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STRATA CONTROL IN UNDERGROUND COAL MINES A RISK MANAGEMENT PERSPECTIVE

Chris Allanson[1]

INTRODUCTION

Hawcroft Miller Swan (HMS) reviews approximately 120 mines per year, around the world. Of these approximately 60% mine coal and the remainder metal and other minerals. Also approximately 60% of these mine underground. From our experience it is apparent that the mines with a well-developed understanding of their risk profile and a systematic approach to the way they do business, enjoy better business outcomes in terms of safety, productivity, cost control, profitability and reputation. Others without systems in place, consume a phenomenal amount of time and energy dealing with day-to-day issues, without ever gaining effective control of the critical issues that drive their business.

This paper seeks to share HMS experiences in relation to risk management in Australia with particular focus on the underground coal mining industry of New South Wales and Queensland and geotechnical matters. It provides a brief overview of the legislation in both states and the use of risk assessment in relation to statutory compliance and as a business management tool. Comment on the benefits and limitations of risk assessments are given from the perspective of an organisation providing risk management services to the industry, or utilising industry-specific examples.

Over the past decade the Australian underground coal industry and the mining industry in general has experienced an increasing application of risk assessment processes as a proactive initiative for improving safety. Tougher economic, environmental and legal pressures, coercion from employee, government and social groups (including local trade unions and the ILO), the recognition that a contract of employment does not include acceptance of personal injury and an awakening to the principles of due diligence, have all fuelled this new perspective.

It is true that underground coal mining is inherently more hazardous than other industries, but this doesn't mean we should simply accept it to be more dangerous. Accident investigation has demonstrated that in most cases sufficient information was present before an accident for someone to have intervened and prevented it from occurring.

In the philosophy of risk management, the fatalistic acceptance that *accidents will happen* has been replaced by the realisation that impending loss is in most cases predictable and therefore preventable.

Damage control and reactivity in Australia has been overtaken by active participation to gain understanding of the hazards before engineering changes, implementing systems and building competence to gain effective control by eliminating or effectively mitigating the risks. The process most widely used is risk assessment. Done properly, this process incorporates local knowledge and experience with external expertise in a forum where the principles of involvement and consensus are used to identify and prioritise hazards and to recommend appropriate means of controlling risk.

On average HMS facilitate one risk assessment every two weeks. Risk assessment topics and applications vary from the very simple to the subtly complex. Some organisations are quite experienced with the risk assessment process and embrace it for all the benefits it provides, while others are in denial, applying the process because of statutory compliance or corporate directive. The more experienced workplaces have become quite adept with the process and efficiently achieve significant benefits while others need on-going education and coaching to get it right then battle through as management and workplace cultures are reprogrammed away from the compliance-based mindset.

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WHY DO RISK ASSESSMENTS

In general there are two main reasons why mines do risk assessments – for statutory compliance or because within the organisation there is a higher level of appreciation for the benefits of a risk management and a systematic approach to operating their business.

For those that embrace the risk management philosophy there is the acceptance that good safety performance, like good productivity are simply outcomes of a well-managed system.

From a world wide perspective Australia seems to be leading the pack when it comes to risk management and the utilisation of the risk assessment process for safety and whole of business considerations. Mines reviewed throughout mainland Europe and the United States were generally not using risk assessment as part of their business management strategy. Some US mine operators are not familiar with a generic risk matrix. South African mines have a greater appreciation of the risk assessment process. Having been introduced to the philosophy in 1996, they are a couple of years behind Australia and have confined its use to purely health and safety applications.

Larger international corporations such as Rio Tinto, BHP Billiton and Shell/ Anglo Coal have embraced risk management and incorporated the philosophy as a Corporate Standard and irrespective of the country, those sites are in general, well advanced in applying the process.

In NSW risk assessment was introduced approximately ten years ago and eagerly promoted by the Chief Inspector of Coal Mines. Since that time and subsequent to the Moura Inquiry, the Queensland coal industry followed suit. Both states moved to enshrine risk assessment in legislation in 1999. NSW and Queensland are equally well advanced in their application of risk management and in particular, risk assessments.

More recently the Western Australian Department of Mines required mandatory risk assessments for justifying areas wherever rock bolting is not adopted following significant strata-related failures and fatalities.

Despite Australia having the jump on the rest of the world in risk management there is by no means reason to become complacent in the sense of a job well done. There is still a long way to go and no excuse to not continue to be the world leader.

STATUTORY COMPLIANCE

The principles of risk management in Australian Mining Legislation are either by direct reference or through the imposition of Australian Standards, "*accepted practice and due diligence"*.

Underground coal mines in New South Wales currently operate under the NSW Coal Mines Regulation Act 1982, No. 67 ("CMRA 1982", "*The Act*") and the NSW Coal Mines Regulations 1999 - General and Underground ("The 1999 Regulations", "CMR Gen 1999", "CMR U/G 1999"). In Queensland the Coal Mining Safety & Health Act 1999 ("CMS&HA 1999") and the Coal Mining Safety & Health Regulations 1999 ("The 1999 Regulations", "CMS&HR 1999") are the current statutory instruments for administering underground coalmines. The interrelationships between these legislation and corresponding occupational health and safety legislation have not been considered in this paper.

The NSW 1999 Regulations have introduced the principles of risk management over the existing framework of the CMRA 1982. The resultant NSW legislation is a combination of prescription and self-regulation, however in the ability to self regulate, mines are required to develop and implement systems for specified *core risk*[1] areas, e.g. inrush, ventilation and emergency escape. The pre-existing Act of 1982 remains for now unchanged and the requirement for Managers to make Rules and Schemes continues.

The first reference to strata control in the CMRA 1982 is Section 37 (2) (c) (ii) which defines one of the functions of the Mine Manager as "*ensure that the roof and sides of working places and roadways in the mine (other than roadways located in a part of the mine which is fenced off in pursuance of the regulations) are adequately supported where necessary for safety*".

[1] Core risk areas are areas of operation of coal mines with generic hazards that have the potential to cause multiple fatalities.

Later in the Act Section 102 requires the Mine Manager as to make support rules, while Section 105 requires that those rules are provided to the District Inspector for Confirmation.

