quality (cont.)	(2) Geotechnical exposure mapping of the rock mass For both underground and open pit mines consider the following: • Mapping representative samples of the rock mass conditions. • Appropriate mix of spot mapping, scan line mapping and area mapping. • Recording coordinates of area being mapped. • Collecting discontinuity data; namely distance along tape, number of endpoints, discontinuity type, orientation, roughness, planarity, trace length and termination types. • All logging data recorded promptly into a suitable geotechnical database using appropriate manual or electronic techniques, recognizing the potential for data loss. Data gathered from geotechnical diamond drilling and exposure mapping can be used to establish an appropriately detailed three dimensional model of the rock mass geotechnical and hydrogeological conditions. Data from the three dimensional geotechnical model can be used as input for rock mass classification systems, etc. Appropriate rock mass classification systems can be applied. Techniques often used include RMR system, Q system and MRMR system as detailed in Brown (2003:100-116).

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Potential for instability of in-situ rock (cont.)	7. Geotechnical conditions (cont.)	
	(b) Rock Mass Quality (cont.)	*Caving methods* Rock mass classification systems and undercut geometry can form the input to caveability assessment methods, sometimes referred to as "Laubscher's caving chart" and "Mathew's stability graph approach", see Brown (2003:126-155).
	(c) Structures	*Planning* Consider the orientation of stopes to main geological structures with a view to minimising the potential instability of any span. *Geotechnical assessment* Geotechnical data from a three dimensional geotechnical model could be analysed using recognized analytical methods (possibly software) to determine geological structures, such as planes of weakness found in the rock mass. Variability of the rock mass geotechnical conditions, including geological structure, is an inherent feature that needs to be quantified. Note: Rock mass classification schemes do not explicitly take into account the full range of geological structures found in the rock mass. Rock mass behaviour is usually controlled by geological structures in most mining environments, particularly low and moderate rock stress levels. The division of the rock mass into geotechnical domains of broadly similar characteristics may be useful. Domains may be based on geological structure, rock mass classification systems or preferably a combination of both. Rock within a given geotechnical domain will generally exhibit similar behaviour, failure mechanisms, ground support requirements, etc.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	7. Geotechnical conditions (cont.) (d) Pre-mining stress	*General* Consideration should be given to an adequate number of pre-mining rock stress measurements taken to estimate the rock stress field magnitude and orientation in three dimensions and the rate of stress increase with depth. Also consider various measurement techniques such as hydraulic fracturing and those based on acoustic emission. These offer the advantage of being able to remotely determine the rock stress field using bore holes and drill core respectively. Over-coring techniques have been used for some time in the mining industry and are widely recognized as being able to provide reliable “point” estimates of the rock stress field in three dimensions. However, consideration should include several rock stress measurement techniques to ensure that there is sufficient independence in the results. Then consider interpreting results of rock stress measurements having regard for • the geology of the deposit, • its geological structure (including shear strength of discontinuities), • the physical properties of the rock mass (e.g. strength and deformability), and • the portion of rock measured is representative of rocks in the rock mass.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	7. Geotechnical conditions (cont.) (e) Induced stress and regional stress	*General* Induced stress around openings is a complex issue and relating a modeled induced stress to the possibility of any rapid failure is inherently difficult. Induced stresses are created in the rock mass by the presence of excavations. The induced stress surrounding an excavation can be greater than or less than the pre-mining rock stress field. The combination of adversely oriented geological structure and induced rock stresses can result in failure of the rock mass, for example, by slip on geological structures. Regional stresses may be affected by the presence of large scale geological structures that lie outside the immediate mine area. Regional scale mapping is required to gain a good understanding of the regional geological structures. Geophysical methods, such as seismic may be useful in determining large scale geological structures. Estimates of the rock stress field remote from the mine could be undertaken using hydraulic fracturing or methods based on acoustic emission.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Potential for instability of in-situ rock (cont.)	7. Geotechnical conditions (cont.) (e) Induced stress and regional stress (cont.)	However, modelling changes to the rock stress field may identify areas prone to stress damage. Stress model results may be calibrated by physically measuring stress changes as mining occurs or by visual inspections of areas predicted to be prone to stress damage. Consideration should be given to calibrating models by conducting a back-analysis of any known failure events.