Reference Document for Preparing a Risk Assessment and Management Program of Ground Control Hazards

Workplace Safety North™

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Forward

The results of the Mining Health, Safety and Prevention Review (MHSPR) completed in early 2016 have identified falls of ground and rockbursts as the main causes of underground injuries and fatalities in Ontario's hard rock mines. As a result of the review, the Ministry of Labour, Training and Skills Development (MLTSD), formerly the Ministry of Labour (MOL), proposed new amendments to Regulation 854 to require employers to assess and manage the risk associated with hazards that may arise from the nature of the workplace, and the type of work or the conditions of work, including ground control, seismicity and rockbursting. On January 01, 2017, Sections 5.1, 5.2 and 5.3 of Regulation 854 came into force and the new provisions provide the framework for the implementation of risk assessments and management plans. This reference document is intended to assist Ontario mining operations in developing their internal programs for conducting a risk assessment, preparing a risk register of ground control hazards, and managing the risks associated with the identified hazards.

This document was prepared by ~~the~~ Workplace Safety North's (WSN's) Technical Advisory Committee in Ground Control. WSN gratefully acknowledges the contributions of all members.

WSN Ground Control Technical Advisory Committee Membership as of March 2021

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Reference Document for Preparing a Risk Assessment and Management Program of Ground Control Hazards

1. Introduction

Falls of ground and rockbursts are recognized as one of the main causes of deaths and serious incidents in underground mines. The final report of the formal review of health and safety in the Ontario Mining Sector, known as the Mining Health, Safety and Prevention Review (MHSPR), undertaken by the Ministry of Labour, Training and Skills Development (MLTSD), was conducted throughout 2014. Released in the early part of 2015 , the review included eighteen recommendations, of which two pertained to ground control. This reference document is intended to assist Ontario mining operations toward developing their internal program for risk assessment and management of ground control related hazards as an integral part of a Ground Control Management Plan (GCMP). In general, the document serves as a reference for the overall process or method of risk assessment and the preparation of a risk register of ground control related hazards, and the management of risks associated with the hazards to an acceptable level.

Workplace Safety North (WSN) and WSN's ground Control Technical Advisory Committee (GC TAC) recognize that individual companies must develop health and safety policies and programs that apply to their workplaces and comply with appropriate legislation, including a risk assessment and management program of ground control hazards. This document is intended as a reference to that process.

2. Scope of the reference document

The information contained in this reference material is distributed as a guide only to assist Ontario mining operations in developing a risk assessment and management program for ground control hazards as required under Sections 5.1, 5.2 and 5.3 of Regulation 854 (Mines and Mining Plants) that came into effect on January 01, 2017. The reference document consists of a description of risk assessment and relevant terminologies including importance and goal, when and how frequently to conduct and plan for a risk assessment, conducting risk assessment, hazards identification process, determining level of risk, risk ranking or prioritization management of hazards including control methods, and review and monitoring of the assessments for the effectiveness of the controls and associated documentation required including managing a risk register.

The document will include an example process of ground control hazard identification, risk ranking, and management of hazard and a sample risk register. It will also include sample risk register forms with varying complexities.

The intent of the document is to promote risk assessment as an inherent part of the operations and not only as a moral or legal obligation. It is not intended to replace existing standards and guidelines, including the MLTSD's guideline on 'Risk Assessment and Management for Mines and Mining Plants,' but to supplement with more complete and process-oriented information.

Risk assessments and management processes of ground control hazards are very important as they form an integral part of an occupational health and safety management plan (OHSMP), in general, and the ground control management plan (GCMP), in particular. The processes help to:

- Create awareness of ground control hazards and risks;
- Identify who may be at risk (for example, employees, cleaners, visitors, contractors, the public, etc.);
- Determine whether a control program is required for a particular ground or strata related hazard;
- Determine if existing control measures are adequate or if more should be done;
- Prevent injuries, especially when the assessment is performed at the design or planning stage;
- Prioritize ground control hazards and control measures; and
- Meet legal requirements where applicable.

The content of this reference document is generally based on the Risk Management model in the AS/NZS 4360:2004 - Risk Management as shown in **Figure 1**.

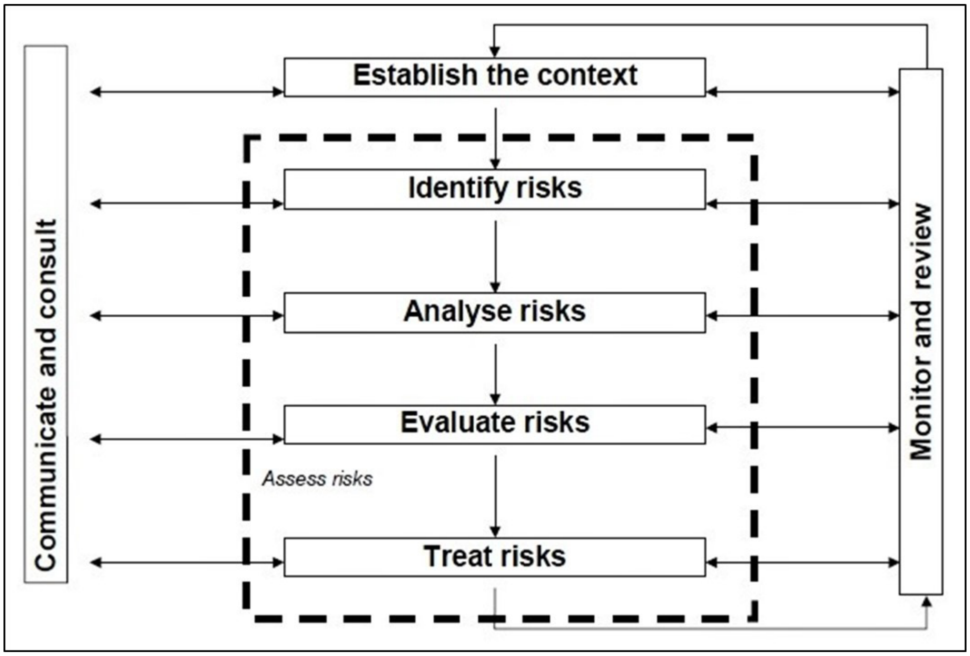


Figure 1 – Risk management process model (source: AS/NZS 4360:2004)

3. Discussion

Sections 5.1, 5.2 and 5.3 of Ontario's Regulation 854 (Mines and Mining Plants) read as follows:

5.1 (1) An employer shall conduct a risk assessment of the workplace for the purpose of identifying, assessing, and managing hazards, and potential hazards, that may expose a worker to injury or illness.

(2) A risk assessment must take into consideration the nature of the workplace, the type of work, the conditions of work at that workplace and the conditions of work common at similar workplaces.

(3) The results of an assessment must be provided, in writing, to the joint health and safety committee or the health and safety representative, if any.

(4) If no joint health and safety committee or health and safety representative is required at the workplace, the results of an assessment must be communicated to workers at the workplace and provided, in writing, to any worker at the workplace who requests them.

(5) The requirement in subsection (1) to conduct a risk assessment is in addition to any specific assessments required by the Act or any Regulation made under it.

5.2 (1) An employer shall, in consultation with the joint health and safety committee or the health and safety representative, if any, develop and maintain measures to eliminate, where practicable, or to control, where the elimination is impracticable, the hazards, and potential hazards, identified in a risk assessment conducted under subsection 5.1 (1).

(2) The measures referred to in subsection (1) shall be put in writing and shall include each of the following, as applicable and reasonable in the circumstances:

1. Substitution or reduction of a material, thing, or process.
2. Engineering controls.
3. Work practices.
4. Industrial hygiene practices.
5. Administrative controls.
6. Personal protective equipment.

(3) Personal protective equipment shall only be used as a measure if the measures referred to in paragraphs 1 to 5 of subsection (2) are not obtainable, are impracticable or do not eliminate or fully control hazards and potential hazards.

5.3 (1) The risk assessment required by section 5.1 must be reviewed as often as necessary and at least annually(2) When conducting the review, the employer shall ensure that,

(a) new hazards or new potential hazards are assessed;
(b) existing hazards or potential hazards that have changed are re-assessed; and
(c) the measures required by section 5.2 continue to effectively protect the health and safety of workers.

(3) Subsections 5.1 (3) and (4) and section 5.2 apply with necessary modifications in respect of any new hazards and potential hazards and any existing hazards or potential hazards that have changed.

WSN's Ground Control Committee obtained and reviewed several reference risk assessment and management guidelines and procedures and programs prepared by member companies. Examples of risk assessment and management procedures and programs are attached in **Appendix A** of this document. The example document was prepared for a specific risk of a 'fall of rock or loose rock while working at the face' and provided proposed methods to mitigate these risks. A program for risk assessment and management of ground control hazards can be prepared in a similar manner. **Appendix B** shows an example of risk registers for ground control and related hazards from operating underground mines. Note that they differ in content and degree of specificity based on the specific sites hazard profile, and the level of risk resulting from those hazards.

4. The goal of risk assessment for ground control hazards

The risk assessment process aims to evaluate ground control hazards, then eliminate or mitigate that hazard or minimize the level of risk by adding control measures as required. By doing so, a safer and healthier workplace is created. The goal of the risk assessment should answer the following questions:

a. What can happen and under what circumstances?
b. What are the possible consequences?
c. How likely are the possible consequences to occur?
d. What are the current controls, is the risk controlled effectively, or is further action required?

5. Risk assessment process of ground control hazards

Risk assessment of ground control related hazards is a term used to describe the overall process or method of:

- ***Ground control hazard identification*** – Identify ground control related hazards and ground control risk factors that have the potential to cause harm to personnel or damage to mine equipment, ground support systems, and/or infrastructure
- ***Risk analysis and evaluation*** – Analyze and evaluate the identified consequence associated with the ground control hazards and risk factors. Determine the seriousness of the risk and risk/hazard prioritizing or risk ranking.
- ***Risk control*** – Determine appropriate ways to eliminate the ground control hazard and risk factors or control the risk when the ground control hazard cannot be eliminated.
- ***Risk management and documentation*** – Monitor and assess the effectiveness of controls implemented to eliminate ground control hazards and risk factors. Keep records of the assessment process and control actions taken to eliminate hazards in a risk register.

A risk assessment of ground control hazards is a thorough look at the workplace to identify conditions, situations, processes, etc., that may cause harm, particularly to people. After identification is made, the likelihood and severity of the risk are analyzed and evaluated. Once the hazard has been identified, measures should be investigated and identified to effectively eliminate or control the harm from happening. An overview of the risk analysis and evaluation process for ground related hazards is shown in the flowchart in **Figure 2**.

Applicable terminologies used for risk assessment and management are described in the CSA Standard Z1002 'Occupational health and safety - Hazard identification and elimination and risk assessment and control,' the MLTSD guideline on 'Risk Assessment and Management for Mines and Mining Plants,' the AS/NZS 4360 (2004) 'Risk Management,' and the National Minerals Industry Safety and Health Risk Assessment Guideline (NMISHRAG), Version 4, January 2005.

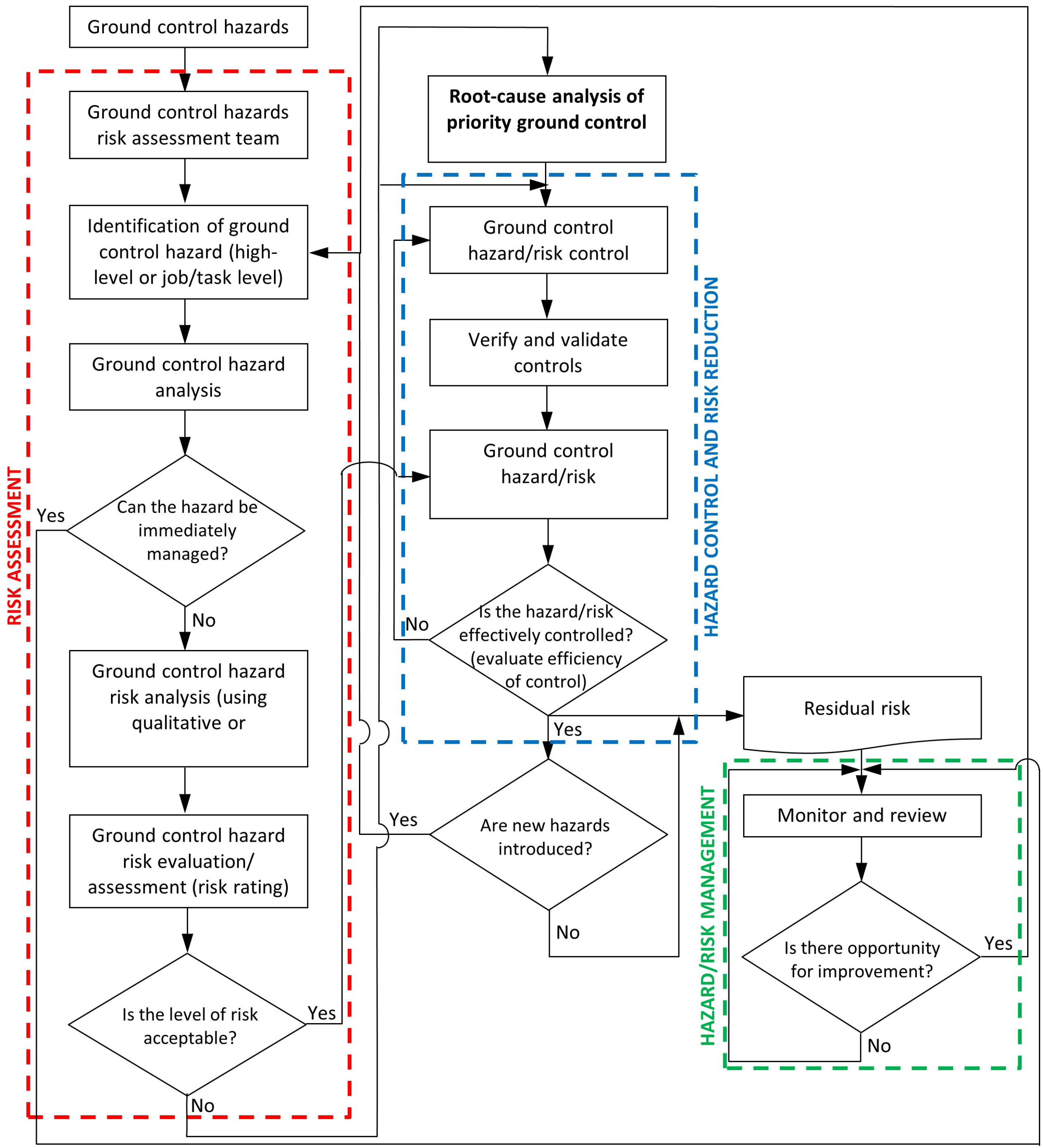


Figure 2 – Process flowchart for risk analysis and risk evaluation of ground control hazards (adapted from CSA Standard Z1002 and AS/NZ 4360)

5.1 Identifying ground control hazards and risks

A HAZARD is something that can cause harm, for example, fall of ground, chemicals, working at heights increasing potential for a fall, noise, stress, etc., while a RISK is the chance that any hazard will actually cause somebody harm. The overall goal is to find and document possible ground control hazards that may be present in the workplace. Working as a team would be beneficial and should include both people familiar with the work area, as well as people who are not – people from corporate office or from a sister company can be part of the team. In this way, both experienced and fresh eyes will conduct the inspection. In either case, the person or team should be competent to carry out the assessment and have good knowledge about the hazard being assessed, any situations that might likely occur, and protective measures appropriate to that hazard or risk. The following should be considered when identifying ground control hazards:

- Look at all aspects of the work.
- Include non-routine activities, such as maintenance, repair, or cleaning.
- Look at accident / incident / near-miss records.
- Look at the way the work is organized or done (include experience of people doing the work, systems being used, etc.).
- Look at foreseeable, unusual conditions (e.g., unusual ground conditions including unidentified geological structures, signs of changing stress conditions, ground and support interaction, ground support conditions, and other possible impact on hazard control procedures that may be unavailable in an emergency situation).
- Determine whether a product, machine or equipment can be intentionally or unintentionally changed (e.g., a safety guard that could be removed, not following procedure and increasing the exposure of personnel, machines, or equipment to unsupported ground, in conjunction with any other SOP's).
- Review all of the phases of the work cycle.
- Examine risks to other workers such as service and support crews, supervisors, engineering, geology, ground control, etc.
- Consider the groups of people that may have a different level of competence or familiarity with the hazard, such as young or inexperienced workers, etc.