In the NSW Underground Regulations, Division 9 sets out in detail the Support Rules. Clause 48 prescribes in detail the process of developing, implementing and monitoring *Support Rules* and specifically includes the following matters:

- *estimate the types of geological conditions likely to be encountered in roadway development*
- *assessment of the stability of roadways to be developed in geological conditions likely to be encountered*
- *development of support measures that will provide roadway stability in geological conditions likely to be encountered*
- *preparation of support plans that explain in full detail the means of roadway support required to be installed and prepared in a manner such that they may be readily understood by those required to install roadway support*
- *provision of safe, effective and systematic work methods for the installation, and subsequent removal where required, of roadway support (including support in connection with the carrying out of roof brushing operations)*
- *provision of adequate equipment and resources to effectively install or remove roadway support*
- *monitoring of the stability of roadways after formation and support installation*
- *training of employees, including; support design principles, support plan interpretation, placement and removal, understanding the need for and importance of the various support systems, recognition of indicators of change that may affect roadway stability*
- *recording of geological features that may affect roadway stability*
- *recording of roof failures that have the potential to cause injury to persons*
- *conducting of periodic compliance audits (not exceeding 12 months)*
- *reviewing of the application and effectiveness of the support rules at intervals not exceeding 12 months.*

In a further requirement of Division 7 – Working Dimensions and Breakaway Rules of the underground Regulations the Manager must make Breakaway Rules "*for fixing the maximum width of intersections, the manner of commencement of drivage of roadways, showing the sequence of forming the intersections and the manner of support"*.

In Section 37 (2) (h) "*the manager must ensure he is in possession of all available information relevant to the behaviour of strata surrounding the mine and its relationship to the safe working of the mine and all available information regarding disused excavations or workings in the vicinity of the mine"*

In relation to the stability of workings, Clause 38 of NSW Underground Regulations and Section 139 of the Act prescribe the minimum permitted pillar sizes and location and size of barriers respectively.

Although the NSW legislation can be considered largely prescriptive in nature, In Clause 6 of the general Regulations, owners are required to assess risks to health or safety regularly and ensure that identified risks are dealt with in the following order of priority:

(a) *eliminate the risk,*
(b) *control the risk at its source,*
(c) *minimise the risk by means that include the design of safe work systems,*
(d) *in so far as the risk remains, provide for the use of personal protective equipment, having regard to what is reasonable, practicable and feasible, and to good practice and the exercise of due diligence.*"

Clause 6 locks the owner/ manager into adopting a risk-based assessment of operations in general (including strata control). Indeed many NSW operators have already adopted a risk management approach to strata control and routinely conduct risk assessments for new panel layouts as part of Section 138 Applications. Alternatively a risk assessment may be required by an inspector on submission of Support Rules in accordance with Section 105 of the Act for confirmation.

Many mines have developed support rules in the formof a strata control management system and incorporated matters in addition to the prescribed matters of the Regulations. Furthermore compliance with Section 4.2.2 of AS 4804 - Australian Standard for Risk Management Systems requires that hazard identification is adopted in the development of safety management systems. Accepted processes are described in AS4360 and MDG1010.

In a similar manner Section 30 of the Queensland Act requires a risk management approach be adopted according to the following criteria:

- *identify*
- *analyse*
- *assess risk*
- *avoid or remove unacceptable risk*
- *monitor levels of risk and the adverse consequences of retained residual risk*
- *investigate and analyse the causes of serious accidents and high potential incidents with a view to preventing their recurrence*
- *review the effectiveness of risk control measures, and take*
- *appropriate corrective and preventive action*
- *mitigate the potential adverse effects arising from residual risk*

In general there are more direct references to adopt risk assessments in the Queensland Coal Mining 1999 legislation than the corresponding NSW legislation. The Act identifies strata control as a principal hazard, requiring a hazard management plan to be developed while Clause 63 of the CMS&HA 1999 requires principal hazard management plans to "*identify, analyse and assess risk associated with principal hazards"*. Irrespective of this Section 4.2.2 of AS4804 requires that hazard identification is undertaken for the development of safety management systems in general.

Section 29 of the Queensland CMS&HA 1999 places the responsibility of reducing the risk to persons from coal mining operations to an **"***acceptable level*" or within "*acceptable limits"* and "*as low as reasonably achievable"*. This is similar to Clause 6 of the NSW General Regulations, requiring "*reasonable, practicable and feasible, and to good practice and the exercise of due diligence"* from operators.

Clause 317 of the Regulations specifically requires that a risk assessment must be carried out for second workings including consideration of the following matters:

- *any surface features, artificial structures and water reserves that may create a hazard if disturbed by the workings*
- *any other workings located in close proximity above, below or adjacent to the proposed second workings, whether in the same or an adjacent mine*
- *known geology affecting the intended workings*
- *anticipated gas make*
- *pillar stability*
- *proposed method and sequence of coal extraction*
- *proposed methods for the following*
- *strata control and support*

Clause 318 required that the system of extraction be "*based on"* the risk assessment identified in Clause 317 and Clause 320 requires a further risk assessment for subsequent changes to an extraction system.

Clause 323 (2) requires the underground mine manager to ensure suitable strata support methods are designed and implemented for the working place. Unlike the NSW legislation the Queensland legislation refrains from defining the process of design, implementation and monitoring of support systems.

In relation to the design and layout of panels and pillars, Section 138 CMRA 1982 requires that mines obtain Ministerial approval for mining by methods other than bord and pillar (Pillar extraction, longwall or mini wall mining, auger mining, punch mining, single entries). The NSW Department of Mineral Resources has published guidance material for gaining a Section 138 Approval (MDG 1001 and MDG 1005 for extraction systems and draft guide lines MDG 1011 for single entry drives). Reference to the assessment of risk is made in the guidance material (and draft guidance material) and a Section 138 Approval is usually contingent upon a risk assessment and a geotechnical assessment having been done as a minimum.

Clause 321 of the Queensland Regulations simply requires that mines ensure the stability of mine workings in relation to pillar strength and stability and strata support requirements, while Clause 320 makes reference to dangerous mine subsidence.

It is apparent that whilst the legislation pushes mines to adopt a risk management approach to strata control, a level of prescription has been retained as a safety net to maintain effective regulation.

OTHER REASONS

Despite the statutory requirements of the legislation, there are many other good reasons for conducting risk assessments.

Risk assessments consider broader issues to a greater level of detail commensurate with the level of risk. Time is not wasted addressing irrelevant matters and important issues are not skipped over to simply comply with legislation.

It is not possible to prescribe in legislation and associated codes, standards and guidelines all the permutations to cover all mines, their systems and mining conditions, let alone the other idiosyncrasies of each mine that are relevant at the particular time. Risk assessment is a situational analysis whereby the subject can be assessed in the context of its environment. Prescription does not incorporate the site specific knowledge and issues.

Risk assessment can be scoped broadly or focused to suite the need. Site personnel utilise the experience and expertise to develop appropriate controls.