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	8. Potential for caveability	*Coal* The caveability of roof strata in coal mines is a critical issue. Further, airblasts have occurred from violent pillar failure. It is critical to design pillars either not to fail or to yield in a controlled manner. Whilst several airblasts have occurred as a result of pillar collapse the majority events have been associated with goaf caving events in longwall and pillar extraction panels. *Metal mines and pillar design* In metal mines an airblast is often associated with caving and sub-level caving operations. But an airblast has also been known to occur from crown or rib pillar failure with open stoping. Thus, pillar design and extraction sequence is critical for the prevention of an airblast from occurring. *Investigation and design* It is important to realize the huge variation in caveability properties between material that is solid, broken, finely fragmented, partially weathered, totally weathered, clay-rich or other types of material. The likelihood of uncontrolled failure resulting in an airblast may be a function of the ease with which the rock mass breaks up. Consideration should also be given to failure occurring due to dominant structures in the rock mass that could result in rapid plug failure.
Potential for instability of in-situ rock	9. Designed ground failure	If appropriate, consideration is given to planning and design, ground failure may be induced so that the fall of ground is managed safely. This induced failure may reduce the risk of an airblast occurring. Ground failures could be induced or controlled. Blasting or hydro-fracturing to increase the base area have been used to induce and control ground failures.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	10. Potential for ground failure which is not designed	*General* Consider the possibility of an airblast occurring as a result of rapid unravelling of strata or sudden mass failure due to unstable structures or lithology. *Investigation (modelling)* In mines where the possibility of an airblast is ongoing, wind gust models can be developed for various scenarios corresponding to various void heights and spans. Potential maximum velocities can then be determined should an airblast occur. *Monitoring using TARPs* Consider summarizing this monitoring process in a Trigger Action Response Plan (TARP) which would become a key component of a mine's safety management plan. A TARP system of risk management can be developed to continually evaluate and act on various levels of risk of an airblast. This involves controls to reduce the risk to an acceptable level and procedures to monitor the effectiveness and integrity of those controls. Experience has shown that a TARP document can be a very useful tool to regularly review the integrity of controls and help identify and act on early warning signs when the risk of an airblast is increasing. A TARP is a useful system to ensure actions are pre-planned and have been well thought through. The TARP's results and monitoring process could be reviewed on a regular basis by independent persons sourced internally and/or externally. This will ensure "group thinking" does not develop and issues are dealt with objectively and with good tangible reasons for any decisions made. *Review possible changed conditions* Consider examining scenarios for various changed conditions that may occur and then affect airblast controls could be reviewed. A trigger levels identified from monitoring could then be established to cover possible situations that have been identified and to maintaining the integrity of those controls.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	11. Status of mine openings	*Monitoring* Consider monitoring for early warning signs any large mine openings or openings that have a potential for wall(s) to be unstable and create larger openings. Monitoring the size of openings should be considered with open stopes and large excavations particularly if there are any geotechnical considerations that could lead to scale strata instability. An airblast could result from such instability with any mine opening with such strata. *Block caving and sub-level caving* Monitoring is particularly important in block caving and sub-level caving operations to detect and monitor the creation of any void being formed in the mined out areas. In these cases, if any void develops and enlarges further planned measures should be considered to minimise the risk of an airblast. In such situations in caving operations consideration should be given to inducing caving to minimise such a void. Also consider using a TARP management system to determine planned responses at an early stage of the operation with an ongoing review process and monitoring results should changes be detected.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	12. Trigger mechanisms (a) Blasting influences	An airblast could occur following blasting if particular circumstances exist. For example in areas where blast vibration could induce a failure of the ground, the use of electronic 'icon' detonators to accurately control initiation sequences may be appropriate. Particular consideration should be given to this possibility with mass blasts underground using programmable initiators. If there is a likelihood of induced failure, then changes in the blast design and method of initiation may assist in controlling the outcome. Experience has shown that investigating and then monitoring for this possibility has been critical in preventing an airblast from occurring.