Table 1 shows a simplified example of a hazard and risk inventory identified in a risk assessment process for a specific task of 'installing ground support using a mechanized bolter in high stress ground.' Other examples of ground control hazards inventories and risk registers are shown in **Appendix C**).

Table 1 – Example hazard and risk inventory identified in a risk assessment process

Task	Hazard	Risk	Risk Rating	Control
Installing ground support using a mechanized bolter in high stress ground.	Rockburst/strainburst	Major equipment damage, injury, fatality, production delays		
	Falls of ground	Major equipment damage, injury, fatality, production delays		
	Ground support failure	Major equipment damage, injury, fatality, production delays		
	Struck by an object	Injury		
	Slips, trips, and falls	Injury		
	Worker performing work in an awkward position and may have to carry heavy materials	Fatigue, injury to back from lifting, reaching, carrying, awkward posture, etc.		
	Worker often works alone	May be unable to call for help if needed		

5.2 Risk analysis and evaluation of ground control hazards and risks

Risk analysis and evaluation is a process to determine the magnitude, amount, or extent of the hazard and thus its potential consequences, as well as identification of any uncertainties about the nature of the hazard (e.g., lack of certainty about its nature, size, consequences, etc.). Risk analysis should consider the controls already in place. The process includes ranking or prioritizing ground control hazards or risks to help determine which hazard or risk is the most serious and thus which control should be implemented first. Priority is usually established by considering worker exposure and the potential for incident, injury, or illness. By ranking or prioritizing hazards or risks, an action item list is created.

5.2.1 Selecting risk analysis method – the means of calculating and examining the level of risk

There is no simple way to determine the level of risk. Several techniques can be applied in most situations. Each operation should determine which technique will work best for each situation. Ranking hazards requires the knowledge of the workplace activities, processes, and the potential for unusual situations, and most importantly, objective judgement.

Risk analysis is about developing an understanding of risk. It provides an input to decisions on whether risks need to be treated and the most appropriate and cost-effective strategies to address them. Risk analysis involves consideration of the sources of hazard or risk, their consequences, and the likelihood that these consequences may occur. As such, Risk analysis involves different ways of calculating risk considering "how often" (probability or likelihood) and consequences (or severity). There are three (3) types of risk analysis methods: qualitative, quantitative, and semi-quantitative.

5.2.1.1 Qualitative risk analysis

Qualitative analysis uses words to describe the magnitude of potential consequences and the likelihood that those consequences will occur. These scales can be adapted or adjusted to suit the circumstances and different descriptions that may be used for different risks (HB 436:2004 Risk Management Guidelines Companion to AS/NZS 4360:2004).

Qualitative risk analysis methods are used to set priority for various purposes including further analysis. They are useful when reliable data for more quantitative approaches is not available. A basic qualitative risk analysis matrix is shown in Figure 3, which are suitable for categorizing risks based on individual or team opinion.

BMA
BHP Billiton Mitsubishi Alliance

QUALITATIVE RISK MATRIX

	Consequence Severity				
Likelihood or Frequency	Low 1	Minor 2	Moderate 3	Major 4	Critical 5
Almost Certain (> 1/ week) A	High	High	Extreme	Extreme	Extreme
Likely (>1/month) B	Moderate	High	High	Extreme	Extreme
Possible (>1/ year) C	Low	Moderate	High	Extreme	Extreme
Unlikely (>1/ 10 years) D	Low	Low	Moderate	High	Extreme
Rare (>1/ 100 years) E	Low	Low	Moderate	High	High

TOLERABLE	ALARP	ALARP	INTOLERABLE

Figure 3 – Example of a basic qualitative risk analysis matrix (source: BHP Billiton Mitsubishi Alliance)

It is a very rough method of risk analysis that simply divides the identified risks into 4 categories - red, green, blue, and yellow; it does not provide any description of the difference between high, medium, or low, simply the words. It remains for the team or person(s) using this method to determine those differences. However, a description can be provided as shown in **Subsection 5.2.1.2**.

Other qualitative risk analysis methods are available which have been adapted from a version used in a number of industries.

5.2.1.2 Quantitative risk analysis

Quantitative risk analysis involves the calculation of probability, and sometimes consequences, using numerical data where the numbers are not ranked (1st, 2nd, 3rd) but rather "real numbers" (i.e., from 1 to 25 where increase in number indicates the increase in the severity of the hazard/risk). The method provides an accurate quantification of risk which offers the opportunity to be more objective and analytical than the qualitative approaches **(Figure 4)**.

Most commonly, quantification of risk involves generating a number that represents the probability of a selected outcome, such as a fatality. Other quantitative risk analysis methods are available and used in a number of industries.

RISK ASSESSMENT MATRIX RISK = LIKELIHOOD x CONSEQUENCE

LIKELIHOOD						
	5 ALMOST CERTAIN (Expected to occur - more than once per year)	5	10	15	20	25
	4 LIKELY (Will probably occur - every 1 to 5 years)	4	8	12	16	20
	3 POSSIBLE (Might occur - every 5 to 10 years)	3	6	9	12	15
	2 UNLIKELY (Could occur - every 10 to 30 years)	2	4	6	8	10
	1 RARE (May occur - once every 30+ years)	1	2	3	4	5
CONSEQUENCE		1 INSIGNIFICANT (No injury/illness)	2 MINOR (No lost time injury, but first aid treatment and/or no significant damage)	3 MODERATE (Lost time or temporary disability, serious injury or illness with medical treatment)	4 MAJOR (Lost time injury/illness or extensive injury/illness)	5 EXTREME (Fatality or permanent disability)

RISK MATRIX RESULT	RISK RATING
15 to 25	HIGH
6 to 12	MEDIUM
1 to 5	LOW

Figure 4 – Example of a quantitative risk analysis matrix

5.2.1.3 Quantitative/qualitative risk analysis

Quantitative/qualitative analysis uses both numbers and words to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

Setting priority using this method provides an accurate quantification of risk which offers the opportunity to be more objective and analytical, and categorizing risks based on individual or team opinion (**Figure 5**).

When using any method to estimate risk, the likelihood or probability should be estimated while considering existing controls in place. It will be unrealistic to consider the risk without the existing controls that have been in place for some time.

Event Risk Rating/ Priority (1)					
Consequence / Likelihood	1 Minor	2 Low	3 Medium	4 High	5 Major
5 Almost Certain	Medium (11)	Significant (16)	Significant (20)	High (23)	High (25)
4 Likely	Medium (7)	Medium (12)	Significant (17)	High (21)	High (24)
3 Possible	Low (4)	Medium (8)	Significant (13)	Significant (18)	High (22)
2 Unlikely	Low (2)	Low (5)	Medium (9)	Significant (14)	Significant (19)
1 Rare	Low (1)	Low (3)	Medium (6)	Medium (10)	Significant (15)

Figure 5 – Example of a basic quantitative/qualitative risk analysis matrix

5.2.2 Determining acceptable levels of risk

As risk analysis involves the determination of the magnitude, amount or size of the hazard and the potential consequences to provide risk ratings, and each operation should decide if the level of risks related to an identified hazard or risk are acceptable. Deciding risk acceptability involves initially determining the risk acceptance criteria. This is followed by the process of reviewing the hazard or risk, establishing the relevant risks with controls in place and deciding whether the relevant residual risks are or can be reduced to an acceptable level.

Risk acceptance criteria are the limits above which an operation will not tolerate risk associated with identified ground control hazards. These criteria must be defined for each type of risk to be assessed. Risk acceptance criteria should be established for the following types of risks:

- Personnel risk – fatality or critical injury
- Risk of property damage – equipment or infrastructure
- Economic risk – loss of production or loss of property

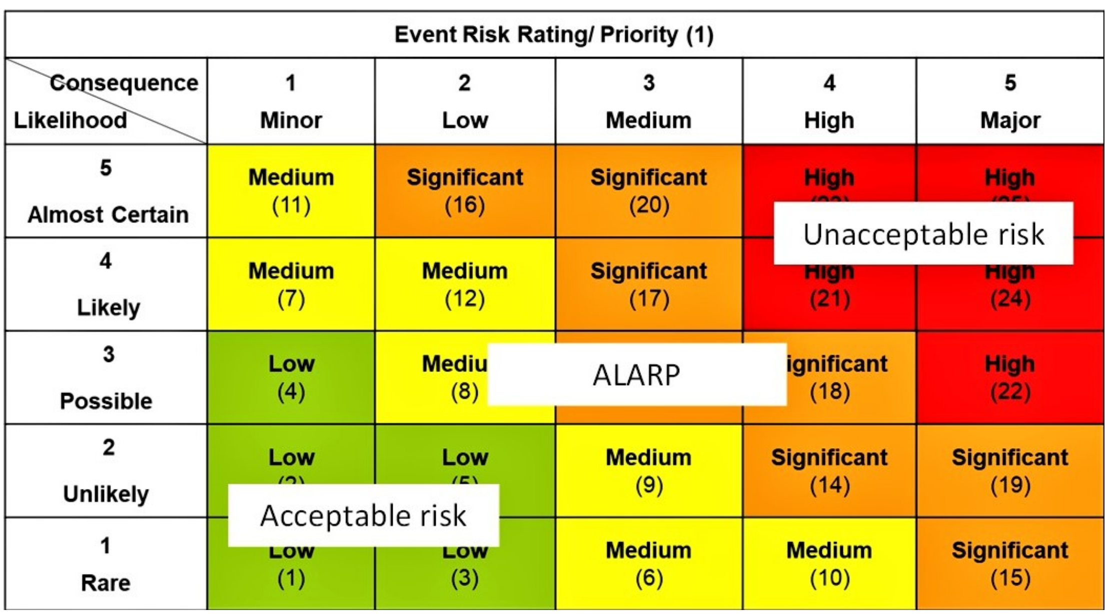
For a rational reduction of risk related to ground control hazards, such as those identified in Table 1, it is necessary to establish a risk acceptance criterion. Without a generally agreed acceptance criterion, it may not be possible to find the balance between safety in terms of risk reduction and the cost to the operation. Most importantly, in ground control, the safety level depends on the workplace condition and location, awareness and skill set of workers, and workers following safe work practices, including following prescribed procedures, and using appropriate equipment and accessories. For example, for the hazards identified in Table 1, if the location of the task is in a sensitive area, such as a high stress and structurally controlled location, then the risk class or rating could be considered to be high.

The risk acceptance criteria are also used to derive the appropriate controls, which are carried out prior to the acceptance limit being breached. This would allow either the reassessment of the risk level based on better information, a detailed evaluation of any damage, or the timely repair or replacement of the degraded component.

The acceptance criteria are defined for each of the different consequence categories. It can be based on previous experience, design requirements, workplace practices, national and provincial legislation, or corporate or operation risk tolerance. The acceptance criteria for a work cycle or function may be 'broken down' into acceptance criteria for the performance of the individual task comprising the work cycle.

5.2.2.1 The ALARP principle

The acceptance criteria with regard to personnel risk, risk of property damage, and economic risk may be represented by a risk matrix as illustrated in **Figure 6**.



Event Risk Rating/ Priority (1)					
Consequence / Likelihood	1 Minor	2 Low	3 Medium	4 High	5 Major
5 Almost Certain	Medium (11)	Significant (16)	Significant (20)	High [illegible]	High [illegible]
4 Likely	Medium (7)	Medium (12)	Significant (17)	High (21)	High (24)
3 Possible	Low (4)	Mediu (8)	[illegible]	ignificant (18)	High (22)
2 Unlikely	Low	Low	Medium (9)	Significant (14)	Significant (19)
1 Rare	Low (1)	Low (3)	Medium (6)	Medium (10)	Significant (15)

Figure 6 – Example of a risk acceptance criteria

The acceptance criteria for injuries (fatalities and critical injuries) related to ground control accidents can also be based on two principles:

- The individual injury risk, fatal or critical, shall be approximately the same as typical for other occupational hazards.
- The frequency of incidents with several fatalities, such as the societal fatality risk, shall not exceed a level defined as unconditionally unacceptable, and moreover, the general concept of managing risk to 'as low as reasonably practicable' (ALARP) shall be applied. **Figure 7** illustrates the principle of the ALARP acceptance criterion (Trbojevic 2002).

The ALARP argument is based on using cost-benefit analysis to attempt to argue that it is acceptable to reduce safety standards, and thus the cost of the controls, provided that reducing the risk has to be less costly than the consequence if an incident occurs. The use of the ALARP principle may be interpreted as satisfying a requirement to keep the risk level "as low as possible" provided that the ALARP evaluations are extensively documented. In the ALARP region (see Figure 7), the risk is tolerable, only if risk reduction is impracticable or if its cost is grossly disproportionate to the improvement gained. The common way to determine what is practicable is to use cost-benefit evaluations as a basis for the decision on whether certain risk reducing measures should be implemented. A risk may not be justified in any ordinary circumstance if it is higher than the 'upper tolerable limit.' The 'upper tolerable limit' is usually defined, whereas the 'lower tolerable limit' may sometimes be left undefined. This will not prohibit effective use of the approach, as it implies that ALARP evaluations of risk reducing measures will always be required. The ALARP principle used for risk acceptance is applicable to risks regarding personnel, the environment or workplace, and assets.

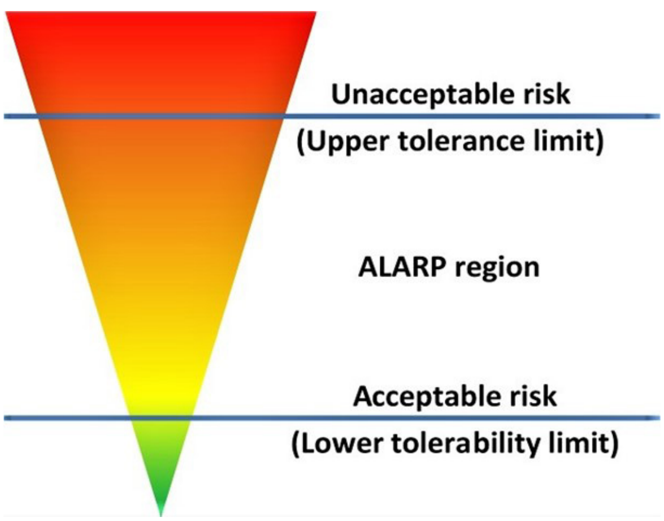


Figure 7 – Principle of the ALARP acceptance criterion (source: Trbojevic 2002)

5.3 Control measures

After priorities are established, the organization can decide on ways to control each specific hazard. Control measures may include proactive and reactive methods.

Control measures can be considered as the barriers between the inherent ground control hazards of an operation and the realization of an unwanted incident as a result of the hazards and ultimately the harm that may be caused to people, property and economy in the event of the unwanted incident. These can be identified as part of the hazard identification process. For an existing operation, a range of these measures would be readily identified: both existing measures and possible alternatives. The assessment of the effect of the measures on the hazard/outcomes needs to be determined for each hazard and outcome. The record for this can be maintained in the risk register and reviewed annually as required by the legislation, or periodically at agreed intervals.

It is important to determine the control measures that are critical to the management of the operation, particularly if there are multiple control measures. The criticality of a measure has an important bearing on the maintenance frequency, test regime and management action if the measure has to be disabled. Consider some factors that indicate a critical control measure:

- The control measure is relied on to prevent the occurrence of a number of different significant hazards.
- The control measure is relied on to prevent the most likely cause of significant incidents.
- The control measure is relied on to reduce or mitigate incidents potentially having very severe consequences.
- Other control measures that provide backup are known to be less effective.
- There is a small number of controls or barriers available for a significant hazard.

All the control measures identified through the various hazard identification processes need to be assessed as to:

- Functionality - does it control the hazard in the intended manner?
- Survivability of the measure in an incident.
- Reliability of the control, both individually and in combination with other controls.
- Position in the hierarchy of control - is the control at the least desirable end of the hierarchy or at a higher level?
- Independence and diversity - can a set of controls be disabled by a single failure mechanism or does the failure of a control disable another?