Risk assessments provide a forum in which to:

- identify information gaps. When undertaken in the early stages of design, it has the ability to identify whether more data or research is required in order to make properly informed decisions
- determine if design assumptions are relevant and appropriate for the application
- assess the impact on associated and related systems
- allow balanced assessment and prioritisation of multiple and diverse risks. Bland compliance with prescription limits the opportunity to manage the total system
- provides opportunity to capture the full range of hazards relevant to the particular situation in terms of business interruption, material damage and reputation - not only safety
- flush out implementation issues

The process of identifying and quantifying and prioritising risk directs focus on the important issues so the mine does not waste time pursuing pet topics or matters that prescription might otherwise set priority upon without it being relevant at the particular mine. For example, outburst may not be of relevance at some mines but may be of critical importance at others.

There are many examples of the limitations of prescription through Regulation and guidelines. One such example in NSW is the failure of the Wardell guidelines to address all relevant matters in panel and pillar design. Mining layouts designed in accordance with the specified guidelines did not take into account the behaviour of pillars with claystone in the surrounding strata and resultant mine subsidence exceeded the design amount.

Where specific design guidelines are provided, there is a real danger that they can be misinterpreted or applied incorrectly to geological/ mining conditions for which they were not intended. In some instances compliance with specified guidelines has been interpreted as having followed a satisfactory design process. Prescription can perpetuate an attitude where compliance is taken as sufficient without any further investigation. A full risk assessment however, scoped to incorporate safety, business interruption, material damage and reputation will lead operators to applying a level of rigour commensurate with acceptable risk exposure and utilise appropriate design principles including proper engineering practice.

WHAT IS A RISK ASSESSMENT

Risk assessment is a structured situational analysis of a particular interaction between equipment/ people/ environment to identify, quantify and prioritise risk against a predetermined standard and identify appropriate means of control.

There is no such thing as a "one size fits all" or a superior risk assessment technique. The Safety Systems Society Handbook (1993) covers over seventy risk assessment techniques while the NSW Department of Mineral Resources (DMR) publication MDG 1010 (DMR, 1997) provides examples of the most common techniques for

the mining industry. Each has its own strengths and limitations. The question is which technique is most useful in assessing strata control.

RISK ASSESSMENT TECHNIQUES

This section briefly touches on some of the risk assessment techniques and their applicability to strata control in underground coal mines.

The Workplace Risk Assessment and Control (WRAC) technique is commonly used throughout the industry for identifying potential operational production and maintenance loss. It is the technique most commonly used. WRAC has the capacity to focus on a variety of aspects including, support type, installation method, inspection regimes and other activities. It can be applied in areas of the mine or at particular times of activity.

WRAC is most effective when it is scoped with appropriate detail, including clear objectives and the boundaries of the system have been defined. Long and short term stability can also be assessed if known, depending on the mining process used.

Fault Tree Analysis (FTA) is used when it is necessary to show the logical structure of major undesired events by graphical means. The outcome is highly visual for ease of understanding failure mechanisms. Fault Tree Analysis may be extended to include a quantitative analysis, whereby probabilities of separate events are analysed to give an overall probability of a particular major loss event. Data is often not available nor this level of analysis necessary for mining applications. FTA can be very time consuming and produce few benefits beyond WRAC.

Both WRAC and FTA techniques however are good for identifying multiple failures. For example strata failure due to one or all of the following would be identified:

- Incorrect type of support used for conditions
- Incorrect assessment of environmental conditions
- Failure or inadequacy of inspections
- Incorrect installation
- Support equipment failure
- Insufficient skills/ competencies

Human behaviour or error and equipment component failure studies need to be closely scoped so they do not become unwieldy. Behavioural risk assessments can be difficult as they are dependent upon development of templates for perfect behaviour. This is particularly difficult if multiple tasks are involved. They also assume that the system, environment and machines are perfect, when in fact this is often not the case.

When dealing with machinery used for the installation of supports or working within a defined support regime the Machinery Hazard Identification method may be appropriate.

Failure Mode and Effect Analysis (FMEA) is appropriate for focusing on hardware failures, and quantifying risk if probability of failure can be defined. This technique is good for analysing equipment designs and modifications and pre-commissioning assessment, for example development of a mobile bolter.

In general, qualitative risk assessments are adequate for most circumstances in the mining industry and quantitative risk assessment may not even be possible because of an absence of reliable data.

An example of the commonly used WRAC (qualitative) risk assessment technique follows.

Examples of qualitative descriptors for consequence are provided below in Table 1.

Table 1. – Qualitative Consequence Descriptors

Rating	Injury
1 – Catastrophic	Multiple Fatalities
2 – Major	Fatality
3 – Moderate	Serious Bodily Injury
4 – Minor	Lost Time Injury
5 – Insignificant	First Aid

A holistic view of mining activity in the context of the business can be taken by including additional consequence descriptors such as business interruption, material damage, environmental impact and reputation. Many Australian mines now include these considerations in risk assessments, having recognised the benefit of taking a holistic view of the mine as a business. In practice the most severe risk, in terms of safety, business interruption, material damage, environmental impact or reputation, is adopted.

This approach recognises that safety, like productivity and profitability are simply outcomes of a well-managed system.

In determining the consequence, both instantaneous and cumulative loss should be considered. Subsidence, like health related considerations should be considered from an exposure and repeat activity viewpoint to capture long term consequences.

Examples of qualitative descriptors for likelihood which are self explanatory are provided below in Table 2. They usually result in some conjecture and it is often necessary to remind risk assessment teams to risk rank in absence of soft barriers.

A - Certain	**B - Probable**	**C - Possible**	**D - Remote**	**E - Improbable**
Will occur	Likely to occur	Could occur	Unlikely to occur	Practically impossible

Table 2 – Qualitative Likelihood Descriptors

Risk is determined by considering the consequence and likelihood in relation to a matrix such as that shown below in Table 3.

Table 3. Risk Matrix

	A – Certain	B – Probable	C.- Possible	D – Remote	E - Improbable
1 – Catastrophic	1 (E)	3 (E)	5 (H)	7 (H)	11 (S)
2 – Major	2 (E)	4 (E)	8 (H)	12 (S)	16 (M)
3 – Moderate	6 (H)	9 (H)	13 (S)	17 (M)	20 (L)
4 – Minor	10 (S)	14 (S)	18 (M)	21 (L)	23 (L)
5 – Insignificant	15 (S)	19 (M)	22 (L)	24 (L)	25 (L)

The matrix shown in Table 3 is a 5 x 5 safety risk matrix. The number in each of the coloured cells indicates the risk index for particular consequences and likelihood. One (1) is the most severe risk raking and twenty-five (25) the least severe. Other risk matrices are available. Some don't distinguish between single and multiple fatalities and others are presented as 3 x 3 matrices. Most mining operations have found a risk assessment technique they feel comfortable with, and have developed their own qualitative risk matrices based on AS/NZS4360 and MDG

1010. It is worthwhile noting that it is impossible to achieve a risk rank lower than 1 E (11) for catastrophic consequence unless the hazard is eliminated completely.