<table>
<tr><td><u>Sub-element</u></td><td><u>Issues to be considered</u></td><td><u>Additional notes, controls and monitoring</u></td></tr>
<tr><td>Potential for instability of in-situ rock (cont.)</td><td>12. Trigger mechanisms (cont.)

(b) Seismic influences</td><td>Monitoring
Consider microseismic monitoring as a tool for identifying seismic events. If microseismic monitoring is used then typically three predominant groups of events are recorded. They are:
events above mined out areas
footwall events, and
structural events
Each group of events are recorded to provide:
distinct location,
timing and
seismic characteristics
To clearly identify seismogenic zones a complete record of all events over magnitude –2 has been found to be generally appropriate. Seismic events can not be monitored at a sensor station if a void exists between the event and the sensor station. There is a need to monitor from different sides to get accurate measurements. Some mines have used a minimum of four sensor stations. Even though three are required to establish the location, a fourth sensor station gives management more confidence in the accuracy of the results.

Also microseismic monitoring has been found to be appropriate in monitoring pillar degradation and particularly if such instability has been ongoing.</td></tr>
<tr><td></td><td>(c) Water accumulation influences</td><td>Investigation
Consider rainfall events and the risk of sudden water inflow and/or the susceptibility of material to absorb water and becoming fluidised and create an unstable body of material. The use of a water balance model may assist in determining water inflows and out flows from a mine.</td></tr>
</table>