Some of the common categories of controls are discussed in **Section 3** of this document.

For all control measures, a range of performance indicators is required, particularly for those controls deemed critical. The performance indicators measure both how well the controls are performing and how well the management system is monitoring and maintaining the controls. The performance indicators for control measures will generally relate to some standards or target levels of performance. The measures may be qualitative or quantitative and may include absolute targets allowing no deviation or targets, which may have scope for limited tolerable deviation.

5.3.1 Proactive control measures

Proactive control measures can also be considered as elimination of the hazard and prevention of realization of the hazard. These include:

- Design standards
- Mine planning
- Safe operating procedures
- Inspections
- Isolation systems
- Physical barriers
- Skills and training
- Instrument monitoring of ground conditions
- Ground support
- Change management process
- Others

5.3.2 Reactive control measures

Reactive control measures can also be considered as reduction of the consequence and mitigation of the consequence. These include:

- Provision of fresh air base underground
- Emergency planning
- Permit to work
- Others

6. Risk management and documentation

6.1 Hazard/risk register development

The objective of creating a risk or hazard register is to prepare a document that lists, outlines, and prioritizes the mitigation of ground control related risks/hazards in an operation or organization. It is a document intended to communicate and monitor the current status of priority ground control risks on the site. Communication is the primary intent of the risk register. The risk register should be regularly reviewed for changes in exposure over time and possibly for better understanding of the hazards and consequences (hazard changes, method changes, etc.).

The inputs to a risk or hazard register may come from a wide variety of sources, including:

- Major hazards from risk analysis studies
- Information from accident or incident investigations or from external sources
- Information developed through Management of Change
- Health and safety hazards forms, including:
    - Incident reports
    - Hazard reports
    - Job safety analyses (JSA's)
    - Audit reports
    - Inspection reports
    - Reviews

Potential data for the hazards/risks register is developed using a risk matrix (qualitative, quantitative, or quantitative/qualitative method), which may include records of those hazards that rated as extreme, high, or moderate risks. However, low or negligible risks are expected to be recorded, tracked, and resolved by local management systems. Note that a key part of the hazard/risk register is hazard/risk tracking and close-out mechanisms. **Figure 8** shows a hazard/risk register data flow (source: NMISHRAG, Version 4, January 2005).

An important deliverable from a hazard/risk report is a critical activities list that summarizes activities required to control each identified hazard, which include:

- A listing of control measures and performance measures
- Engineering changes
- Organizational and/or procedural control
- Training and competence assurances
- Recovery measures

All activities in the hazard/risk register should be assigned to individual responsibilities with an appropriate time frame. **Table 2** shows an example of a simple risk register using an identified hazard for the task of 'installing ground support using a mechanized bolter in high stress ground.' The risk assessment was conducted using a quantitative risk analysis matrix shown in **Figure 4**. Using the principle of the ALARP acceptance criterion shown in **Figure 7**, the level of risks related to the identified hazard or risk falls under the ALARP region. In identifying and implementing a better control to prevent the hazard from occurring or to minimize the consequences if the unwanted even was to occur, the operation should refer to **Subsection 6.2.2** (Managing Control Measures) of this document to ensure proper implementation and management of controls.

Example hazard/risk register templates are shown in **Appendix C**. The example includes description of control measures.

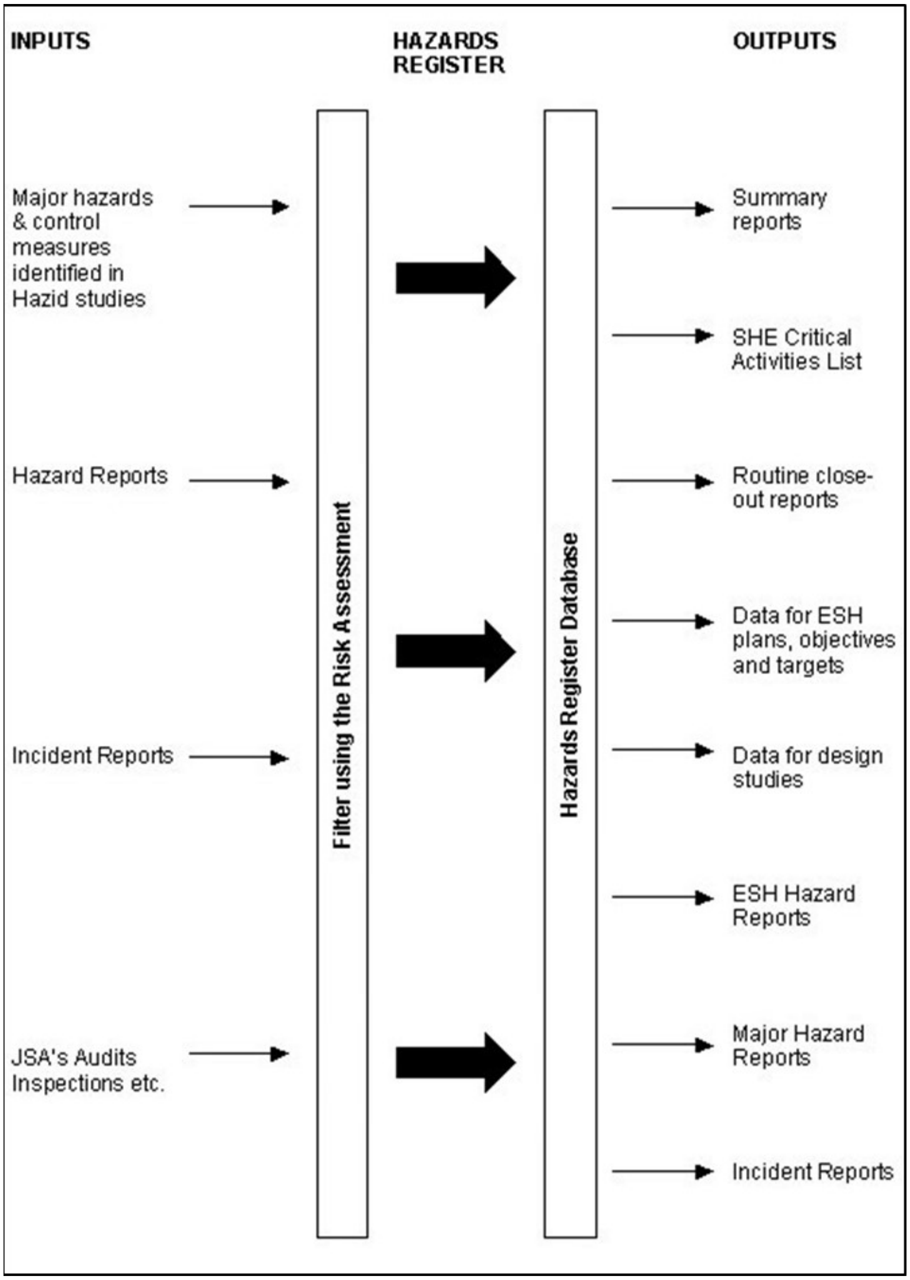


Figure 8 – Hazard/risk register data flow (source: NMISHRAG, Version 4, January 2005)

Table 2 – Example of a simplified risk register for an identified hazard and the associated risks based on a risk assessment using a quantitative risk analysis matrix

Task	Hazard	Risk	Existing Controls	Risk Analysis			Preventative Measures	Responsibility	Comp. Date
				L	C	RR			
Installing ground support using a mechanized bolter in high stress ground	Rockburst/ strainburst	Major equipment damage, injury, fatality, loss of production or production delays	• Checking driving layout or print for any ground control issues and instructions • Perform initial workplace inspection including an assessment of potential hazards • Perform equipment inspection • Ensuring ground support and accessories for the specified ground support standard are available • Using correct procedures for installing ground support • Performing check scaling as required	3	3	9	Ensure the following are performed prior to commencing work: • Check driving layout, get instruction from Supervisor as required • Workplace, equipment, and ground support and accessories inspection prior to commencing work • Follow proper procedure in ground support installation • Check scale as required	Worker Supervisor	Daily

L - Likelihood; C - Consequence; and RR - Risk Rating

Note that the Table is only provided as an example and does not reflect any input from actual mining operations.

6.2 Risk management

Subsection 5.1(1) of Regulation 854 specifies that the purpose of risk assessment is to identify, assess and manage hazards, including potential hazards. Once hazards have been identified and assessed, risk management involves the ongoing monitoring and adjustment of controls that have been adopted for mitigating the risk associated with a health and safety hazard. Some of the common categories of controls are discussed in **Section 3** of this document. Control measures are discussed in **Subsection 5.3** of this document.

6.2.1 Root-cause analysis of priority ground control hazards

Root-cause analysis of priority hazards is a pro-active way of clearly identifying the underlying reason for an unwanted event, and the mitigating controls for each hazard. Priority hazards determined through the risk ranking of all the ground control hazards that were identified during the risk assessment can be put through root-cause analysis. If a qualitative risk matrix had been used in the risk analysis and results have shown a number of priority hazards, the most acceptable methods for identifying priority hazards are as follows *(MLTSD Risk Assessment and Management for Mines and Mining Plants)*:

- Any hazard that could result in an event that has been assigned a critical level of risk should be considered to be a priority hazard.
- If no hazards that could result in events have been identified as having a critical level of risk, then those hazards that are in the top-ranking risk events (i.e., at least the top five) should be considered as priority hazards.
- Hazards that have resulted in fatalities at the mine or mining plant in the past should be considered as priority hazards.

There are several types of root-cause analyses that are available to be used and some of the common methods utilized in Ontario's mining sector are (as per *MLTSD Risk Assessment and Management for Mines and Mining Plants*):

- Bow-tie analysis;
- Failure Mode and Effects analysis;
- Fault Tree analysis;
- Fish Bone (i.e., the Ishikawa) analysis;
- Pareto analysis.

An example of a root-cause analysis of a priority hazard identified in the MLTSD's risk ranking process for the mining sector, conducted in 2014, is discussed below. The 'Fishbone' approach of root-cause analysis was conducted on a ground control priority hazard analysis with the risk statement: 'A rockburst occurs in an underground mine at a location where workers are normally present.'

The root-cause analysis was conducted by peer-recognized Subject Matter Experts (SMEs) from various mining operations (Employer), labour groups (Worker), health and safety association (HSA) and the MLTSD. Fishbone diagrams were prepared for primary, secondary, tertiary, and quaternary causal factors through an open, transparent, and collaborative process. Forty (40) causal factors (primary, secondary, tertiary, and quaternary) were identified in the 'Fishbone' analyses and were ranked and prioritized by the SMEs from the Employer and Worker groups; SMEs from HSA and MLTSD did not vote. **Figure 9** shows the 'Fishbone' diagram listing the primary causal factors. Controls were then identified for each causal factor. **Table 3** summarizes the top 10 primary causal factors and examples of controls for each factor.

Another example of a root-cause analysis using the 'Bow-tie' method conducted by an operating mine for a ground control hazard risk statement (Top Event) 'Uncontrolled ground (or strata) movement releasing stored energies resulting in multiple fatalities and infrastructure damage,' is shown in **Figure 10** (Part 1 and 2). The 'Bow-tie' analysis describes the causes and preventing controls (left side from Top Event) and the consequences and mitigating controls (right side from Top Event).

6.2.2 Managing control measures

Following a risk assessment exercise and once the ground control hazards or risks are known, and the organization had identified ways to control each specific hazard from occurring or to minimize the consequences if a serious ground control incident were to occur, the next step is to ensure that controls are effectively implemented and are performing efficiently. The International Council on Mining and Minerals (ICMM) developed the guidance document titled 'Health and Safety Critical Control Management' in 2015, which was designed to support the principle of continual improvement. The document provides practical guidance on preventing the most serious types of health and safety incidents, which can be referred to as unwanted events (UEs). The approach described in the document is called critical control management (CCM) as it provides guidance on how to identify and manage critical controls. However, the method is applicable to any control implementation intended to prevent the occurrence of a serious incident or minimize the consequences if a serious incident will occur.

The CCM program consists of nine (9) steps which include six (6) steps for planning the program and three (3) steps for implementation (ICMM 2015), as shown in **Figure 11**. The first six (6) steps follow a similar process of hazard/risk identification, risk analysis and prioritization, and control identification as described in the previous sections. It also follows the overall process of risk analysis and risk evaluation, depicted in the flowchart for ground control hazards shown in **Figure 2**.

This section discusses the implementation and management of controls as applied to ground control hazards, including critical controls, if defined. **Table 4** summarizes the steps and target outcomes for accountability, and control implementations and management process, as adopted from the ICMM guide document.

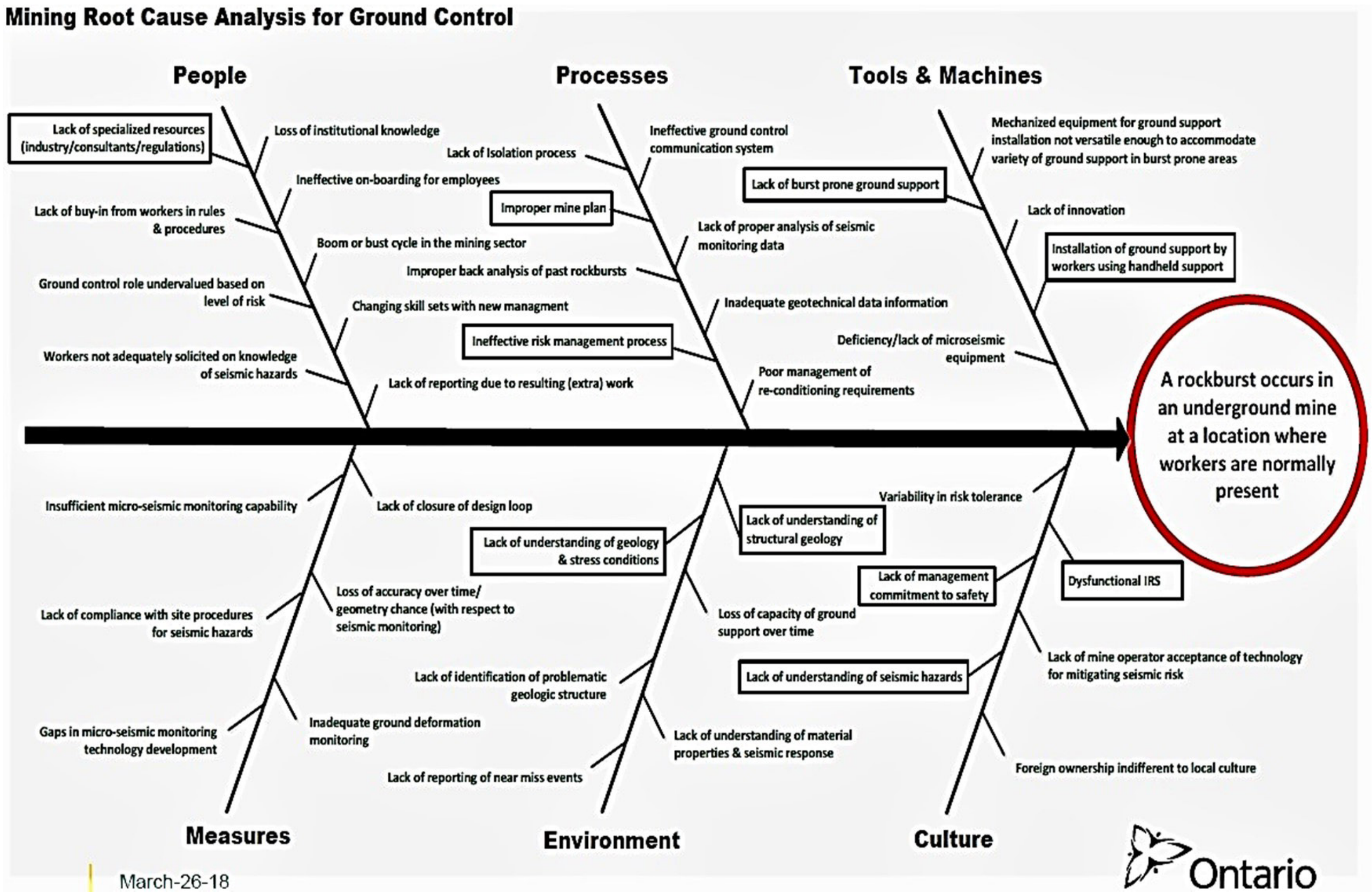


Figure 9 – 'Fishbone' diagram for the primary causal factors (Source: MLTSD)