The most important task in risk assessment is to rate the likelihood and consequences, calculate the risk rank of all related events that could result in loss and arrange those in order of priority to gain an understanding of the most important areas.

Items can take the form of an activity, an object, a condition or a combination of these. People must clearly describe what it is being ranked under the chosen heading in the table e.g. hazard or loss scenario, and be consistent in the language used as this will help for later sorting.

While the risk assessment method chosen is important for capturing hazards and reflecting their seriousness, it is the outcomes of the risk assessment that is most important. People should not take the risk rank as definitive nor waste time haggling over the risk rank. Risk ranking it is not an exact quantification of risk but a means of prioritising actions and allocating resources to control hazards.

Exposure data can be added to the equation, but separate reference is usually not warranted, as it can be reflected in both likelihood and consequence ratings.

RISK ASSESSMENT TEAMS

Risk assessments can be done by an individual, however to maximise the breadth and depth of analysis, team work is best. Individual assessments are best reserved for less complex tasks such as local risk control process, job safety analysis (JSA) or hazard awareness. Group analysis is preferred for larger topics to take advantage of the collective knowledge, experience and technical expertise of a group to provide a more comprehensive coverage of the topic.

The benefit of utilising groups to assess risk include:

- A cross section of people who are involved with planning, implementing, operating, monitoring and reviewing the process are included, leading to more comprehensive coverage from all aspects or perspectives, highlighting issues of which management or technical experts may not be aware.
- Technical people become aware of implementation and operational issues they might not otherwise have considered in the design.
- Solutions will be practical for those required to implement them providing at least a chance they will be implemented as designed.
- Management can qualify the economic and operational feasibility of suggested solutions.
- Suggested controls are likely to consider all competency, skills and literacy.

Risk assessments are usually not the forum for assessing geotechnical engineering design unless the participants are technically qualified. Rather most risk assessments are used to check whether the correct design parameters have been used for the proposed design and to consider implementation of the design in the mine environment.

HMS OBSERVATIONS

Despite the lack of direct reference by legislation requiring risk assessment for each type of system, mines have adopted risk assessments as their preferred vehicle for incorporating consultation in developing and reviewing safety management systems. In NSW strata is usually dealt with during the broad-brush risk assessment. The depth to which sites drill down is dependent on the individual site.

Furthermore an increasing number of mines are taking the opportunity to consider business interruption, material damage, environmental impact and reputation in addition to health and safety. Some have taken the process to the next level to identify and evaluate up-side opportunities to determine appropriate improvement strategies.

Some mines do risk assessments for the sake of compliance and are inclined to allocate tight and often unrealistic timeframes, grab personnel on rehabilitation to make-up numbers, exclude union participation and use strong management direction to speed the process along. It is important to let the process unravel, identify the hazards and potential loss, prioritise risk and specify controls and not lose sight of the objective of the exercise.

Risk assessments are often disrupted by people with operational responsibilities attending to mine needs, particularly at shift change. Some operations hold risk assessments off site or at times when other operational personnel are available to avoid disruptions.

Risk assessment applications vary from the very simple to complex. Whilst strata issues may be dealt with at some sites during wide broad brush risk assessments, other more detailed or very specific assessments deal with particular mining systems or equipment. In some cases the assessment will consider a detailed design, including the final draft of a geotechnical design, whilst others may take advantage of the risk assessment group to review and identify hazards and controls on a range of panel design options. Unless the risk assessment team is comprised of a team of expert personnel a risk assessment is not usually the appropriate forum to critique the geotechnical design. However it is appropriate to identify how design assumptions can be compromised and to identify additional or changed factors the geotechnical design may have neglected to address, e.g. wide roadways are required to operate large mining machines.

It is also important to establish that the risk assessment team understand the process before commencement. There is often need for a quick training session before commencement, although pre-assessment training is becoming less common.

The site acceptance of the risk assessment process is variable. Some sites embrace the process as a valuable tool that affords the opportunity to have a real impact on safety and business performance. Other sites see the system as a matter of process or a waste of time and participate to fulfil some statutory criteria and take a passing interest in the overall process. Generally the more familiarity the site with the process the more benefit is derived and the more efficient it becomes.

There is a wide variation of risk tolerance across the industry. Risks that are acceptable to some mines are not to others. Risk tolerance at particular sites can influence the outcome of the risk assessment and hence prevent hazards being identified or appropriate controls being adopted.

Risk tolerance levels can develop in the culture as perceptions, built by a history of what has worked in the past, and accepted practice accumulate in the collective memory of the organisation. Current operational constraints or perception that risks are necessary in the interest of preserving jobs or cutting costs also have an effect. It could also be simply a lack of risk management philosophy by management. An added danger is that if the facilitator is not aware of a high level of risk tolerance the risk assessment teams could down rate risk or gloss-over important hazards. Furthermore if the facilitator is a part of the same risk-tolerant culture the risk team may never be challenged and high or extreme risks go unassessed. Closed-shop organisations may not be aware of the folly of the things they do before it is too late.

It is important that all people in the risk assessment team reach consensus as the assessment proceeds. Repeated interjection by overzealous people, with pre-set agendas or pre-determined outcomes can, if not controlled, result in short cutting the process or extent of analysis. It is important that the facilitator ensures that all team members get equal say before reaching consensus.

For tightly constrained risk assessments it is imperative that the scope reflects the timeframe of the assessment and that all assumptions and limitations are properly defined, understood and carefully recorded. This helps to circumvent the problem of people becoming sidetracked by incidental issues.

Most clients prefer to conclude the group session before finalising the action plan. For small risk assessments this may not be a problem because the senior person in the team can ensure the actions are followed through. Similarly for complex risk assessments it would be grossly inefficient to occupy the time of personnel allocating tasks for hundreds of actions. Diligence however is required in follow-up to ensure actions are assigned to appropriate personnel and that those actions are actually completed.