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	12. Trigger mechanisms (cont.) (d) The influence of changed ground conditions	*General* As a mine develops conditions will change. These conditions could be planned or unplanned and could trigger a situation of unstable ground conditions. For example a simple change in the shape of openings or a more gradual change of ground conditions in time, may all have an influence in increasing the risk of ground instability and the possibility of an airblast occurring. *Coal* In coal mines the most likely change is in the nature of the stratigraphy above the seam. In pillar extraction operations, a changing goaf width and/or coal left unmined in the goaf may increase the risk of an airblast. *Monitoring* If there is any possibility of conditions changing that could be critical then monitoring should be considered. Also appropriately planned responses can be ready to be implemented in a timely manner. This monitoring and their corresponding planned responses could be summarized in a TARP table (see Appendix I). *Examples* Changed conditions in the following could create the likelihood for an airblast to occur. (1) A cumulative effect of small failures could create potentially unstable spans. (2) A mine opening that could potentially create a large fall of ground may, with additional wall failures, affect the integrity of bulkheads, drives or even monitoring stations themselves.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of in-situ rock (cont.)	13. Effectiveness of ground support	*General* The effectiveness and continued integrity of ground support is essential to maintaining control of potential instability of in situ rock. Some support can reduce its effectiveness over time. Therefore a monitoring program of their continued effectiveness should be considered. *Monitoring* To ensure the integrity that ground support is maintained consider developing a plan to schedule regular reviews of ground control measures with observation, testing and evaluation. The scope of this should be defined in a ground support management plan that is specific to the mine. This plan may assist in identifying poorly installed ground support or other weaknesses in the ground support regime. Also back analysis of failures may assist in identifying design criteria that should be modified or improved.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of backfill material.	1. General	Consider referring to the *Handbook on Mine Fill* as a guide when using mine fill. Consideration should always be given to the possibility of mobilization of fill material if fill material is being used in a mine. Backfilling can create its own potential to produce an airblast if not managed and controlled effectively. Amongst other considerations the following issues are suggested: • The mined areas or stopes to be surveyed in three dimensions prior to filling to record their geometry. • The amount of fill material being placed in mined areas or stopes to be documented on a daily basis as filling takes place. • Monitor pulp density, adequate drainage, water balance, design pressure for bulkheads, water not ponding on top of fill, adequate fill pour and rest times to ensure drainage • The engineering properties of the fill to be known. • The number of exposed fill surfaces to be known. • The height of the exposure of fill surfaces to be known. • Schedule backfilling to prioritize the filling of potentially unstable voids first as well as having a regard for secondary stope mining requirements. • Consider reviewing the backfilling schedule as further information is obtained. *Planning* The location of stopes and mined out areas can be important in relation to already filled stopes or stopes ready for fill placement. It is worth considering the possibility of various scenarios if fill material becomes mobilized and enters nearby mined out areas or stopes as well as any effect this scenario may have on surrounding ground stability. It is also worth considering the pathway of any likely airblast which may actually be different to the direction that mobilized fill may travel.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for instability of backfill material. (cont.)	2. Quality and moisture content of fill material	*Quality of fill* The quality of fill material being placed underground is of vital significance. If the fill material is of poor quality it could have little strength. Poor quality fill material includes weathered material, high clay content material, poor quality control or chemically reactive material. In general terms the strength and binder content of the fill material are the most critical in preventing failure that could lead to an airblast. Therefore, laboratory tests to determine the fill's physical properties and strength should be part of the mine fill management system. *Moisture content* Control of the moisture content within backfill material is also of vital significance in maintaining its stability. Further detail can be obtained from the *Handbook on Mine Fill*.
Potential for instability of backfill material.	3. Mass failure of fill	*Experience* Massive failure of fill material into adjacent voids has occurred which resulted in an airblast in the mine. This possibility should always be considered in a stoping risk assessment. However, the risk assessment should consider the possibility of a domino affect in that if there is a massive fill failure what is the possibility of a second failure of ground as a consequence, which could then also result in an airblast occurring.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for uncontrolled water flow	1. General	To understand and to control the potential for the inflow of water, it is generally worth considering as a minimum the following: • obtaining hydrological, hydrogeological as well as geotechnical reports, • studies on the potential for rapid inflow and ongoing inflow of ground water, and • the various monitoring systems available. It is good practice to be sure water is not channelled into mined out areas or potentially unsafe areas, such as stopes or the cave (in caving operations).
Potential for Uncontrolled water flow	2. Induced water flow	*Investigation* Before development openings are excavated consider: (1) if nearby voids have the potential to hold water. Nearby voids could include: • aquifers, • old workings, • drill holes, • stopes, and • water drainage into stopes via intersecting drill holes (2) the existence of any surface infrastructure or natural features such as dams, lakes or rivers. Consider estimating water inflow rates from aquifers using a researched groundwater model and appropriate numerical model. *Monitoring* Consider monitoring for controlling induced water flow by using: • dewatering boreholes, • piezometers, • diversion or relocation of flow.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Potential for uncontrolled water flow (cont.)	3. Mudflows	*General* There is a real potential for a mudflow if a mine has stopes being filled with hydraulic fill material or a mine uses a caving method of mining. The risk of a mudflow greatly increases if the material within these stopes or caved areas become saturated. Water should be channelled so that it does not enter a stope or cave and create a potential for a mudflow to occur. For a mudflow to occur it generally requires a trigger to set it off such as a blast or when loading material both of which disturbs the moist material enough to cause it to flow. *Caving mines* In caving mines hydrological studies have been completed to determine: • the size of particles within the material in the cave area, • the cave material's absorbent qualities, and • the cave material's susceptibility to flow. Once hydrological studies have been completed a monitoring program can be developed with trigger values and planned responses. This could be tabled in a TARP document to continually manage and control the level of risk of a mudflow.