Table 3 – Top 10 primary causal factors and example of controls

No.	Top 10 Primary Causal Factors	Examples of Controls for Each Causal Factor
1.	Lack of burst-prone ground support	• Improve Cost effectiveness, efficiency • Excavation design for potential installation of burst-prone support
2.	Lack of understanding of geology and stress conditions	• Optimize use of diamond drill information (analysis of borehole breakouts using Acoustic televiewer) • Increased use of cutting-edge technology, but due diligence required before use. Currently using mechanical engineering software (finite element software)
3.	Lack of management commitment to safety	• Define seismic risk management plan in corporate health and safety policy • Formal audits and reviews to ensure operational execution is aligned with corporate expectations
4.	Ineffective risk management process	• Educate and involve all workplace parties in the power of risk assessment and management • Report near-miss data to incorporate into risk assessment analysis
5.	Improper mine plan	• Pre-mine geomechanical/stability analysis • Deliberate effort to get strategic geotechnical information as early as possible
6.	Lack of understanding of seismic hazards	• Educate on and keep workplace parties aware of seismic hazards • Ensure conversation at the face (muck-pile discussion)
7.	Dysfunctional IRS	• Clear definition of IRS • Management commitment to IRS
8.	Lack of understanding of seismic hazards	• Proper blasting controls • Scaling before installing ground support
9.	Lack of understanding of structural geology	• Having processes to collect geotechnical information (geophysics: Acoustical Televiewer (ATV), Optical Televiewer (OTV), diamond drilling, mapping) • Better classification of structures/faults with regards to seismic risk
10.	Lack of specialized resources (industry/ consultants/regulators)	• Better collaboration with universities, colleges, and industry toward providing programs that have better emphasis on geology and ground control • Setting up an environment for better collaboration between geology and mining programs

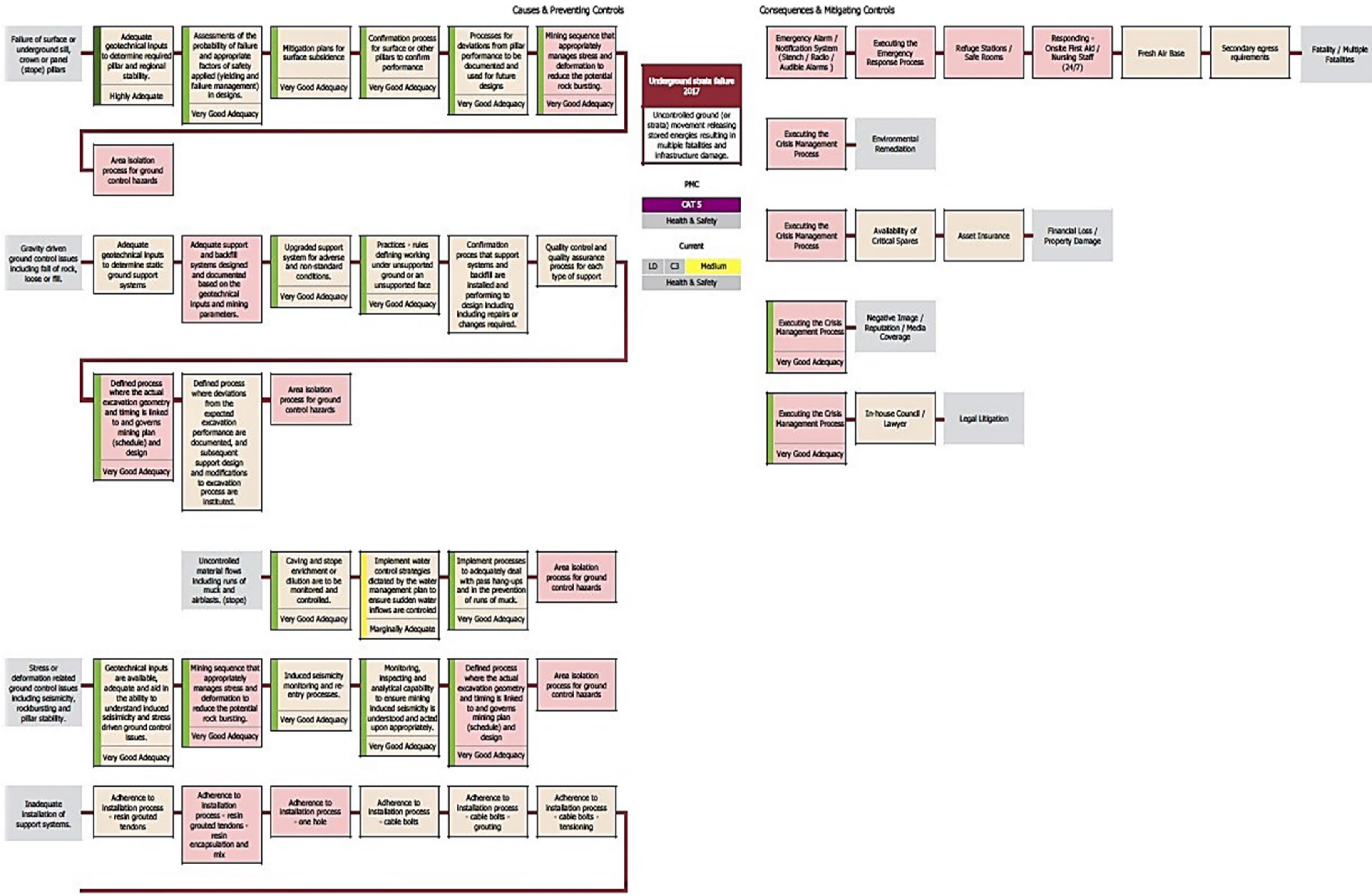


Figure 10 – 'Bow-tie' analysis describing the causes and preventing controls (left side from Top Event) and the consequences and mitigating controls (right side from Top Event) of a Top Event (Part 1)

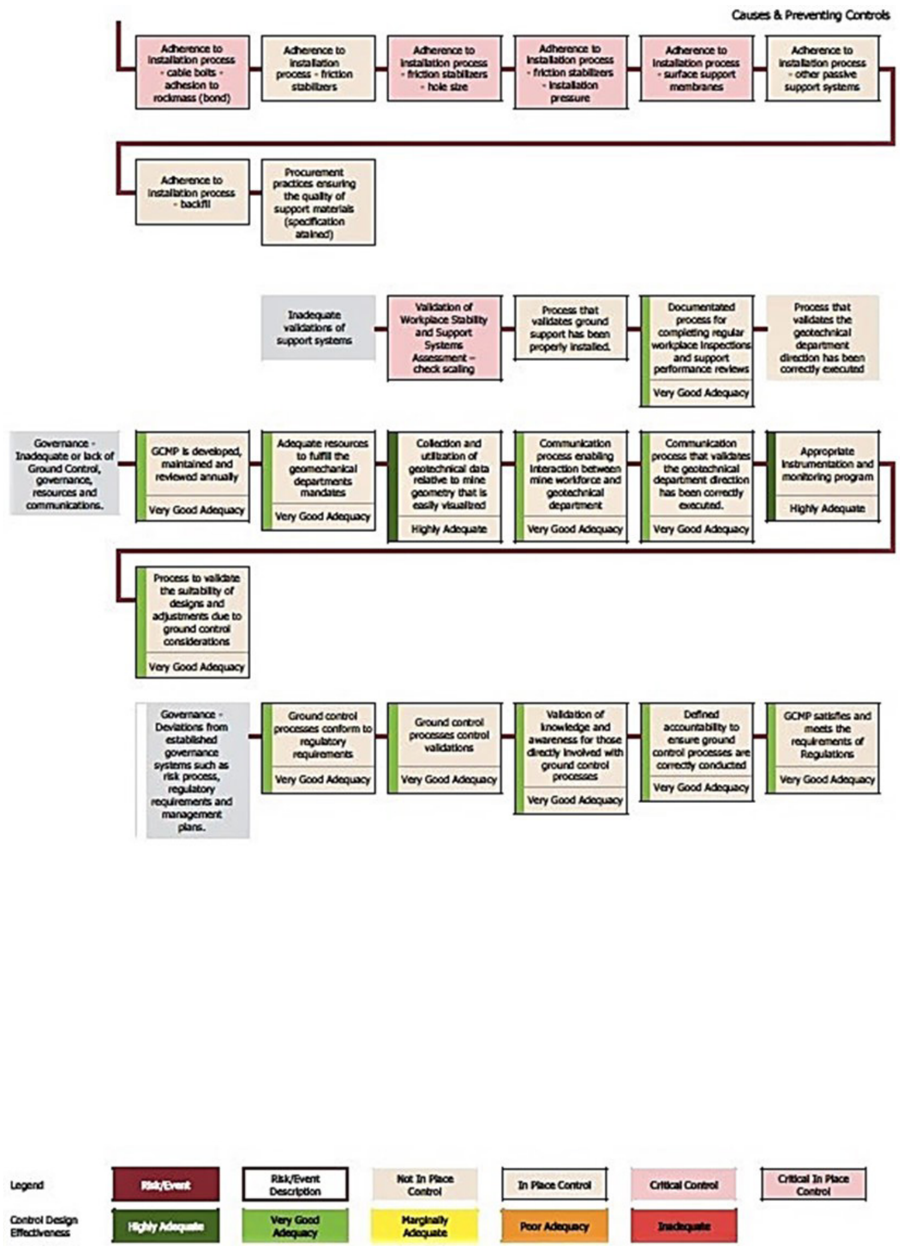


Figure 10 – ‘Bow-tie’ analysis describing the causes and preventing controls (left side from Top Event) and the consequences and mitigating controls (right side from Top Event) of a Top Event (Part 2)

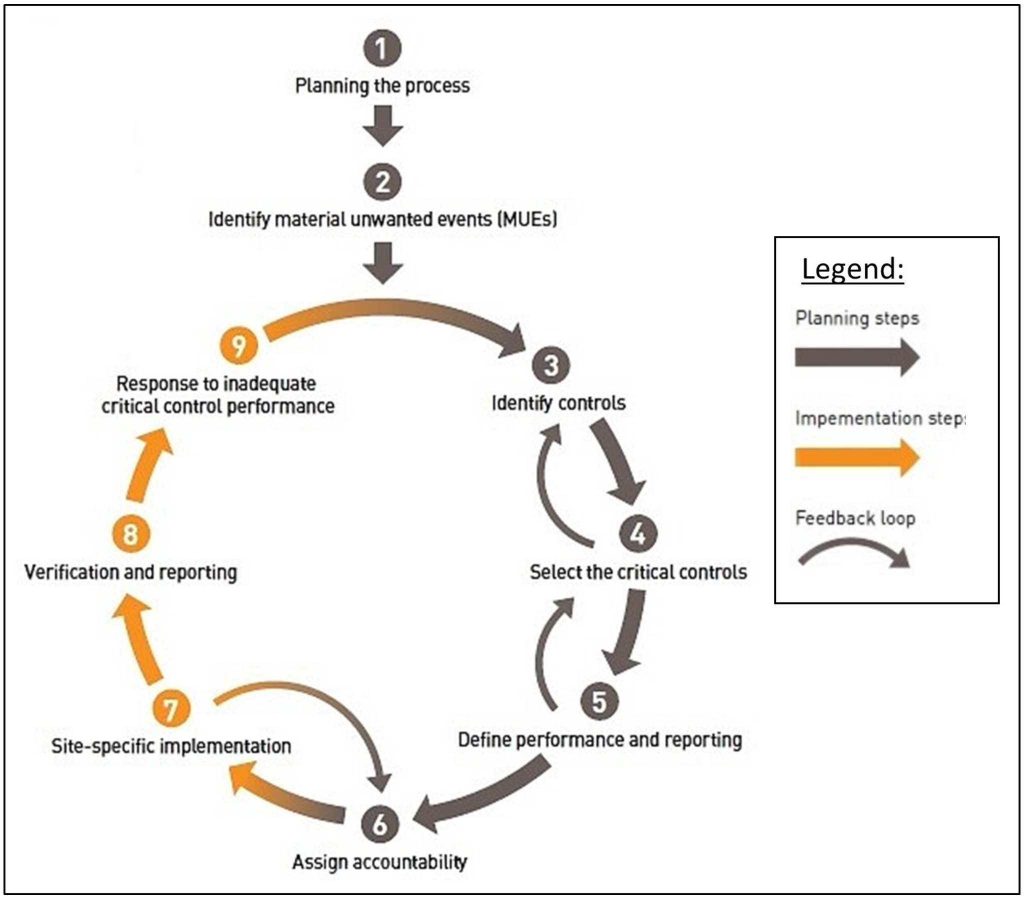


Figure 11 – The critical control management process (Source: ICMM 2015)

Table 4 – Target outcome for each step of the implementation and management process of controls for ground control hazards (adapted from ICMM 2015)

STEP	TARGET OUTCOME
Assigning accountability (Step 6 in **Figure 11**)	A list of individuals who will be responsible and accountable for the implementation of controls for each of the identified ground control hazards/risks and verification of activity. A verification and reporting plan is required to verify and report on the efficacy of each control.
Implementation (Step 7 in **Figure 11**)	Defined implementation strategy of controls for each ground control hazard/risk, verification process, and reporting plan.
Verification and reporting (Step 8 in **Figure 11**)	Implement verification activities and report on the process. Define and report on the status of each control.
Response to inadequate control performance (Step 9 in **Figure 11**)	Awareness of individuals who are responsible and accountable on the performance of controls. If controls are underperforming or following an incident (if an incident occurred despite the implementation of the control), investigate, and take action to improve performance or identify other controls.

6.2.2.1 Assigning accountability

To ensure ground control hazards are being managed, the controls must be performing effectively. Assign individuals within the operation to be responsible and accountable to ensure that control strategies are implemented to prevent the hazard from causing an incident or to minimize the consequence if the hazard were to occur. These individuals must also be responsible for ensuring hazards are being managed, documented, and communicated. Those accountable are required to monitor through verification activities on the effectiveness of the controls. This can be described in a verification and reporting plan as summarized in **Table 5**.

Table 5 – Example of control verification and reporting plan for a ground control hazard (adapted from ICMM 2015)

HAZARD Rockburst/strainburst	**CONTROL** Performing initial workplace inspection including an assessment of potential hazards	**VERIFICATION ACTIVITY** Review worker safety card and field level risk assessment; discuss hazard identified by worker
HAZARD OWNER Ground control personnel, First-line supervisor, Worker	**CONTROL OWNER** First-line supervisor, Worker	**VERIFICATION ACTIVITY OWNER** First-line supervisor, Worker
ROLE OF HAZARD OWNER *Ground control personnel:* • Review ground control logbook, seismic monitoring data (if equipped) • Decide on required action • Set expectation *First-line supervisor:* • Communicate with cross-shift • Review ground control and shift logbook, seismic monitoring data (if equipped) • Communicate and discuss required action with worker *Worker:* • Review driving layout • Communicate and discuss required action with supervisor	**ROLE OF CONTROL OWNER** *First-line supervisor:* • Communicate and discuss implementation of control with worker • Verify that control is implemented by worker • Report to ground control personnel *Worker:* • Communicate and discuss implementation of control with supervisor • Implement control • Manage control to ensure efficiency	**ROLE OF VERIFICATION ACTIVITY OWNER** *First-line supervisor:* • Conduct, gather and review field level-based verification activity requirements and compare to expectations • Initiate actions as required • Provide verification summary ground control personnel *Worker:* • Verify efficiency of control and provide verification summary to supervisor

6.2.2.2 Implementation

As part of the control implementation process, control strategies determined to prevent the occurrence or minimize the consequence if an incident occurs for a certain ground control hazard requires the review of the risk assessment process to ensure that they are appropriate and practicable for the identified hazard. Planning for the implementation of controls is an iterative process to ensure appropriateness and practicability as indicated by the feedback loop shown in **Figure 2** and **Figure 11**. The implementation of controls should include leadership, accountabilities, a communications strategy, implementation standards and developing knowledge and understanding of the performance of controls.