HMS conducted a review of a number of risk assessments covering the following strata-related topics:

- Pillar extraction – Wongawilli, Pillar stripping, breaker line supports
- Longwall extraction
- Cut/ flit mining
- Massive strata
- Section 138 application
- Mobile bolters
- Longwall mining through disused shaft

- Drift excavation
- In close proximity to overlying workings
- Thin seam operations

TYPES OF STRATA HAZARDS

The review identified the following distribution by energy type is shown in Table 4

Table 4 Risk Data by Energy Type

Energy Type	Proportion
Gravitational	82.4%
Mechanical	7.2%
Chemical	6.4%
Thermal	2.4%
Pressure	1.6%

Whilst the vast majority of hazards are concerned with falling roof material a significant number of hazards relate to the operation of equipment associated with roof control or a mining system being assessed for strata hazards.

Some examples although not exhaustive, of the types of hazards identified by the strata-related risk assessment review are:

- rib failure
- operator position under unsupported roof
- recover C/M from unsupported roof areas
- ventilation disruption by choked goaf
- windblast and gas emissions from goaf
- undetected change in strata conditions, adverse geological conditions
- roof failure in work areas adjacent to goaf
- fall of roof between supports
- BLS over-ridden by goaf fall
- Person crushed by BLS or continuous miner
- failure of supported ground, bed separation, anchor failure, poor installation or setting
- shape & size of pillars or roadways, roadway alignment
- pillar failure or collapse - punching, weak interfaces, width to height, grade
- load transfer, abutment stress, periodic weighting, face slabbing
- orientation to structures, joint sets, cleat
- support setting or installation hazards

The diversity of the above list demonstrates the ability of the risk assessment process to flush out a broad array of hazards. More importantly the list demonstrates how comprehensive a prescribed list of considerations might be required in order to identify specific hazards for all mines.

Considering the examples listed above it is apparent that no level of prescription would identify relevant hazards for each site. Two examples are set out below

Example 1.

Consider the operation of a large remote control continuous miner in cut flit development under strong roof, with good bridging properties. Two hazards at this operation could have been ranked as follows:

No	Area	No.	Activities/ Process	No.	Hazard	C	L	R	Existing Controls	Additional Controls
1	Strata Control	1.1	Remote control cutting	1.1.2	Crushed by RC C/M in 5.5 m wide roadway	1	C	**4**	▪ Safe Stand Areas defined ▪ Operator competence	▪ Drive wider roadways for safe clearance ▪ Redesign support system for wider roadway.
1	Strata Control	1.1	Remote control cutting	1.1.1	Failure of supported Roof in 6.5 m wide roadway	1	D	**7**	▪ Support Rules ▪ Inspections ▪ Operator competence	▪ Design Support System for the place

In Example 1 the risk assessment has identified that the risk of the remote control continuous miner crushing the operator is greater than that of being injured by a fall of supported roof. In mitigating risk, the risk assessment team must deal with risks in order of severity – highest to least. The team could have decided that an appropriate control to reduce the risk of crush injury from a continuous miner is to drive roadways wider to provide more clearance. To make this recommendation the team must make the fundamental assumption that an alternative roof support system can be designed for the wider roadway without increasing the risk to personnel by a fall of supported roof.

The benefit of using risk assessment processes to distil priorities from an array of hazards is demonstrated by this example. In the first instance the absolute necessity of protection personnel from falling roof material is the most basic of mining practice, hence the provision of support. Secondly the C/M operator has highlighted the possible danger ofworking in the vicinity of the RC C/M and offered a possible solution. If geologists and geotechnical engineers are present they have the opportunity to comment on the concept of driving wider roadways and to give an initial opinion as to whether effective redesign of support appears feasible. In addition, bolter operators can assess the proposal with a knowledge of the operational capabilities of the mobile bolter. Management can have input from the perspective of the impact on factors such as control of widths and cost of support. Fundamentally the process provides a balanced approach and detailed assessment on the solution of seemingly conflicting controls.

Having considered the proposal it is important to ensure the wording of the proposed control is consistent with the intent of the workshop. In this case all indications at the time of the workshop are that the concept is feasible, however the final width and support system design are as yet unresolved. Despite the column heading being changed from "Additional Controls" to "Potential Controls" the entry may be better stated as " Assess the feasibility of wider roadways to provide more clearance". The final decision will be based on a proper geotechnical assessment and if in NSW gaining an exemption from the Department of Mineral Resources from the relevant part of the Regulations.

It is important to clearly record the actual intent of the risk team in the *potential controls* to avoid confusion during implementation or reviews.

Example 2.

Reconsider an alternative situation where a remote control continuous miner is driving longwall gate roads in weak roof.

No	Area	No.	Activities/ Process	No.	Hazard	C	L	R	Existing Controls	Potential Controls
1	Strata Control	1.1	Longwall retreat	1.1.1	Failure of 5.5 m wide supported Roof	1	C	**4**	▪ Support System designed for the place ▪ Support Rules ▪ Inspections ▪ Operator competence	▪ Reduce roadway width ▪ Install secondary support before longwall retreat
1	Strata Control	1.1	Gate road development	1.1.2	Crushed by C/M in 5.5 m wide roadway	1	D	**7**	▪ Safe Stand Areas defined ▪ Operator competence	▪ Install single pass C/M

In Example 2 the team identified roof fall on the Long wall retreat as the highest risk, however the mining conditions and mining method have led to a completely different outcome, substituting a standard C/M for a single pass, wide-head machine. The risk of crush in a narrower roadway is mitigated by the wide head configuration, limiting the ability of the C/M to slew during cutting.

Although the above examples are obvious they do illustrate the benefit of conducting site-specific risk assessments to sort out where the priorities lie. Again it is apparent that prescription in legislation is not equipped to determine the relative importance or severity of hazards for individual sites.

MAXIMUM REASONABLE CONSEQUENCE OF STRATA HAZARDS

From the HMS analysis of strata hazards it is apparent that the majority of hazards (82.4%) are objects falling. In an underground environment, unless the objects are small they have the ability to inflict serious injury or result in death.

Wherever the hazard relates to unsupported roof, the injury can only be a fatality because no controls are in place to regulate the size of material. Likewise in some instances, high ribs for example, the consequence must be serious injury to fatality.

The consequence of falling material can be reduced by installing hard barriers - support. By using support the size of material can be controlled somewhat so the hazard changes from "fall of unsupported roof" to "fall of roof between supports". If for example 100 x 100 mm mesh is installed than the object size can be controlled to less than the mesh size, consequently the maximum reasonable consequence may be reduced to a lost time injury. Considering the application of soft barriers to a similar example eg personnel operating remote control continuous miners are prohibited by the Regulations and Support Rules from going under unsupported roof without setting some type of support. If the operator considers that his knowledge and experience allow him to make an accurate assessment of the roof integrity, he could decide to disregard the rule and duck out to reset the miner. In this example the soft barrier is quickly rendered ineffective by factors that at that moment are beyond the control of the law or management. The maximum reasonable consequence in this case is fatality.