	ELEMENT	
PART A	**(3) OPENINGS INTO A VOID FROM THE MINE**	**There needs to be at least one opening into a void which may be the source of an airblast to create the possibility of a pathway for an airblast to affect a mine. That is, an airblast through a mine would not occur:** • **If there are no openings connecting a void which may be a source of an airblast, or** • **If there is sufficient distance of solid ground from such a void to the mine so that any potential over-break of ground cannot then connect the void to the mine.**
Sub-element Planned openings connecting a void to the mine	Issues to be considered 1. Number of openings	Additional notes, controls and monitoring *Mine planning* When planning a mine consider minimising the number of mine openings that may connect a mined out area or a potentially large void with the rest of the mine. *Preliminary bulk sampling* If bulk sampling of an orebody is to be carried out then there is a need to carefully consider its location in relation to the long term mine design so that the potential risk of an airblast is taken into account. The worst case would be to locate it with the highest potential energy situated above it with a potential for an airblast. If block or sub-level caving is being considered, then consider planning the location of the bulk sample so that there will be no way it will create a connection of the cave with the rest of the mine for the full duration of the mine's life.

<u>Sub-element</u> Planned openings connecting a void to the mine (cont.)	<u>Issues to be considered</u> 1. Number of openings (cont.)	<u>Additional notes, controls and monitoring</u> (cont.) A bulk sample could be taken in a location which would not connect a void to the rest of the mine. This could be a location where future development is likely to be positioned, such as where a drill drive or extraction level will exist.
Planned openings connecting a void to the mine	2. Location of openings	*Mine planning* Planning should consider minimising the risk of a potential airblast at all phases of mining. Consider the location of openings so that any potential airblast is not going to enter the rest of the mine workings. Then if an airblast should occur its pathway will simply go to unmanned areas of the mine such as ventilation shafts or other areas where persons are not located. Planning could also consider the proximity of mine workings to any potentially large mined out area or possible void. If, for instance over-breaking of ground occurred in a mined area then the resulting large void could inadvertently connect the void to the rest of the mine and an airblast could then potentially travel through the mine. If there is a possibility of a potential airblast then further consideration could be given to planning safe havens, remote loading areas and locations along drives for engineered bulkheads or stoppings.

<u>Sub-element</u>	<u>Issues to be considered</u>	<u>Additional notes, controls and monitoring</u>
Planned openings connecting a void to the mine (cont.)	3. Cross-sectional area of openings	*General* The larger the cross-sectional area of openings or drives the easier an airblast will travel through those drives. Conversely, the smaller the cross-sectional area of drives the more pressure that is built up and the higher the velocity of airflow. By reducing the cross sectional area of some drives and an airblast goes through then the air pressure will increase. But beyond that point the pressure will drop and the velocity of air reduces and the energy is dissipated. Other practical measures to mitigate the effects of an airblast with respect to different cross-sectional areas, refer to *Part B Mitigating the potential effects of an airblast Element 5.Control of airblast pathways*.
Planned openings connecting a void to the mine	4. Path of least resistance and concentration effect	*General* If there is a potential source for an airblast then consider the pathways of least resistance through the mine that an airblast may follow to vent to the atmosphere. Return airways are likely paths as they offer negative pressure. Also it is worth considering the potential air velocities taking into account the cross sectional areas of the drives and the airblast could concentrate through certain sized openings. Again planning for stoppings or bulkheads may be considered. *Coal* In coal mines, longwall maingate and tailgate roads represent a high potential exit path for airblast. These roads are likely to contain workmen and have critical infrastructure.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Unplanned openings connecting a void to the mine	Proximity of mine workings to a void	*General* The proximity of mine workings to a void which has a potentially unstable back (or roof) can be a significant factor in increasing the risk of an airblast to potentially pass through the mine. Considerations may include: • proximity of openings to a void or to regional openings • interaction of ground stress between mine openings and the void • instability or potential failure of ground in the openings and the void • ground conditions that may change as further openings are excavated • proximity of old workings • ore-passes that may have been worn to a larger area or have the potential to be worn away and become unstable • stability of bulkheads if an unstable void is nearby or has the potential to increase in volume • instability of fill if fill material is being used. *Planning* Consider during the mine planning phase the separation distances of openings into a void or potential voids that may create an unplanned connection. Other considerations include: • the number of openings • the location of openings • the size of openings • the cross-sectional area of openings • the path of least resistance should an airblast occur.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Unplanned openings connecting a void to the mine (cont.)	Proximity of mine workings to a void (cont.)	• any concentrated effect along its pathway should an airblast occur • location of bulkheads and their design and specifications • access to a void • potential connections to the surface • old plans and what has been done historically that could affect planning. One cannot always rely on existing data. Experience has shown to be so. *Monitoring* Consider a regular review of the proximity of openings to a void and the suitability of bulkheads as mining progresses. Take into account potential changes in ground conditions and how this may impact on the potential risk of an airblast occurring or affect the capability of bulkheads to remain functional. Consider monitoring the rock noise and movement by using microseismic monitoring, extensometers, depth plumbing via drill holes and visible inspections.