6.2.2.3 Verification and reporting

The information regarding the performance of each control will be gathered and reported at a defined frequency. This information flow should be designed to efficiently communicate variances between expected and actual control performance. The threshold of unacceptable control performance can be defined based on the operation's acceptable level of risk, as discussed in **Subsection 5.2.2** (Determining acceptable level of risk). Questionable or substandard performance of controls for hazards with a residual risk above the acceptable level of risk should trigger action, which might vary from re-assessment of control strategy to ordering immediate stop of the relevant work processes.

6.2.2.4 Response to inadequate control performance

Underperforming or a failure of controls to either prevent an incident from occurring or minimize the consequence if an incident occurs for a certain ground control hazard requires investigation to understand the cause to allow the continuous improvement of controls. The absence of accidents or incidents must not be taken as evidence that controls are working adequately. It is common to implement more than one control for a specific hazard; a control may fail without any incident occurring because of redundancy in the controls. As a result, the verification process is important to detect controls that are not performing according to the specified requirements.

The failure of a control detected following an incident could result due to a potential hazard or at-risk situation (usually associated with a human action/error), a failure of other redundant controls, or an event that could cause serious harm or that has the potential to cause serious harm. In most cases, root-cause analysis is conducted to understand why a control failed.

A review the current site incident investigation methods is necessary to ensure that the investigation process includes identification of relevant controls, understanding of their status at the time of the event and their relation to the control failure. Incident investigation as a result of a control failure may require a review of the risk assessment process relating it back to its previously documented objectives and performance requirements, including the determination or design of control.

The intent of the investigation of control failures and subsequent control review process is to establish required improvements or changes related to the control, including modification of performance requirements and the verification activities, or even replacement of the identified control with another control. It provides important lessons learned for continuous improvement of the hazard/risk control management process. The control failure investigation and review may require looping back through the risk assessment process in a number of iterations to determine the appropriate control that could prevent an incident from occurring or reduce the consequence if an incident occurs.

An example set of questions for reviewing control design, selection and management after an incident that is applicable for management of controls, adapted from BHP Billiton information, is summarized below.

For the inadequate performance of the control in an incident:

1. What controls failed?
2. How did the control fail or perform inadequately?
3. What were the causes of the failure or inadequate performance of the critical control? In order to determine the cause, it can be helpful to use the '5 Whys' root-cause analysis tool.

Based on the answers to the third question, the following sample control questions might also be helpful:

a. Was the control designed to operate in the incident situation?
b. Was the description of the control performance requirements adequate?
c. Did the defined control performance requirements include the management activities that are required to ensure its function in the circumstances of the incident?
d. Did the owners and operators of the control understand its objective, design, and operation (i.e., are they suitably trained and/or experienced)?
e. Was the appropriate control documentation available to all relevant control operators?
f. Did the verification activities check the status of the control in a manner that could have avoided the incident?
g. Did the verification reporting system communicate critical control status prior to the incident to initiate required action and to prevent the incident?

6.2.2.5 Measuring impact of control initiative for ground control hazard/risk

Methods to measure the degree to which control initiatives for ground related hazards are functioning as expected can be based on both lagging and leading indicators. Lagging indicators are based on incident statistics that could be the frequency of those major events and, possibly, the resulting consequences. A more effective lagging indicator may be found in the frequency of incidents related to the ground control hazards. Frequency trends of incidents pre- and post-control implementation can be captured and compared.

Leading indicators on the other hand can be found in reports from control verification activities. Verification reports contain information summarizing the performance status of the control versus defined expectations. Well-defined and well-executed verification activities could yield control efficiency in a quantified format (either in percentage or scale format). **Figure 12** shows an example of basic time lagging and leading indicators for two (2) selected controls specified in **Table 2** (Checking driving layout or print for any ground control issues and instructions; and Performing initial workplace inspection including an assessment of potential hazards) to prevent the occurrence of a hazard (rockburst/strainburst) or minimize the consequence if an incident occurs. Note that the data used in the graph are assumed values of lagging and leading indicators.

The performance indicator shows a continuous improvement of controls over time resulting in the decrease in injury associated to the type of hazard being managed.

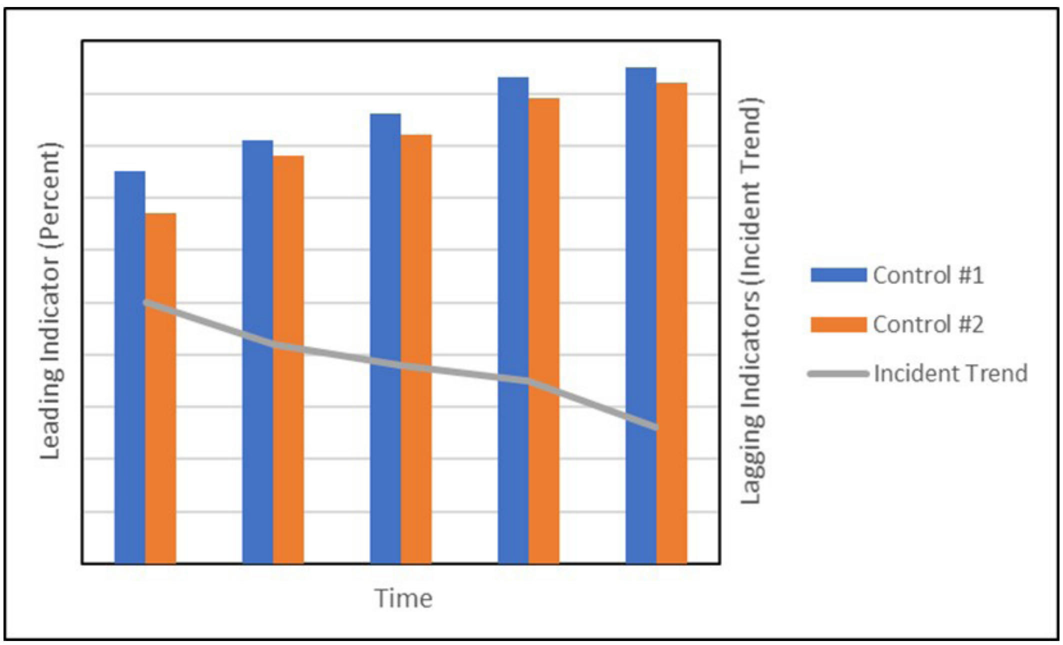


Figure 12 - Example lagging and leading indicators for two (2) controls related to a rockburst/strainburst hazard

Figure 13 illustrates a guide from the United Kingdom Health and Safety Executive (UK HSE), 2006, on 'Developing process safety indicators' focusing on "risk control system" that can be adapted for **Subsection 6.2.2** (Managing control measures).

The guide document recommends regular review of the entire risk assessment and management process and system in order to identify the degree to which the initiative is being implemented and operated to expectations.

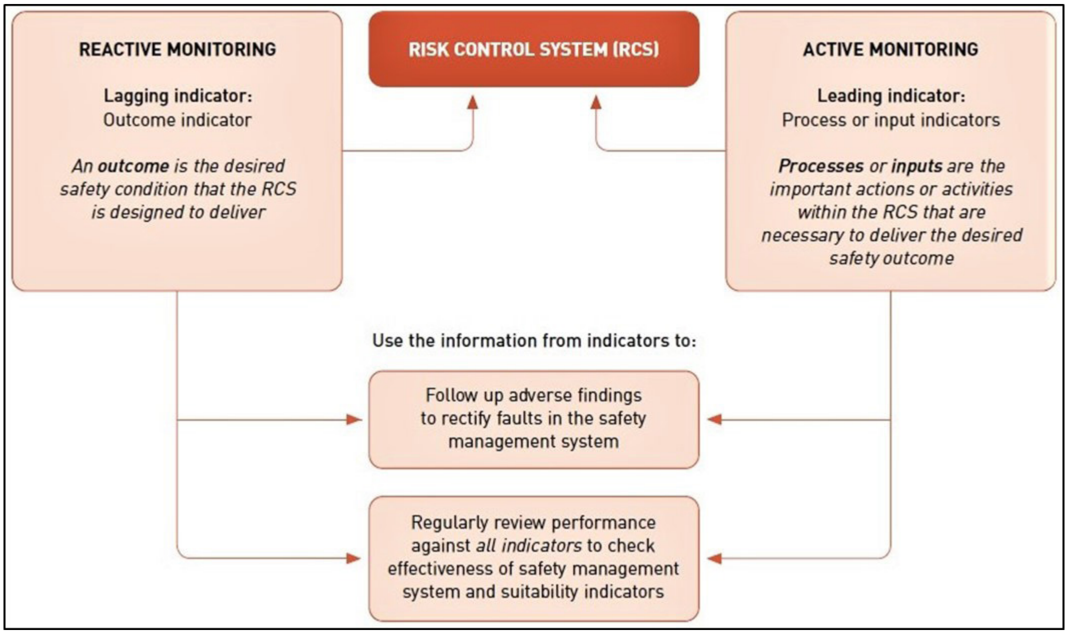


Figure 13 – Illustration of 'Dual assurance - leading and lagging indicators measuring performance of each control system' (source: UK HSE, 2006)

6.3 Documenting the risk assessment process and deliverables

A formal risk assessment should be documented for many reasons, including the need for future reference. The specific format will vary depending on the complexity and purpose of the assessment. As a minimum, it is necessary to use a logical approach to the risk assessment report, which may include the following suggested contents:

- Executive Summary
- Introduction
  - Context (strategic, corporate and risk management)
  - Issues / Reason for review
- Objective
- Method
  - Team (names, positions, and related experience)
  - Hazard inventory table
  - External potential impacts
  - System description and boundaries
  - Risk identification tool
  - Risk analysis method

    - Determination of acceptability
- Documentation used for study
- Results (tables, charts, etc.)
    - Risk registerPriority risks
    - Priority existing controls and performance indicators
    - Priority new controls and performance indicators
- Recommended action (the action plan information), including accountabilities and timelines

Note that there is more guidance on report content in the CSA Standard Z1002 'Occupational health and safety - Hazard identification and elimination and risk assessment and control', the MLTSD guideline, 'Risk Assessment and Management for Mines and Mining Plants,' the AS/NZS 4360 (2004) 'Risk Management', and the National Minerals Industry Safety and Health Risk Assessment Guideline (NMISHRAG), Version 4, January 2005, including the New South Wales (NSW) Department of Mineral Resources MDG 1010 and 1014.

Table 6 provides suggested information to be considered for the development of a risk assessment and management program. Individual operations may choose to omit unnecessary elements or include additional items in order to tailor the mine design to their particular requirements.

The final report should be stored in a manner that facilitates retrieval and review as required by legislation or periodically at agreed-upon intervals.

Table 6 – Suggested information for the development of a risk assessment and management program.

APPROVALS	This page contains signatures, titles, and dates for all personnel responsible for approving the risk assessment and management document.
REVISIONS	This page identifies the date of revision release, and a brief itemized description of the information that has been modified in the new version.
EXECUTIVE SUMMARY	This section provides brief statements of purpose and scope of the analysis, assessment steps and whether this is an initial or subsequent risk assessment, as well as a brief summary of the findings and overall level of risk.
INTRODUCTION	This section provides general information concerning the mine (location, history, etc.). Changes made to the risk assessment and management document since the last annual revision should be outlined.
RESPONSIBILITIES IN RISK ASSESSMENT AND MANAGEMENT OF GROUND CONTROL HAZARDS	This section outlines specific responsibilities, accountabilities and required competencies of workers, first-line supervisors, ground control personnel, other engineering and geology personnel, upper management, and external consultants in the risk assessment and management program.
OBJECTIVE	This section outlines the intent of the program to comply with pertinent sections of Regulation 854 (Sections 5.1, 5.2, and 5.3). It may include brief information on the assessment process of evaluating workplace ground control hazards including risk ranking; considerations to control workplace ground control hazards to remove the hazards or minimize the level of risks; appropriate workplace parties involved in the required risk assessment and management processes; and frequency of carrying out risk assessments.
METHODS	This section provides information on the following: Risk assessment team (names, positions, and related experience); Hazard inventory table used; External potential impacts; System description and boundaries; Risk identification tool; Risk Analysis method; Determination of risk acceptability; and others.
DOCUMENTATION/ RISK ASSESSMENT RESULTS	This section outlines the process of documentation used for the assessment and observations. This section should include a risk register, priority risks, priority existing controls and performance indicators, as well as priority new controls and performance indicators.
RECOMMENDED ACTION INCLUDING ACCOUNTABILITIES AND TIMELINE	This section outlines the recommendations to reduce the level of risk to acceptable level, especially for the priority hazards/risks, specifying who will be responsible and accountable to ensure that recommended controls are implemented, completed, and evaluated within a given timeframe.
COMMUNICATION	This section outlines the process for the timely communication of the risk assessment results.

Appendix A: Example of a risk assessment and management procedure

Risk Analysis for:

Risk of Working at Face.

REPORT

Prepared by:

Executive Summary

This report provides the analysis of the risks of a "fall of rock or loose while working at the face at [redacted] and proposed methods to mitigate these risks.

This analysis was done using a benchmark and brainstorming methodology where the present method and several alternate methods were ranked using the [redacted] risk matrix. The results of this assessment can be found in the appendices and body of this report. A number of solutions were selected for testing to reduce the risk of exposure to fall of muck at the face.

The development of the process flow sheet and where the history of incidents occurs in the process helped to focus the group on the following actions:

1. Test the use of split set ground support in the face- (in consultation with Ground control determine optimum pattern)
2. Develop changes to the procedure to install face ground support – need to answer the following:
    - 2.1. Is the support to be installed prior to drilling the round/slash?
    - 2.2. Is the support to be installed after drilling the round/slash?
3. Test the use of lifter tubes to reduce the exposure at the face when clearing lifter holes after drilling.
4. Change loading SOP to ensure only 1 person loads at a time so that boom is never over second worker.

Seventy-five (75) percent of all injuries to workers at [redacted] happened during or after the drilling phase of the process and the controls proposed should minimize the exposure to the hazard. Overall, the introduction of bolting at the face, using lifter tubes and changing the loading SOP, should reduce the exposure of workers at the face resulting in a residual ranking of 5 minor for this risk.

1. Introduction and Background Information

[redacted] is strongly committed towards Sustainable Development (SD). The corporation has defined 17 standards that state the management expectations regarding SD. Risk management is one of the SD standards. Each site is expected to identify the risks that it is exposed to. As risks are identified, they are accessed using the [redacted] risk matrix to quantify the exposure with and without controls. See definitions for details. Depending on the ranking, the operations will then determine if further actions/controls are required to reduce the risk to "As low as reasonably practicable" (ALARP).

This study was mandated by [redacted], Superintendent – Development and Rehab at [redacted] A charter can be found in Appendix 1.

The goals of the study were to:

- Assess the present risks and rank the health effect/injury.
- Brainstorm options to reduce the risk.
- Identify any new recommendations/actions to reduce risk.

The risk assessment was conducted at the [redacted] on August 15, 2012.

This specific scenario of loose or fall of ground while working at the face is a part of the catastrophic hazard for "uncontrolled ground movement" and would be a sub element of this overriding risk.

2. Methodology and Definitions

2.1. Brainstorming Methodology

For the purposes of this study, a brainstorming methodology was used.

<u>Overview</u>

- The risk was defined as any fall of ground from the working face of a drift.
- The history of incidents and injuries over the last eight years was reviewed in the context of where in the work cycle the injuries/incidents have occurred.
- The risk was ranked with the present controls.
- Experienced personnel brainstormed a series of options to reduce the exposure to the risk.
- The risk was ranked with the proposed controls.

2.2. Definitions

For the study, we used the [redacted] Assessment matrix (below) to rank the risks on the health effect/injury category.