The preceding two examples consider different situations but the facilitator needs to be aware of the factors that influence decisions people make and risk when conducting the risk assessment to ensure that the group does not disregard or underestimate consequence on these types of issues. The hazards are situational and the group needs to give careful consideration eg the size of the falling object before determining maximum reasonable consequence. For roof fall hazards a useful means of grading hazards may be for the group to develop a guide such as the example in Table 5.

Table 5. – Example - Object size/ Injury Guide

Mass of Falling Object	Maximum Reasonable Consequence
Less than 5 Kg	lost time Injury
5 Kg to 10 Kg	serious Injury/ permanent disability
More than 10 Kg	Injury resulting in loss of life

The *Mass of Falling Objects* selected in Table 5 have been arbitrarily selected for the purpose of the example and could vary, depending upon the mining height, strata type, local geology and stress.

We therefore know that it would be inappropriate to rate the consequence of a person injured by a fall of unsupported roof as anything less than a single fatality because there is no control over the size or quantity of material falling.

In a similar manner the maximum reasonable consequence of rib fall injuries is related to the size of material that falls.

LIKELIHOOD

For qualitative risk assessments the terminology *likelihood* is preferable to probability or frequency. As previously stated there is generally an absence of adequate data for statistical assessment of probability. Furthermore people who are not familiar with probabilities will revert to qualitative descriptors to evaluate likelihood in their own minds.

Likelihood relates to the likelihood of the event. For example when assessing the hazard of roof falling on a person in a particular part of the mine, the likelihood is of a person being injured by a fall of roof and not the likelihood of the consequence of the incident.

Factors that may affect the likelihood include:

- Type of strata and support used.
- Frequency of exposure to the hazard eg. exposure to bad roof on a travelling road compared to bad roof in a waste areas.
- Location of personnel in relation to the hazard eg personnel operating equipment adjacent to the goaf compared to personnel grading an effectively supported transport road.
- Prevailing conditions in the area eg. roof, rib, goaf pressure, structures.
- Variability of the environment and presence of clear indicators eg. identification of orthogonal joint sets in a pillar split.

Considering the risk matrix, it is apparent that one cannot reduce the risk of a catastrophic consequence hazard to any less than 1 E (11) by making the event as "Practically Impossible". The only way to reduce the risk of a catastrophic consequence event further is to completely eliminate the hazard itself.

PRIORITISING ACCORDING TO RISK

The reason for prioritising according to risk is to enable allocation of resources for the development of appropriate controls to maximise early benefit.

In accordance with AS/NZS 4360 (1999), risks should be "assessed in the context of existing controls". This causes considerable confusion for some operations. It has been found as a general rule, risks should be assessed with hard barriers in place and assuming soft barriers are not in place or are ineffective. If we ignored hard barriers that are functioning effectively, we would practically be assessing the risks of mining in the last century,

and vastly over-estimating the risks. On the other hand, if we have not properly assessed the adequacy of soft barriers prior to the assessment, we may have the false belief that we are protected when we are not in reality, therefore under-estimating the risks. While competency is something we can measure and prove (or otherwise), other "soft barriers" such as adherence to procedures and supervision can be variable, and are certainly not foolproof controls. Soft barriers require constant monitoring, and a great deal of hard work to remain effective controls. Human factors are discussed in more detail later in the paper.

Therefore while some hazards may appear to be ranked a little high considering the efforts an operation is expending in controlling it, and a good track record may currently exist, this method serves to reinforce the importance of constant vigilance in this area.

RISK CONTROLS - ELIMINATE OR MITIGATE RISK

The hierarchy of controls reflects a grading from that is most effective to the least effective. *Table 6* illustrates the types of strata controls commonly identified in relation to the recognised hierarchy of controls for minimising risk.

Table 6. – Hierarchy of Strata Control Examples

Hierarchy of Controls	Strata Control Examples
1. Eliminate the hazard	Redesign of panel width to prevent full goaf caving and eliminate windblast hazard
2. Substitute alternative process/ equipment	Fixed cable handling device attached to continuous miner to replace cable hand
3. Engineering/ Isolation, including guards and barriers	Breaker Line Supports replace breaking off timber in Wongawilli extraction
4. Procedures/ administration/ training	Pillar extraction operating procedures
5. Personal Protective Equipment	Hard hat

Items 1 to 3 in Table 6can in general be considered hard barriers in that they are designed to physically separate personnel from the hazard. Item 3, isolation and guards, can also be considered in part soft barriers because they are reliant on people to ensure they are properly in place before they can provide the desired protection. Controls of this nature are usually accompanied by procedural type controls. Items 4 and 5 are soft controls because they rely on diligence to be effective.

Personal protective equipment is often the last resort for providing protection from hazards but is often used in conjunction with other higher-level controls.

Mines should take care when deciding upon the level of control that choosing procedural over the seemingly more expensive high-level controls could well result in higher overall costs. The following example demonstrates this principle:

Example 3. – Rib Control

Workings oriented sub-parallel to the major cleat in a bord and pillar operation were experiencing increasing rib spall with increasing depth of cover. Slabs up to 20 m long and 1 m thick were detaching in panels being developed for extraction. There was a cultural resistance to supporting ribs and the mine was financially constrained.

Installation of rib dowels would have placed additional financial strain on the business and the allocation of limited resources to rib bolting all headings would impinge on productivity.

The solution derived was to change the orientation of subsequent panels (a level 1 control) and adopt a rib support program based on assessment of ribs (a level 4 control). Rib dowels installed are a level 3 control. The rib support program was sustainable, resulting in mainly only pillar corners requiring support, without affecting productivity.

Mines are now realising the resources required for maintenance of work procedures. Most operations have at least one person on site, dedicated full time to managing systems and procedure documentation. In addition as well as the training costs there is the on-going commitment to involving personnel and outside experts in reviewing and updating. It makes good business sense to eliminate hazards at their source once and for all through the application of higher-level controls and to minimise the use of procedural controls.

LIMITATIONS OF THE RISK ASSESSMENT

Despite the increased popularity of risk assessments, there are areas of concern that mines and facilitators need to be aware of in their use.

The purpose of risk assessments is not to provide excuses for not being diligent in the manner in which risks are managed. Invariably a risk assessment will lead to further work, research, data collection, training or analysis or design work, but focused to reduce risk exposure in the subject area. They should never be taken as a definitive solution in isolation but an action plan based on valid assessment of the risks.