PART B	**ELEMENT**	
	MITIGATING THE POTENTIAL EFFECTS OF AN AIRBLAST	**The following examines various situations and issues in the case when there is a potential risk of exposure of persons and/or infrastructure to a potential airblast.**
Sub-element	Issues to be considered	Additional notes, controls and monitoring
Planning and monitoring	1. Zones of influence of a potential airblast	*General* Identify zones of influence of a potential airblast which could affect personnel and/or infrastructure. *Investigation* Consider investigating and determining the potential pathways, air velocity and secondary effects (debris becoming airborne) in the vicinity of persons or infrastructure should an airblast occur. Velocities of up to 15m / sec. have been accepted by the coal industry as a minimum threshold above which an airblast is likely to have a marked effect on either persons or infrastructure.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)

Planning and monitoring (cont.)	1. Zones of influence of a potential airblast (cont.)	*Mine design and planning*
		If there is any potential for an airblast to occur consider the:
		• pathways of a potential airblast.
		• areas of highest resistance and therefore potentially highest velocity. However, this could be deliberately planned to reduce resistance beyond that point to help dissipate an airblast's energy.
		• location and impact of potential airblasts on:
		    • areas where people have access,
		    • the surface should a collapse of ground occur due to a break through to the surface. A surface exclusion zone could be considered.
		    • the ingress and egress drives and the effects on egress from the mine should it be blocked after an airblast has occurred,
		    • effects on ventilation fans, and
		    • all other infrastructure
		• there is sufficient distance between drives and mined out areas that could become a potential source for an airblast. This distance may allow for establishing safe havens and/or stockpile locations for rock material to be stored and/or bulkheads to restrict or stop the flow of air should an airblast occur.
		• suitable locations for seismic and/or other monitoring provisions to gather accurate data on any changed conditions that may occur and increase the risk of an airblast occurring.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Planning and monitoring (cont.)	2. Restricting access	*Investigation* When reviewing access ways when there is a potential for an airblast, consider the following • develop an airblast model and predicted pathways and any associated issues that may occur if an airblast did occur • restrict access to certain areas where the risk is too great • place rock material (either permanently or temporarily) as well as bulkheads between where the potential airblast source exists and where people are likely to be located. Even a temporary barrier of rock could greatly restrict the flow of air should an airblast occur or if the risk of one has increased to an unacceptable level. *Monitoring* Regularly monitor any changes in ground stability and review restricted access areas if results indicate the risk has changed. Consider adding this issue to a TARP management system so there is regular and systematic reviews carried out.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Planning and monitoring (cont.)	3. Provision of safe havens	*General* Establish safe havens so that personnel can escape to a safe location if the risk of an airblast appears imminent. However, often there can be no warning. Also securing safe access to areas of the mine and egress out of the mine need to be considered if they could be affected by an airblast. Experience from airblasts has indicated that if persons go into a nearby dead-end cross-cut (or dead end heading) then they would be kept safe from the effects of an airblast should one occur. The pathway of an airblast would not flow through a dead end cross-cut. *Procedures and training* Procedures should be developed for persons to follow should an airblast appear to be potentially imminent. This should include communication with mine control. Protocols should be developed and training of personnel should be given on procedures to follow if the potential for an airblast appears to become imminent. *Monitoring by personnel* A procedure for persons to go to a safe haven would not be practical unless there is sufficient warning so that persons can get to a safe haven in time. These warnings could be from persons being aware of severe ground vibration or constant noise. These warnings may be coming from the initial breaking up of large blocks of ground. An alarm system also may be installed near potential airblast sources using geophones or seismic monitoring systems.