[redacted] Risk Assessment Matrix

LIKELIHOOD						
Certain (>1 event per year)	E	[11] Reportable	[16] Reportable	[20] Significant	[23] Significant	[25] Significant
Likely (1 event per year)	D	[7] Reportable	[12] Reportable	[17] Significant	[21] Significant	[24] Significant
Possible (1 event every 2 to 5 years)	C	[4] Minor	[8] Reportable	[13] Reportable	[18] Significant	[22] Significant
Unlikely (1 event every 5 to 20 years)	B	[2] Minor	[5] Minor	[9] Reportable	[14] Reportable	[19] Significant
Rare (<1 event every 20 years)	A	[1] Minor	[3] Minor	[6] Reportable	[10] Reportable	[15] Reportable
RISK CATEGORY or CONSEQUNCE RATING		IMPACT				
		Negligible	*Minor*	*Moderate*	*Serious*	*Disastrous*
		Category 1	Category 2	Category 3	Category 4	Category 5
Health & Safety		- Injury or health (reversible) effects requiring first aid and medical treatment	- Injury or health (reversible) effects resulting in 5 or less disabling injury days	- Injury (reversible) effects resulting in more than 5 disabling injury days - Health effects resulting in an occupational	- Single fatality - Permanent (irreversible) disabling injury or health effects to 1 or more persons	- Multiple fatalities - Permanent disabling (irreversible) injury or health effects to 10 or more persons
Environment		- Negligible reversible impact with very minor or no remediation	- Minor reversible impact with minor remediation	- Moderate reversible impact with short term effect requiring moderate remediation	- Serious impact with medium term effect requiring significant remediation	- Disastrous impact with long term effect requiring major remediation
Community/ Reputation		- No media coverage - No community complaints	- Local media coverage - Complaint to site and/or regulator	-Local media coverage over several days -Negative impact on local economy. - Persistent community complaints	- National media coverage over several days - Significant negative impact on share price for weeks - Community / NGO legal actions - Impact on local economy	- Prominent negative International media coverage over several days - Significant negative impact on share price for months
Legal and Compliance		-Minor legal issues - Non-compliances and breaches of regulation	- Breach of regulation with investigation or report to authority with prosecution and/or moderate fine possible	- Major breach of regulation with punitive fine - Significant litigation involving many weeks of senior management time.	- Major litigation costing >$10m; - Investigation by regulatory body resulting in long term interruption to operations; and - Possibility of custodial sentence	- Major litigation or prosecution with damages of >$50m - Custodial sentence for Company Executive - Prolonged closure of operations by authorities
Investment Return US$ NPV (+ or –)		<$600k	>$600k	>$6m	>$60m	>$600m
Property Damage US$ LOSS		<$10k	>$10k	>$200k	>$2m	>$20m
Financial Impact US$ EBIT (+ OR -)		<$200k	>$200k	>$2m	>$20m	>$100m
					HIGH HAZARD ACTIVITY	CATASTROPHIC HAZARD

Likelihood Table

Category		Likelihood Criteria
CERTAIN		• 99% probability, or • consequence is occurring now, or • could occur within months
LIKELY		• 50% and < 99% probability, or • balance of probability will occur, or • could occur annually
POSSIBLE		• 20% and < 50% probability, or • may occur shortly but a distinct probability it will not, or • could occur in 2 to 5 years
UNLIKELY		• 1% and < 20% probability, or • may occur but not anticipated, or • could occur within 5 to 20 years
RARE		• < 1% probability • occurrence requires exceptional circumstances • exceptionally unlikely, even in the long-term future • occurs less than once every 20 years

3. Workshop Sessions

The workshop was held on August 15, 2012 with the following participants:

Name	Title	Company
[redacted]	SD and Risk Coordinator	[redacted]
[redacted]	Senior Ground Control Engineer	[redacted]
[redacted]	Drill and Blast Superintendent	[redacted]
[redacted]	Development and Rehab Superintendent	[redacted]
[redacted]	Jumbo Driller	[redacted]
[redacted]	Development Supervisor	[redacted]
[redacted]	Best Practice Mentor	[redacted]
[redacted]	Worker Certified Representative	[redacted]
[redacted]	EIT	[redacted]

3.1. Present Risk Ranking

The inherent risk was ranked as a Category 4 (Single fatality – Permanent (irreversible) disabling injury or health effects to 1 or more persons) with a likelihood of Possible (20% and < 50% probability or may occur shortly but a distinct probability it won't, or could occur in 2 to 5 years) this would result in a Ranking of [18] Significant. The residual risk ranking, using the list of controls on the following page and the "Development cycle flow sheet" found in Appendix 3, was ranked as a [13] Reportable with the likelihood staying the same but the impact dropping mostly due to the scaling that is done to control the risk.

3.2. Controls

Coding	Title
[redacted]	Fall Protection Program
[redacted]	Standard – Fall Protection
[redacted]	Mechanical Scaling
[redacted]	Line and Grade Procedure
[redacted]	Scaling from the Ground of Muckpile Procedure
[redacted]	Face Preparation Procedure
[redacted]	Jumbo Operation Procedure
[redacted]	Working Near Rotating Jumbo Drill Steel Procedure
[redacted]	Blasting with i-kon Detonators Procedure
[redacted]	Ground Stability Assessment Standard Work Instruction
[redacted]	Mine Geotechnical Design Document
[redacted]	Ground Support Guidelines
[redacted]	Blasting Procedure
[redacted]	Loading a Face Procedure
[redacted]	Underground Geological Mapping Procedure

3.3. Benchmarking

A simple benchmark exercise was completed looking at [redacted] versus several other sites as shown below. [redacted] brought forward several options which were discussed and brainstormed with several other items being added.

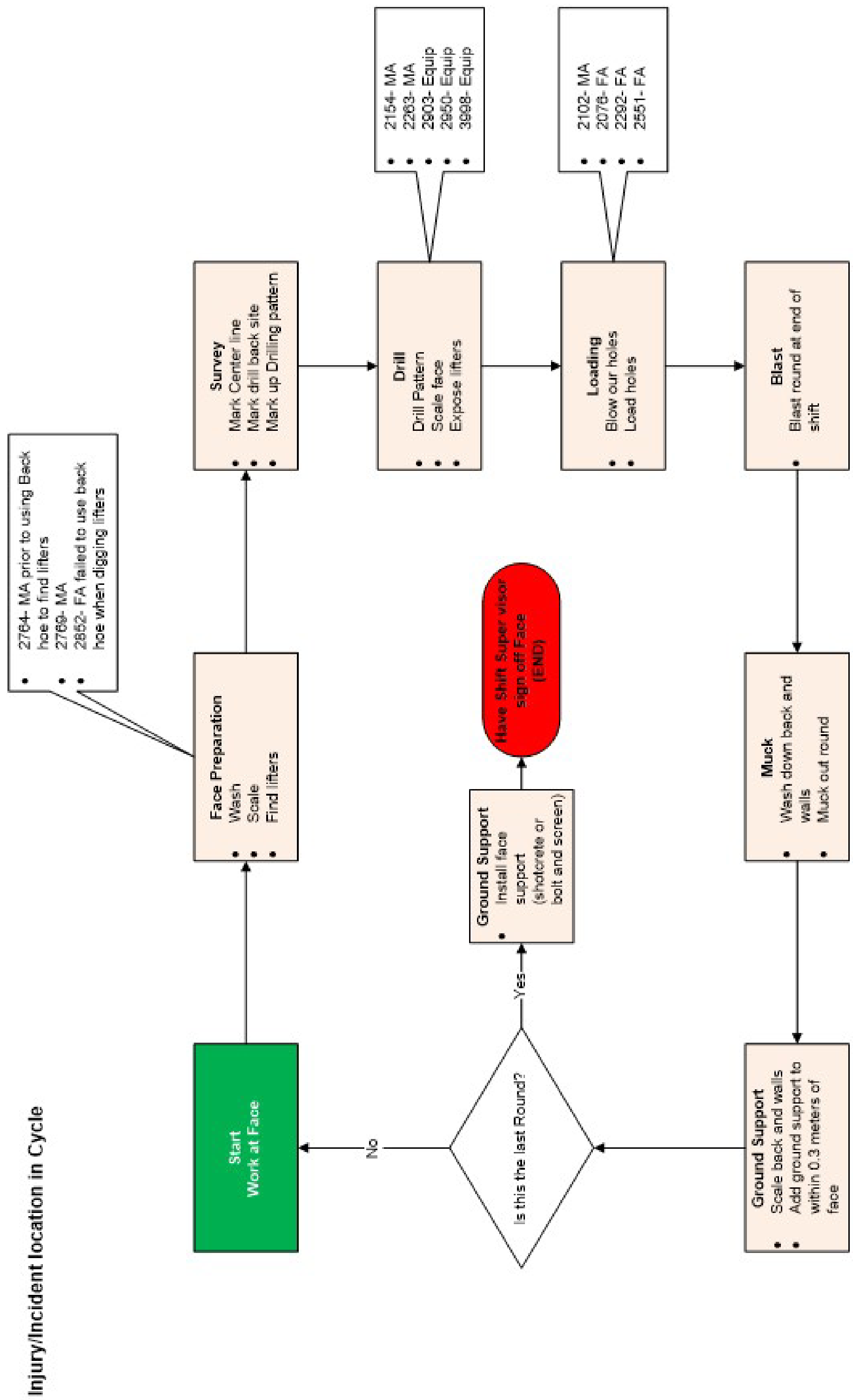
Face Safety

Benchmark Study

Cycle	[redacted]			
Prep	Scale, prep and mark up face. Use scoop to scale face by hand and backhoe/grub hoe to clean the floor.	Scale, prep and mark up the face.	Scale the face and then split set the whole face down to grade line using a jumbo. The split sets are left loose.	Scale, prep and mark up the face.
Drill	Drill face, lifters, first then burp the face.	Drill face and burp afterwards. Then using the jumbo install 1 sheet of screen width ways with 4 split sets. Headings over 5m x5.3m require screening.	The jumbo drills through the screen and taps the bolts in after it has completed drilling to limit bagging issues.	Drill the face and burp afterwards. If the face is over 4.9m (16'), then they will split set and screen to within 4.6,(15') of the floor.
Load	Scale face, top down and dig out lifters. Load round top down.	Scale the face top down and load the face top down.	Scale the face top down and load the face top down.	Scale the face top down and load the face top down.
Additional Notes	We bolt and screen the face if there is a sizeable quartz vein running through it.	If strain bursting potential, then the face is screened down to grade line.	In [redacted] the development miners were given training on how to read the face.	When stoping using the drift, they screen and split set to within 4.6m of the floor and split set down to 2.1m of the floor; these faces are typically much wider.

3.4. Accident/Incident Review:

Injury/Incident Location in Cycle



The worker is exposed to the risk of loose or fall of ground every time he/she works at the face. The simplified flow sheet above shows the number of incidents/injuries in the cycle. This information indicates that 75% of the incidents occur during or after drilling the round. When preparing the options, the location of the control (where in the cycle) was considered to minimize the workers' exposure to the risk.

Brainstorming and Option Review

Possible Options

Possible Options

	1	2	3	4	5
	As now RR= 13	Bolt before Prep - with jumbo & screen (RR> 13 , 16 or 17)	Bolt after Prep - with jumbo & screen (RR> 13 , 16 or 17)	Bolt after Drilling - with jumbo with screen (RR> 13 , 16 or 17)	Bolt after Drilling - with jumbo & loading unit & screen (RR> 13 , 16 or 17)
Prep	Scale, prep, & mark up face. Use scoop to scale face by hand and backhoe/grub hoe to clean the floor.	When bolting the round screen is hung down the face using push plates. The jumbo then moves in and split sets the face. The split sets are installed loosely. After the screen is loosely fitted the face is prepped and marked up.	Prep the face as standard, and allow the jumbo rig to move in. Screen after initial scale and find lifters after scale.	Prep the face as standard, and allow the jumbo rig to move in.	Prep the face as standard, and allow the jumbo rig to move in.
Drill	Drill face, lifters first then burp the face	The jumbo is then moved back in and it drills the round. After drilling the round the jumbo installs the split sets tightly to the face.	Jumbo moves in and partially screens the face. Does not fully tap in the split sets to stop the screen from bagging. Then drills the face	Drill the round, then install the screen using the jumbo.	Drill off round and drill additional bolt holes for swellex
Load	Scale face, top down and dig out lifters. Load round top down	The round is then loaded as per normal.	The round is then loaded as per normal.	The round is then loaded as per normal.	The loading crew comes in and installs the screen using Swellex. Then loads the round.
Advantages	Efficient process	The process partially supports the round for the prep process but could affect the ability to scale effectively.	Supports the round for the drilling and blasting process, dont have to move the jumbo in twice.	Easier drilling, less likely to bag the screen.	Not reliant on the jumbo operator to bolt and screen. Protects the loaders.
Disadvantages	Reliant on effective scaling of faces and reading of ground	The jumbo drill has to be moved in twice. Tying the screen to the back would likely tear the screen off the back when the round is blasted. Makes screening ineffective Bootleg issue when drilling for bolts prior to prep, work up.	Still drilling through a bolted face and likely to bag, doesnt support the face when prepping the round. Additional skill required to hang the screen off the bolt and install them into a previously drilled hole. Debagging risks increase & therefore possible increase in risk of minor accidents while at the face debagging.	Only supports the face for the loader not the driller or prep crew. Additional skill required to hang the screen off the bolt and install them into a previously drilled hole.	Only supports the face for the loader not the driller or prep crew. Would need to install Swellex pumps too the loaders, could be a risk of injury in hanging the screen using a basket. Swellex is higher value bolt than split sets. May also end up putting bolts in the wrong holes and requiring the jumbo to move back in to drill additional blast holes.

The first 4 options included screening of the face and were all deemed a higher risk due to the amount of screen cutting that would have to be done due to bagging of the screen when loading & an increased likelihood of poor scaling during the loading process, the lack of a second stage of scaling after drilling and the risk from rocks bagging the screen. The group felt that the risk may not have a higher impact but at a minimum would result in a category 3 impact at a higher frequency than the present residual ranking of [13] Reportable. At the maximum end of the scale this scenario with bagging of screens and minimal scaling due to screen at the face, there is a potential for the risk of a category 3 incident with a higher likelihood due to the increased exposure of the workers. Therefore options 2, 3, 4, 5 are not recommended.

	1	6	7	8
	As now RR= 13	canopies on equipment (RR> 13)	Use lifter tubes to keep holes clear during drilling (RR=< 13 , possible 9)	shotcrete face (RR= 18)
Prep	Scale, prep, & mark up face. Use scoop to scale face by hand and backhoe/grub hoe to clean the floor.	Use scoop and backhoe to scale the face and mark up		
Drill	Drill face, lifters first then burp the face	Drill face, lifters first then burp the face		
Load	Scale face, top down and dig out lifters. Load round top down	Scale face, top down and dig out lifters. Load round top down. Canopy installed on loading rig.		
Advantages	Efficient process	Same as now - canopy would limit some flexibility.		
Disadvantages	Reliant on effective scaling of faces and reading of ground	Workers end up reaching outside of canopy resulting in more exposure.	Reduces the exposure of workers when finding the lifters.	shotcrete loose just as likely to create a risk. Issues with drilling into bootleg.

The next 3 options included adding canopies to equipment and shotcreting the face. These options were also ranked as higher than the present method due to the workers' potential to reach outside the canopies; canopies are more related to overhead risks and the use of shotcrete would add the risk of shotcreting loose. Therefore options 6 & 8 are not recommended. The use of lifter tubes to reduce the exposure of workers at the face while cleaning lifters was deemed an improvement and is in the process of being tested. The use of lifter tubes should result in an improvement but due to the unknown exposure we can only surmise that it would be better. The incidents reviewed indicated that approximately 22% of the injuries occur during the cleaning of lifters.