Additional limitations of risk assessments include:

- Risk Team disbanded or partially disbanded before the risk assessment controls are finalised. This applies particularly operational staff at shift change.
- Inappropriate selection of team members such that the required experience and expertise is not covered eg. topping up numbers from people on rehabilitation.
- Participants who attempt to direct the process towards preconceived outcomes.
- Failure of the group to reach consensus in determining risk due to pre-set agendas – usually management or rushing to complete.
- Poor or inadequate definition of the hazard or loss scenario.
- Tendency to underestimate consequence and cultural risk tolerance. In-house facilitators could be part of a risk tolerant culture and fail to challenge the team to consider risk from an unbiased viewpoint
- Assessment with soft barriers effectively in place can be lead to false assessment of the actual risk
- Unqualified transposing of results from one risk assessment site to another.
- Ambiguous or incorrect wording of potential controls.
- Failure to assign people to risk assessment outcomes or actions and failure of management to follow-up to ensure they are done.
- Failure to implement the agreed controls.
- Failure to review the risk assessment at some future time to confirm that the controls are effectively implemented.
- Disinterested participants don't exercise diligence during the process. Everything ends up a 3 C (13).
- Over-complication or over-simplifying the risk assessment scope. The process must be time and cost effective yet comprehensive enough to ensure important issues are properly addressed.
- Assumptions and limitations in relation to the risk assessment topic are inadequately defined.

HUMAN ELEMENT

It is important to understand that behavioural factors play a significant role in the effectiveness of the risk controls that are nominated. For example, despite legislation, rules and procedures people still get injured doing exactly the things rules were designed to prevent. It is for this reason that soft barriers should be disregarded during risk assessments and the hierarchy of controls should be closely adopted in order to achieve effective risk reduction.

Pitzer (2000) investigates risky behaviour in relation to personnel working around remote control continuous miners. In his paper he found that mine workers identified the following face-area risk in order of severity:

1. Rib spall
2. Roof fall
3. Hit by shuttle car
4. Struck by miner
5. Hit by loose rock

There was a perceived lower risk from roof fall than rib spall because of an ingrained assumption that the roof was controlled by support whereas ribs are often not, and of equipment being competently controlled by an operator whereas there was no one in control of the ribs. (Pitzer, 2000).

Another interesting finding by Pitzer was that personnel routinely enter dangerous work areas such as unsupported roof areas despite legislation and rules to the contrary. Mineworkers stated that they would enter unsupported roof areas without using temporary support to rectify equipment breakdowns or quickly reset equipment. This was often done with the full knowledge the supervisor. Risk assessment facilitators and risk management system development teams need to be aware of and understand the motivation of these foolish acts of risk taking behaviour that may be present in individuals and in some workplace cultures.

Whilst ever there is potential for risk taking behaviour to exist or be introduced mines need to place greater emphasis and insistence on hard barriers over soft controls.

Human error encompasses more than blatant disregard for rules. Mistakes, slips and lapses are also possible.

MISTAKES

Mistakes are self explanatory and result for a variety of reasons. The may occur because a person thought he was using the correct procedure, or had the correct information, and didn't. These occur because people assume they have the correct information and neglect to verify the information is correct. It may result from being supplied incorrect procedures (wrong version) or data (out-of-date or wrong purpose).

SLIPS & LAPSES

Mining people can all relate to having at some time found othemselves in a position that, had they had their wits about them we would not have happened eg. like being chased up the rib by a continuous miner boom as the operator backs it out of a lift. Even the more experienced personnel, in a place fully signposted and with which they are intimately familiar, can mistakenly find themselves in a less than desirable position.

Example 4 – OOPs I didn't realise I was under unsupported roof

This example refers to the cut flit system of mining. A senior experienced mining official proceeded to walk past the "Last Bolt" sign in a recently cut place, looked up and realised he was well inbye the last row of bolts, and warning sign. This time he escaped injury!

Following this example the "Last Bolt" signs were upgraded to a portable barricade, consisting a steel tube that screws onto the last bolt. Two hinged arms are folded down to the horizontal position to form a barricade across the roadway at chest height. On the barricade was attached "No Road" signs and a blackboard for mining officials to record inspection details.

DEVIANT VIOLATIONS

Occasionally personnel believe they know a quicker or better way of doing things and disregard the rules. Thankfully instances of this type of violation appear to be less frequent than other human errors, however a person may choose to disregard a rule, believing he is working in the interest of the mine and that this level of experience allows him to make that judgement.

CULTURAL VIOLATION

Use of external resources such as OEMs, geotech consultants and the like should be encouraged, both as team members, and specialist facilitators and scribes. This will avoid bias and vested interests compromising the results of the risk assessment, and ensure the process and results are adequately documented

Example 5 – Working Under Unsupported Roof

At a mine operating the cut and flit system of mining, personnel were told to "hog-out" and move the remote miner to perform the next cut and not to worry about cleaning the slack coal off the floor. This was some how

interpreted as management condoning the relaxation of safety standards. The slack coal left on the floor caused problems for the bolter.

Due to traction difficulties of the mobile bolter in slack coal, the bad habit developed of sending an Eimco into the unsupported place to clean the floor before bolting. The paradox of this practice is that prior to remote control miners the rule ingrained in the mine culture was that the miner would not proceed beyond the last line of supports. The Eimco operator relied entirely on one control, the roll bar-type canopy fitted to the Eimco that did not provide complete cover for the operator and had a very much lower rating than a manual miner canopy.

Although this behaviour had been identified by the risk assessment process as high risk and the principle of not going under unsupported roof had not changed, acceptance of this practice by front-line and middle management, allowed it to become ingrained in the culture of the work place.

It took an outsider to recognise the ridiculous acceptance of risk behaviour before it could change. The practice took some time of targeted education and clarification of business priorities to eliminate.

Example 6 – Re-stetting Gas Trips on Remote Control Continuous Miners

At a mine using remote control continuous miners in moderately gassy conditions, it was common for the miner power to be tripped by gas in excess of 2%. The rule in the mine had always been that "No person shall go under unsupported roof".

The practice developed whereby people, including supervisors were going under unsupported roof to press the reset button, located on the miner, to enable the power to be reset. Apparently they made a judgement that by testing the roof and making a quick dash out and back that they were reducing their risk exposure- Dumb!!!

The reality of using a remote control continuous miner in extended cuts in a moderately gassy environment, equipped with an automatic methane monitoring system set to trip power at 2% was that at some time the machine would have to be recovered from unsupported roof areas. The inherent problem with the system was that the means for resetting ie. support the roof into the miner was not part of the normal system of work and not the natural choice for personnel. Add to this the willingness of supervisors to break the rules, led to this becoming accepted practice.