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Planning and monitoring (cont.)	4. Location of contaminants Note: In coal mines – the risk level can significantly increase with the presence of flammable dust and gases	*Coal* In coal mines airblast excursion distances have been measured to be hundreds of metres from the source of the airblast. Areas which are generally considered outside the Hazardous Zone (HZ) can be inundated with explosive atmospheres. It should be remembered that electrical equipment in non HZ's may not be protected from an explosion nor be regarded as intrinsically safe. The risk of an explosion can greatly increase should an airblast occur in a coal mine.
Planning and monitoring	5. Control of airblast pathways	*Planning and control* Consider planning a separate pathway where persons would not be located should there be a potential for an airblast to occur. An airblast would follow the pathway of least resistance and this pathway may take most of the airblast flow. Planning considerations could take this into account for the worst case scenario if there is a risk of an airblast occurring. Consider planning drives with larger cross-sectional area to take an airblast away from where personnel or infrastructure are located. *Control* Broken rock material may be placed in drives between the source of an airblast and the mine to minimise the cross-sectional area of the drives. A series of broken rock placed along drives can progressively de-energise an airblast as it passes over the series of rock piles and no piles and then further rock piles. Enough material strategically placed within particular drives can greatly reduce the velocity and the energy as an airblast travels before it continues its pathway to the rest of the mine where people or infrastructure are located. These temporary series of rock piles could greatly mitigate the effects of an airblast.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Planning and monitoring (cont.)	5. Control of airblast pathways (cont.)	However, important considerations would be to ensure that there is sufficient volume and size of material and consider its porosity and permeability so that the rock or material restricts airflow as planned and not travel with an airblast through the mine. This may require establishing additional drives so that it is possible to place temporary stoppings in appropriate locations. *Monitoring* Consider monitoring for changes in conditions that may indicate the risk of an airblast has increased. Then establish a trigger measure that would bring about actions such as the control measure above.
Planning and monitoring	6. Plan for monitoring the risk of exposure to a possible airblast	*General* Consider monitoring the risk of exposure of an airblast to people and infrastructure by using a TARP. This is a management system to manage and review all monitoring of any changed conditions, the effectiveness of controls and planned responses to any changes in the risk of exposure to an airblast. See *Appendix 1* for an example of a TARP, and Part A *Source of Potential Energy, Potential for instability of in situ rock, Potential for ground failure which is not designed.*

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Mitigating the effects of a possible airblast in existing mines	1. Control airflow	*General* Consider controlling airflow by: • restricting the airflow of a potential airblast by placing sufficient volume of broken rock along drives. • determining the porosity and permeability of broken rock to an airblast if this is acting as a barrier. • erecting engineered bulkheads in drives to stop an airblast airflow completely. *Bulkheads (or Stoppings) design* There is no generally recognized design for bulkheads. However structural engineering considerations are recommended. Each bulkhead should be assessed for its capacity to withstand an airblast on a case by case basis. However, the design may consider: • potential velocities of air and rock material, • pore pressure on the bulkhead, • bulkhead dimensions, • bulkhead load capacity, • material properties, • three dimensional numerical stress analysis, • V or arched shape with the apex facing the potential airblast source, • located in a drive with minimal cross sectional area, • located in solid ground free from major planes of weakness, and • construction practicalities of the bulkhead design