	1	9	10	11	12
	As now RR= 13	Bolt after drilling - bolt only. Bigger mesh plate 2'x 2' (RR=< 13 , possible 9)	Bolt after drilling - bolt only. (RR=< 13 , possible 9)	Bolt before drilling - blast holes (RR=< 13 , possible 9)	fiber glass bolts (RR=< 13 , possible 9)
Prep	Scale, prep, & mark up face. Use scoop to scale face by hand and backhoe/grub hoe to clean the floor.	Prep the face as standard, and allow the jumbo rig to move in.	Prep the face as standard, and allow the jumbo rig to move in.	Prep the face as standard, and allow the jumbo rig to move in.	Prep the face as standard, and allow the jumbo rig to move in.
Drill	Drill face, lifters first then burp the face	Drill off round and drill bolt pattern. Then bolt the face with split sets.	Drill off round and drill bolt pattern. Then bolt the face with split sets.	Drill and then bolt the face with split sets. Then proceed to drill the round.	Over drill holes and insert fiber glass bolts in longer holes so that face is presupported.
Load	Scale face, top down and dig out lifters. Load round top down	The round is then loaded as per normal.	The round is then loaded as per normal.	The round is then loaded as per normal.	The round is then loaded as per normal.
Advantages	Efficient process	Easier process than most of the other options, depending on density.	Easier process than most of the other options, depending on density.	Easier process than most of the other options, depending on density.	Face is presupported.
Disadvantages	Reliant on effective scaling of faces and reading of ground	Is not full surface support, but will prevent large pieces that are more likely to cause a serious injury.	Is not full surface support, but will prevent large pieces that are more likely to cause a serious injury.	Is not full surface support, but will prevent large pieces that are more likely to cause a serious injury.	Difficult to drill, place bolt, expensive, Is not full surface support, but will prevent large pieces that are more likely to cause a serious injury.

The last 4 options all would result in a reduction of exposure to the risk of loose or fall of ground and were the basis of options to select for trial. Option 9 could result in obstructions when drilling so it was regulated to a possible selection: not the preferred option. Option 12 installation would be much more difficult and costly so it was regulated to a possible selection as well. Options 10 and 11 were the preferred options and it needs to be determined during the testing when the face will be bolted with split sets.

4. Results

The risk review and brainstorming of working at the face resulted in 4 actions to reduce the risk to workers at the face. The present residual risk was ranked at 13 – Reportable. Upon review of the [redacted] system, there have not been any lost time injuries and therefore this risk is ranked higher than it should be. See Appendix 5 for data frequency. The residual ranking would then be unlikely (between 2 and 5 years) at 9 – Reportable to be conservative. The group assessed the residual with the new controls (shown below) as a 9 – Reportable but with the data not supporting the severity it should go to 5– Minor. The split set installation is an engineered control and can reduce both impact and likelihood. Lifter tubes allow a reduction of digging out the lifters and can reduce both impact and likelihood. The SOP change can only reduce frequency.

Test the use of split set ground support in the face (in consultation with Ground control, determine optimum pattern)

1. Test the use of split set ground support in the face (in consultation with Ground control, determine optimum pattern)
2. Develop changes to the procedure to install face ground support, need to answer the following:
   2.1. Is the support to be installed prior to drilling the round/slash?
   2.2. Is the support to be installed after drilling the round/slash?
3. Test the use lifter tubes to reduce the exposure at the face when clearing lifter holes after drilling.
4. Change loading SOP to ensure only 1 person loads at a time so that boom is never over a second worker.

Overall, the introduction of bolting at the face, using lifter tubes and changing the loading SOP should reduce the exposure of workers at the face, resulting in a residual ranking of 5 – Minor for this risk.

Appendix 1 – Charter

[redacted]

[redacted]

Problem or Opportunity Statement

Currently, working at the face of a drift there is a risk of loose injuring miner

There are a number of options to further protect the workers exposed to this risk.

Estimated Project Impact

Benefits include....

- Reduction of risk to workers at the face in mine.

Goal Statement

Assess the present risks of working at the face of a round. Brainstorm options to reduce the risk,

Information (residual risk ratings) to support decision to change underground drilling practices.

[redacted] Operations Strategic Objectives

- Create Zero Harm Workplace

Constraints

[redacted] [redacted]

In Scope

Explore implications of adding new controls to development cycle methods or procedures.
Determination of the potential residual risk rating

Out of Scope

Acceptance of risk assessment changes (e.g., alteration of existing controls)
Revision/creation of documentation (SOPs)

High Level Program Plan

Define

Review Existing Studies

Risk Analysis

Risk Evaluation

Risk Reporting

Project y:

- n/a

Constraints

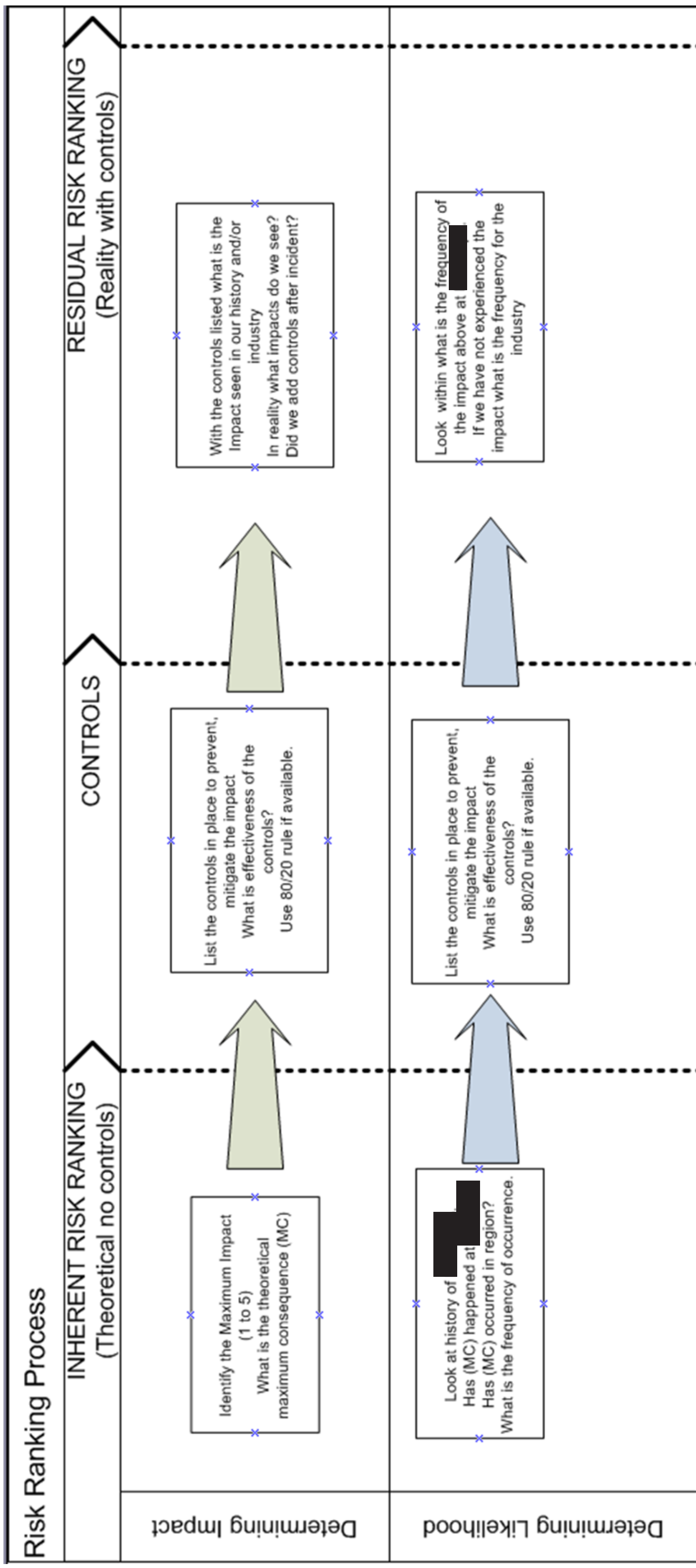
Procedures

Team Members

- Project Leader:
- Risk Owner:
- Ground Support:
- Blasting and Drilling:
- Jumbo Driller:
- Driller Supervisor:
- Worker Rep:
- Mentor:

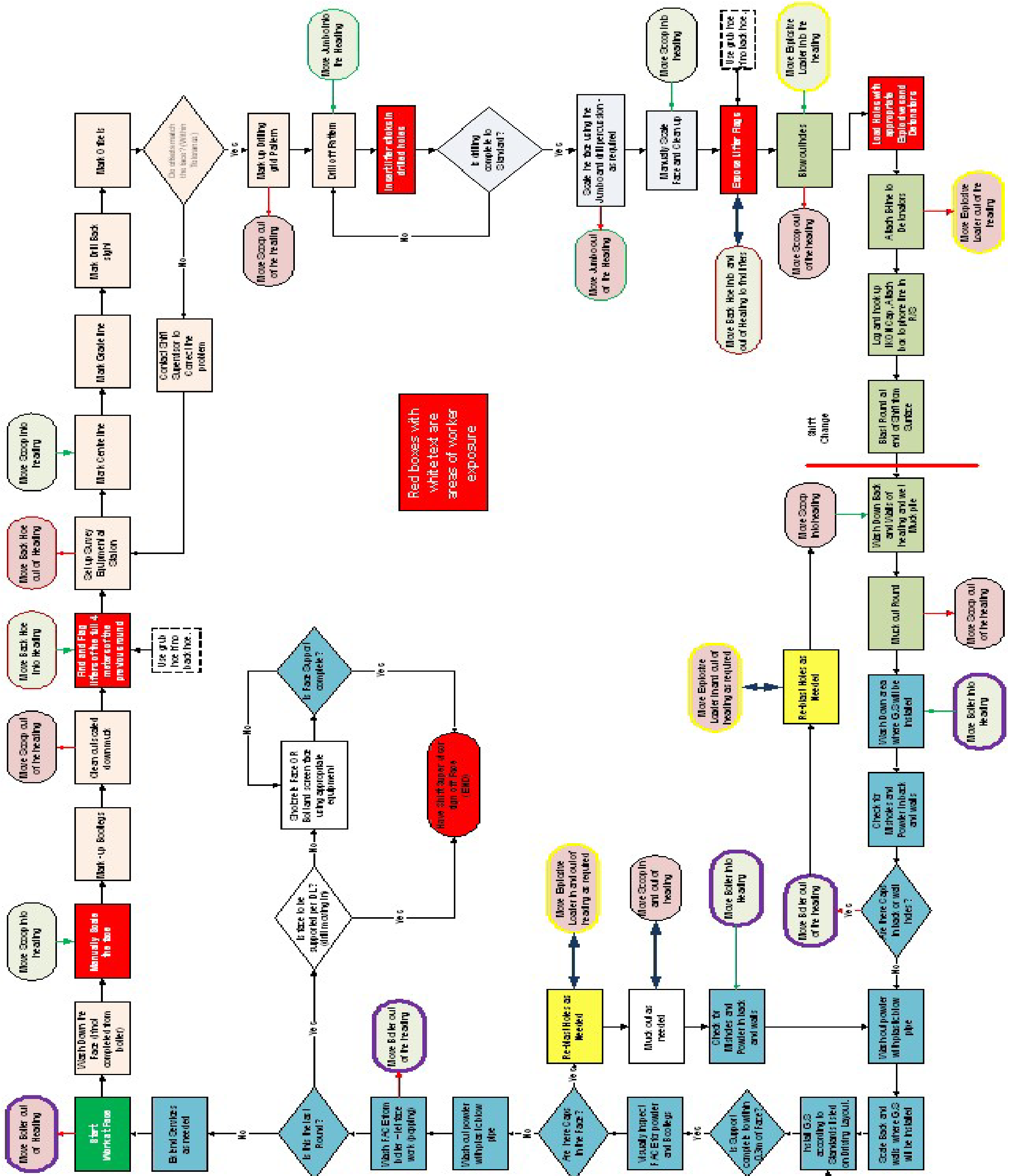
[redacted]

Appendix 2 – Risk Ranking Process

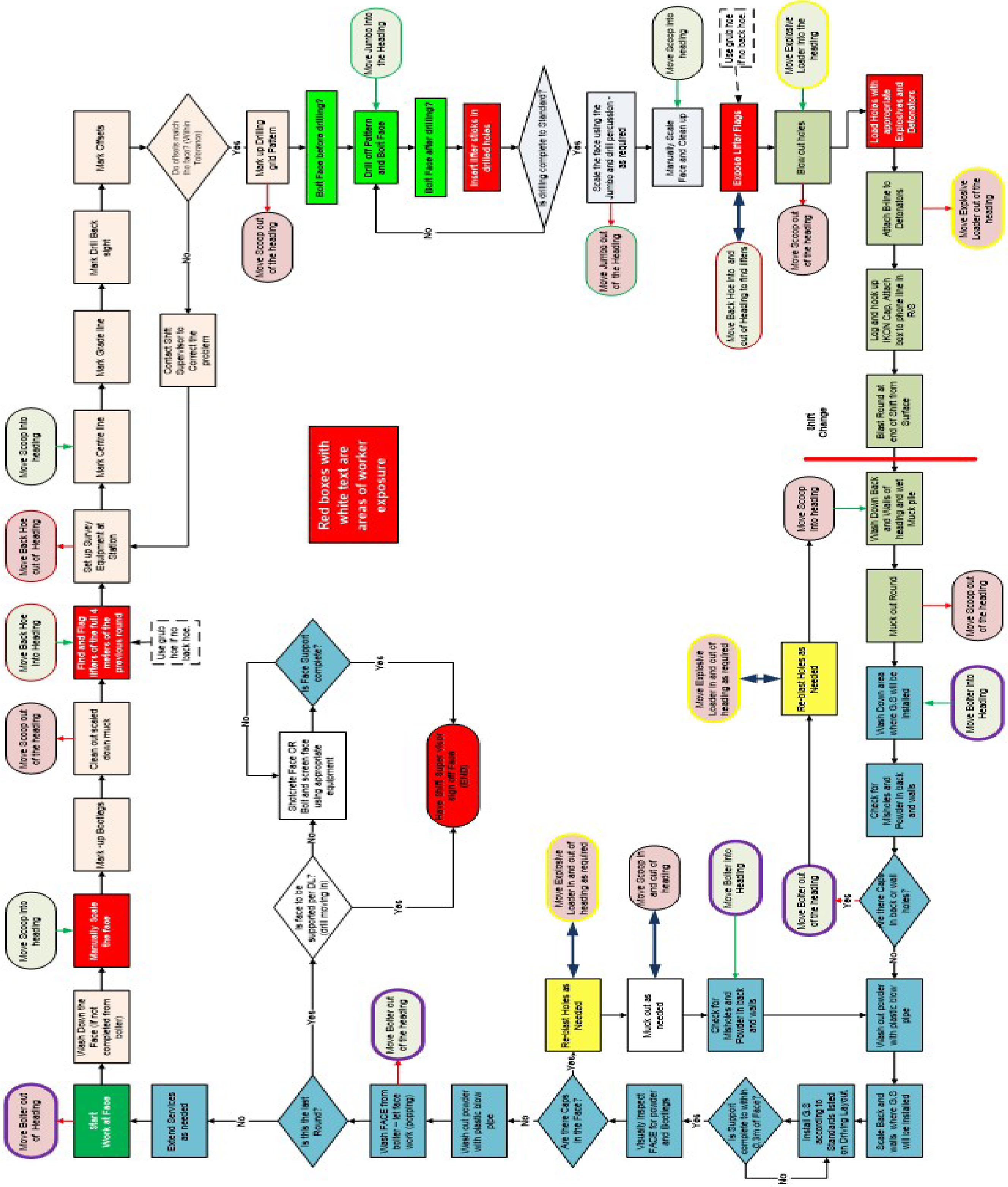


Hierarchy of Contols (HC)		
Type of control	Color code	Criteria Description
Elimination	ELI	Reduces Impact and Probability Remove, redesign the process or plant so the risk does not exist
Substitution	SUB	Reduces Impact and Probability Risk substitution with something of a lesser risk
Engineering / Design	ENG	Reduces Impact and / or Probability Risk controlled through an engineering measure
Administration / Procedure / Training / Awareness	APT	Reduces Probability Risk controlled by influencing people through training and procedures
Personal Protective Equipment	PPE	Reduce Probability Risk mitigated by the use of personal protection measures
Behavior Management	BEH	Not a reliable control - Recorded for information only