Effective elimination of this practice required a fundamental redesign of the equipment provided to operators with greater control over the mining process. Firstly the operator was provided with a numerical display of gas readings that was able to be read from afar. Secondly the automatic methane monitoring system was upgraded to provide continuous monitoring via battery back-up after the mains power was disconnected and the ability to be reset from a remote location – the DCB. In addition intensive retraining and compliance auditing was conducted to ensure the practice did not continue. The area was to be supported to repair other breakdowns.

Management are not always aware of the practices which apply and which are through by workers to be acceptable to management. Many examples can be recounted in risk assessments where management's understanding of safe activities in the workplace have been shattered by comments to the contrary by face personnel. It is for this reason that it is essential to include operators in the risk assessment process and also reason for introducing outside perspectives on what is really an acceptable level of risk.

RISK MANAGEMENT SYSTEMS

NSW legislation is very focused on providing *Rules* eg. support, breakaway and brushing for face operations and specifying the manner in which the rules themselves are to be developed, implemented, monitored and reviewed. NSW does not require a hazard management system to administer these rules. Queensland legislation however requires the development of a principal hazard management plan for strata, based on risk assessment and is less prescriptive.

Despite the legal requirements, strata control management systems or plans are becoming increasingly common in NSW. With reference to appropriate standards - in particular section 4.2.2 of AS4804 the Australian Standard for Safety Management Systems, safety management systems should be based on the assessment of hazards.

Management systems are the means by which the interrelationships of the various system elements; such as rules, procedures, standards, responsibilities, authority levels, and action response procedures, combine to control risk.

At some mines the management systems are in themselves component or modules of an integrated business or safety management system established in electronic form on a server with full document management and security.

Risk management consultants often come across all encompassing and very comprehensive management system documents that despite their excellent content are cumbersome and difficult to follow. There are few people apart from management and those involved with the system development that require this level of detail in a one-stop-shop. We recommend to clients that they break the system up into digestible elements so the people required to use them can do so with ease. Administrative-type sections of the system should be removed for those that need to conduct those tasks. For example the continuous miner operator skills and knowledge requirements are completely different from those of a Shift Undermanager.

A natural hierarchy of system elements in an integrated mine safety system would place matters like document control, auditing and responsibilities database as higher level systems, applicable across all hazard management systems. Miner operators would only be concerned with support rules and support installation procedures for example. Undermanagers would be involved in training, development, monitoring and compliance auditing.

It is important to clearly define roles within the strata control management system so people take the initiative to ensure implementation to standard. To each person's role should be attached the standard to be achieved and means for that person to measure compliance to the particular standards. For example having miner operators report each shift on the sections of roadway they have developed, including width and alignment and reasons for any non-compliance. Similarly personnel installing roof supports should report on the areas supported, conditions encountered, the level and type of support installed and reasons for any non-compliance with the support standards. The mining official in charge of the panel should report on the findings during the shift and actions taken in response to matters of non-compliance. It is important to get the activities for each role and the corresponding responsibility for achieving the prescribed standard aligned. Without clear definition and logical cause and effect type structures the management system will be less than effective.

Clause 48 of NSW Regulations seeks to involve mines in a process of evidence-based design of support systems, presentation in understandable format and the training and monitoring of support systems. The principle of this regulation is consistent with sound engineering and management practice.

Strata control management systems should further develop this philosophy in accordance with the particular requirements of the mine. Geotechnical design methods and the intensity of monitoring will be very different between mines compare a cut and flit in strong strata to longwall in soft strata.

The support designs will then be developed to accommodate expected conditions for which there may be several levels of support.

A three level support regime is provided for mining below abandoned workings. Detailing the support standards for predetermined mining domains as colour coded on mine operating plans as shown in Table 7.

Table 7. – Example of Colour Coded Support Regime

DOMAIN	APPLICABLE TO	SUPPORT STANDARD
Green	Mining below xxx Seam solid coal and first workings as shown on Strata Control Domain Plan	Mains Development Green Support Standard Sub-panel Green Support Standard Mains Development Green Breakaway Standard Sub-panel Green Breakaway Standard
Amber	Mining below xxx Seam goaf areas without pillar remnants as shown on Strata Control Domain Plan	Mains Development Amber Support Standard Sub-panel Amber Support Standard Mains Development Amber Breakaway Standard Sub-panel Amber Breakaway Standard
Red	Mining in the zone of influence of the xxx Seam goaf edges as shown on Strata Control Domain Plan and pillar remnants encountered	Mains Development Red Support Standard Sub-panel Red Support Standard Mains Development Red Breakaway Standard Sub-panel Red Breakaway Standard

Having arrived at an appropriate support design based on all the evidence, including those matters identified by the risk assessment process, namely the full range of design parameters - either defined or the flagged for definition by the appropriate process, the System should then roll-out those design assumptions as triggers to identify the appropriate type of support to be used and when conditions are outside the support design criteria, i.e. "Stop Mining" and holla for the geotechnical engineer to reassess the support regime.

Personnel must be adept at verifying that the design criteria used to develop the support system, standard or rule is present in the workplace in order to install the appropriate support for that ground. And quickly recognise when the mining conditions are outside the scope of the support design.

Ensure that excuses and temptations to venture under unsupported roof areas are eliminated or tightly controlled by the system.

Obtain input from the geotechnical design engineer on the strata monitoring program

CONCLUSIONS

In conclusion the following points should be remembered:

- Legislation has enshrined risk management in how we operate.
- Risk assessment is a management tool and can be applied holistically to the business to identify the critical areas of need, including safety and with an integrated systems approach achieve greater success.
- Risk assessment does not replace sound evidence-based engineering design, but will alert engineer and managers to all the issues in risk priority order at pre-design and pre-implementation stages.
- Risk assessment has its limitations. Become proficient in its application and maximise benefits.
- Action plans are essential. Follow-up outcomes to ensure they are implemented as intended.
- Management systems must be presented in digestible chunks for those that are to use them – don't overburden people unnecessarily, teach them the bits in which they need to be proficient.
- Assign clear logical responsibility to personnel according to their ability to control process.
- Follow-up with support system monitoring, including behaviour compliance.
- Independently audit actual implementation of effective control of hazards and not just the paper trail. Be worried it you score 100%, you are probably not getting the whole story.

The philosophy of risk management is here to stay and is applicable to all areas of mining activity. Mines can maximise benefit if they embrace the concept and apply it to the whole of the business to identify the important issues and manage for greatest effect.

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