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Mitigating the effects of a possible airblast in existing mines (cont.)	1. Control airflow (cont.)	*Planning* The objective may not necessarily be to totally withstand an airblast. But it could be designed to redirect airflow or even to fail at a certain point. And tthen there may be additional means to de-energise an airblast after that point by placing material placed along drives to continue the de-energising process. *Fill behind the bulkhead* If fill material is to be used behind the bulkhead consideration should be given to design considerations that affect the stability of the fill material also. Reference could be made to the *Handbook on Mine Fill*. Also, see additional considerations regarding fill behind a bulkhead in Part A (2) Potential Energy Source, Element ‘Potential for instability when backfilling’. *Experience* Experience has led to one site designing a bulkhead to 770kPa ultimate pressure capacity after research had shown that airblast pressures in that mine could reach 500kPa in the worst case scenario. This design included using four layers of eleven solid 27 mm rebar rockbolts extending into the walls as well as into a shotcrete filled bulkhead with reinforcing mesh which is V shaped with the apex of the V facing the airblast source. Two pipes were placed through the bulkhead at the base to allow water to drain.

Sub-element	Issues to be considered	Additional notes, controls and monitoring
Mitigating the effects of a possible airblast in existing mines (cont.)	2. Debris and housekeeping	*General* Consider secondary impacts of an airblast. Material may get picked up by an airblast which could then impact on persons or infrastructure if an airblast occurs. Consider where electrical installations, fans, vent tubing, ducting, pipes and other infrastructure is located to minimise this risk. Explosion doors could be installed on main fan cowlings to vent the blast and take the forces away from the fan itself. General housekeeping and the selection of appropriate locations for infrastructure may also reduce the potential risk of secondary impacts.

<u>Sub-element</u>	<u>Issues to be considered</u>	<u>Additional notes, controls and monitoring</u>
Mitigating the effects of a possible airblast in existing mines (cont.)	3. Develop an airblast model	Consider developing an airblast model to determine potential pressures and velocities if there is a potential for an airblast to occur. *Wind velocities* Logan (2004) suggests that there are limited international guidelines available to define tolerable wind velocities. Most meteorological scales are not applicable as they measure gust velocities 10m above the ground. However, Logan (2004) states that the Saffir-Simpson Hurricane scale is one that may be more applicable as it measures velocities at ground level. This classification is supported by the Australian Coal Association Research Program (ACARP) work which indicates that laceration injuries of uncovered skin would occur for wind velocities exceeding 15 m/s with projectiles weighing 10 grams or less. Logan also suggests that a theoretical formula and parameters can be established for determining wind velocities in a model. The parameters will however vary for each mine site. He states that a credible peak wind velocity due to air inrush is a function of several key variables, such as: • the expansion void, • the thickness and permeability of broken rock if wind passes through a broken rock, • the number of exit pathways, and • measurement errors can occur because interpretations and estimations have to be made. Wind velocities can be assessed from overpressures using air flow principles. A model can be developed using a “leaky piston” model to assess the overpressure.

Sub-element	Issues to be considered	Additional notes, controls and monitoring (cont.)
Mitigating the effects of a possible airblast in existing mines (cont.)	3. Develop an airblast model (cont.)	This overpressure could be modelled for a range of air gap heights, broken rock heights, and broken rock fragmentation types following a collapse of ground. Principal unknowns include the degree to which a fall of rock breaks up, vertical height of fall, the plan area of the fall and the air flow resistance of the connected openings. A number of assumptions have to be made; such as the fall is uniform. Calculated overpressures applying to different broken rock resistances (if it passes through such broken rock) to enable calculations to be made of various flow rates. Wind velocities can be assessed for a series of voids or air gaps and broken rock heights for different rock porosities. *Charts* According to Logan (2004) a series of charts can then be developed in the model to form a nomogram that links the void height to variable broken rock heights to give separate wind velocity assessments through a single exit tunnel. The nomogram can also show reduced wind velocities for multiple exit paths. Separate nomograms can be produced for different broken rock fragmentations and permeabilities.

Notes