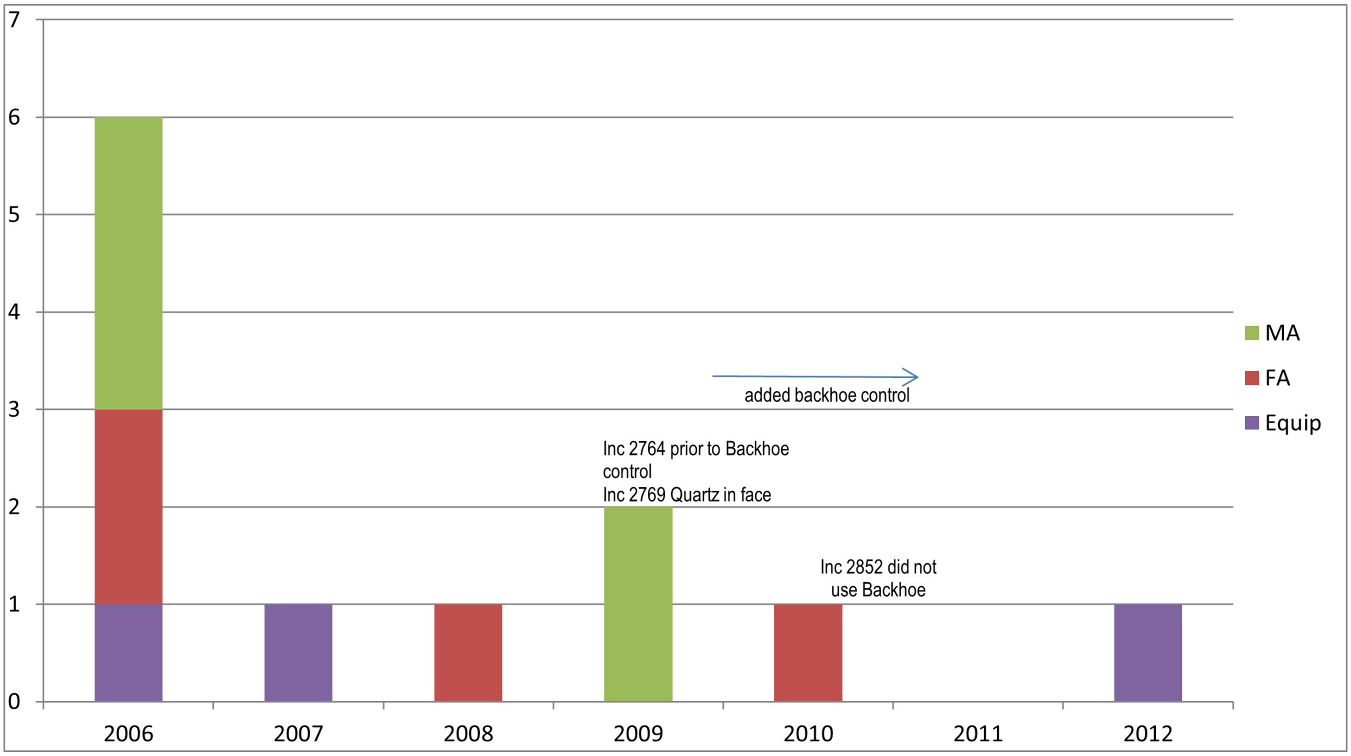
Appendix 3 – Development Cycle Flow Sheet (Present) (Visio file: “Development Process V3”)



Appendix 4 – Development Cycle Flow Sheet (with new controls) (Visio file: "Development Process V3")



Appendix 5 – Incident/Injury by Year



Appendix B: Examples of a risk register for ground control and related hazards from the Ontario Mining Review and Ontario Mining Association

Table B-1 – Mining review top 10 risks out of the total of 263 identified events.

Risk Rank	Category	Situation or Condition or Factor that could result in Injury or Illness OR What could keep you up at night?	L		C		Risk
			L	sd-L	C	sd-C	
1	Ground control	Rock bursts underground	4.75	0.66	4.50	0.50	21.38
2	Mobile Equipment	Large vehicle and pedestrian or small vehicle interaction is common and lethal	4.38	0.70	4.75	0.43	20.81
3	Ground control	Loose rock at the face continues to kill and injure workers UG	4.25	0.97	4.63	0.48	19.68
4	Ground Control	Existing underground mines in Ontario are becoming deeper and incurring higher extraction ratios. These situations can result in various forms of ground instability	4.50	0.71	4.25	1.09	19.13
5	Ground control	High faces not scaled and secured to protect workers	4.25	0.97	4.50	0.50	19.13
6	Mobile Equipment	The mobile equipment employed in many underground mines is getting bigger. Bigger equipment can often result in poorer operator visibility (i.e. more and larger blind spots). This can result in collisions with other vehicles or contact with pedestrians.	4.25	0.66	4.38	0.48	18.62
7	Occ. Disease	Exposure to hazardous substances(dusts, materials, metals), gases/ fumes, biological materials or forms, Physical Hazards (vibration, noise, heat/cold stress, light.)	4.63	0.70	4.00	0.71	18.52
8	Fatigue	Working Shiftwork resulting in disrupted sleeping patterns	4.63	0.48	4.00	0.87	18.52
9	Ground control	Fall of ground while installing ground support	4.38	0.86	4.13	0.60	18.09
10	Training	Supervisors in some mines in Ontario lack the proper experience and Training. Inexperienced and improperly trained supervisors pose a threat to themselves and their direct-report workers.	4.38	0.70	4.13	1.05	18.09

sd = Standard Deviation

Table B-2 – Mining review top 10 ground control risks out of the total of 28 identified events.

Overall Risk Rank	Category	Situation or Condition or Factor that could result in Injury or Illness OR What could keep you up at night?	L		C		Risk
			L	sd-L	C	sd-C	
1	Ground control	Rock bursts underground.	**4.75**	0.66	**4.50**	0.50	**21.38**
3	Ground control	Loose rock at the face continues to kill and injure workers UG	**4.25**	0.97	**4.63**	0.48	**19.68**
4	Ground control	Existing underground mines in Ontario are becoming deeper and incurring higher extraction ratios. These situations can result in various forms of ground instability.	**4.50**	0.71	**4.25**	1.09	**19.13**
5	Ground control	High faces not scaled and secured to protect workers.	**4.25**	0.97	**4.50**	0.50	**19.13**
9	Ground control	Fall of ground while installing ground support.	**4.38**	0.86	**4.13**	0.60	**18.09**
11	Ground control	High faces not supported for ground falls.	**4.25**	0.97	**4.25**	0.66	**18.06**
18	Ground control	Exposure to unsupported ground while working on a scissor lift.	**3.88**	0.93	**4.00**	0.87	**15.52**
24	Ground control	Lack of procedures related to ground support installation, or poorly trained workers.	**3.75**	1.09	**4.00**	0.71	**15.00**
25	Ground control	Rehab of damaged areas.	**4.00**	0.87	**3.75**	0.83	**15.00**
29	Ground control	No legislated protection of workers at face. Face is not required to be bolted and screened like walls and back.	**3.75**	1.71	**3.88**	1.17	**14.55**

Table B-3 – Ontario Mining Association (OMA) high level risk assessment

Threat	Control	Best Practice	Monitoring and Verification		
			Worker	Supervisor	Management
Fall of Ground - Too many unfilled voids - opened stopes (Instability)	1. Surveying, CMS, 3D Scanning - keeping track of open excavations in the mine.	Regular pickup of all openings accessible by all workers. Check surveys to verify.	Performs surveys.	Ensuring frequency and quality.	Ensuring training and competency standards. Sufficient resources.
	2. Backfilling open excavations.	Engineered fill design and monitoring of fill quality.	Fill placement, sampling for QA/QC	As per design.	Competency and resources.
	3. Mine schedule compliance - avoiding prolonged open stopes out of sequence as per the mine plan/model.	Sequence rules/best practices - applied in the development of the mine plan. Early definition of plan, adherence to plan and regular monitoring and review.	Miners executing as instructed.	As per design and standards.	

4. Ground control - containment of expected rock conditions through installation of ground support	Ground control management plan.	Following standards.	Verifying as per design and standards.
5. Seismic or other ground monitoring to verify ground reaction or performance as expected.	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance.	As per design.
6. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication.	
7. Pillar assessments- modelling - assessing condition of pillars prior to loading.	Locally calibrated empirical method or calibrated numerical model.	Following mine plan.	

	8. Geotechnical drilling and structural geological interpretation of drill core (characterizing the ground).	Adequate coverage of data for the mine plan.		
	9. Mine design - developing appropriate plan for extraction given the ground geological interpretation.	Up to date peer reviewed design.		
	10. Restricting access or barricading - ground control barricade warning of unstable ground.	Barricade with clear identification of hazard and communicated instructions for each.	Installing barricades and compliance.	
	11. Equipment Design - ROPs/ FOPS, remote controlled equipment for non man-entry.	Minimize exposure to unsupported ground.		

	12. Procedural limits for access e.g., Minimum 5m “no-entry” limit demarcation from brow for a blasthole stope, 12m set-up for remote operation.	Minimize exposure to unsupported ground.		
Fall of ground – gravity	1. Ground support design and engineering design (span standards).	Ground control management plan.		QA/QC on support standards.
	2. Mine design - developing appropriate plan for extraction given the ground geological interpretation (undercutting).	Up to date peer reviewed design.		

	3. Drilling and blasting and mechanical excavation practices and standards (avoiding excessive blast damage to opening and bad geometries).	Perimeter control techniques.	
	4. Top up backfilling (tight filling) - avoiding excessive stand-up time.	Engineered fill design and monitoring of fill quality.	
	5. Geological Mapping of rock type and structures.	Regular, timely back mapping and 3D interpretation.	
	6. Ground Support design and adjustments based on actual geological rock type and structures as determined from ground observations.	Iterative approach, regular adapting of design as mining progresses. Pre-support (e.g., Spiling) of next round.	

	7. Scaling of loose ground.	Specific tool at appropriate frequencies for the area.		
	8. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication	
	9. Geotechnical drilling and structural geological interpretation of drill core (characterizing the ground).	Adequate coverage of data for the mine plan.		
	10. Instrumentation to monitor ground movement (gauging deformation).	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance	As per design
	11. Keeping workers away from faces.	Use of jumbos and bolting units designed to distance the worker from the face.		

	12. Restricting access or barricading - ground control barricade warning of unstable ground.	Barricade with clear identification of hazard and communicated instructions for each.	Installing barricades and compliance.
	13. Equipment Design - ROPs/ FOPS, remote controlled equipment for non man-entry.	Minimize exposure to unsupported ground.	
	14. Procedural limits for access e.g., Minimum 5m “no-entry” limit demarcation from brow for a blasthole stope, 12m set-up for remote operation.	Minimize exposure to unsupported ground.	
	15. Emergency procedures.	Resourced and prepare procedure for timely response and to minimize exposure to responders.	

Seismic induced fall of ground	1. Ground support design and engineering design (span standards).	Ground control management plan.		QA/QC on support standards.
	2. Mine design - developing appropriate plan for extraction given the ground geological interpretation (undercutting).	Up to date peer reviewed design.		
	3. Drilling and blasting practices (avoiding excessive blast damage to opening and bad geometries).	Perimeter control techniques.		
	4. Top up backfilling (tight filling) - avoiding excessive stand-up time.	Engineered fill design and monitoring of fill quality.		
	5. Structural geological interpretation of drill core (characterizing the ground).	3D Fault interpretation utilizing mapping and microseismic data by a structural geologist.		

	6. Geological Mapping of rock type and structures (drift mapping).	Regular, timely back mapping and 3D interpretation.		
	7. Ground Support design and adjustments based on actual geological rock type and structures as determined from design, extraction, and ground observations.	Iterative approach, regular adapting of design as mining progresses. Pre-support (e.g., Spiling) of next round.		
	8. Scaling of loose ground.	Specific tool at appropriate frequencies for the area.		
	9. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication	

	10. Geotechnical drilling and structural geological interpretation of drill core (characterizing the ground).	Adequate coverage of data for the mine plan.		
	11. Instrumentation to monitor ground movement for gauging deformation and analysis.	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance	As per design
	12. Keeping workers away from faces.	Use of jumbos, bolting units and other equipment designed for away from face.		
	13. Microseismic monitoring and numerical modeling.	Array design for accurate location and quantification of seismic events.		
	14. Re-entry protocols.	Based on seismic data, proactive barricading.		
	15. Closing off inactive headings	Minimize exposure to hazard.		

	16. Restricting access or barricading - ground control barricade warning of unstable ground.	Barricade with clear identification of hazard and communicated instructions for each.	Installing barricades and compliance.	
	17. Secondary egress in mine design.			
	18. Equipment Design - ROPs/ FOPS, remote controlled equipment for non man-entry	Minimize exposure to unsupported ground.		
	19. Procedural limits for access e.g., Minimum 5m “no-entry” limit demarcation from brow for a blasthole stope, 12m set-up for remote operation.	Minimize exposure to unsupported ground.		
	20. Emergency procedures.	Resourced and prepare procedure for timely response and to minimize exposure to responders.		

Fall of ground - Rockburst, fault-slip event	1. Ground numerical modelling analysis.	Array design for accurate location and quantification of seismic events.
	2. Safe work practices for ground support installation.	Procedures to minimize exposure to unsupported ground.
	3. Mine design standard for crossing faults	Cut across fault @ 90 degrees if unavoidable.
	4. Top up backfilling (tight filling).	Engineered fill design and monitoring of fill quality.
	5. Ground support design and engineering design (span standards).	Ground control management plan.
	6. Mine design - developing appropriate plan for extraction given the ground geological interpretation (undercutting).	Up to date peer reviewed design.

	7. Drilling and blasting practices (avoiding excessive blast damage to opening and bad geometries).	Perimeter control techniques.	
	8. Structural geological interpretation of drill core (characterizing the ground).	3D Fault interpretation utilizing mapping and microseismic data by a structural geologist.	
	9. Geological Mapping of rock type and structures (drift mapping) and interpretation (projections).	Regular, timely back mapping and 3D interpretation.	
	10. Ground Support design and adjustments based on actual geological rock type and structures as determined from ground observations.	Iterative approach, regular adapting of design as mining progresses. Pre-support (e.g., Spiling) of next round.	

	11. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication	
	12. Geotechnical drilling and structural geological interpretation of drill core (characterizing the ground).	Adequate coverage of data for the mine plan.		
	13. Instrumentation to monitor ground movement for gauging deformation and analysis.	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance	As per design
	14. Keeping workers away from faces.	Use of jumbos, bolting units and other equipment designed for away from face.		
	15. Re-entry protocols.	Specific (e.g., Longer) re-entry protocols specific to fault slip events.		

	16. Closing off inactive headings.	Minimize exposure to hazard.	
	17. Restricting access or barricading - ground control barricade warning of unstable ground.	Barricade with clear identification of hazard and communicated instructions for each.	Installing barricades and compliance.
	18. Secondary egress in mine design.		
	19. Equipment Design - ROPs/FOPS, remote controlled equipment for non man-entry.	Minimize exposure to unsupported ground.	
	20. Procedural limits for access e.g., Minimum 5m "no-entry" limit demarcation from brow for a blasthole stope, 12m set-up for remote operation.	Minimize exposure to unsupported ground.	
	21. Emergency procedures.	Resourced and prepare procedure for timely response and to minimize exposure to responders.	

	22. Secondary egress in mine design.				
Fall of ground – Rockburst / Strainburst	1. Ground numerical modelling analysis.	Array design for accurate location and quantification of seismic events.			
	2. Safe work practices for ground support installation	Procedures to minimize exposure to unsupported ground.			
	3. Mine design standard for crossing faults or other problematic structures or rock types.	Cut across fault @ 90 degrees if unavoidable.			
	4. Ground support design and engineering design (span standards).	Ground control management plan.			QA/QC on support standards.
	5. Mine design - developing appropriate plan for extraction given the ground geological interpretation (undercutting).	Up to date peer reviewed design.			

	6. Drilling and blasting practices (avoiding excessive blast damage to opening and bad geometries).	Perimeter control techniques.	
	7. Top up backfilling (tight filling) - avoiding excessive stand-up time.	Engineered fill design and monitoring of fill quality.	
	8. Structural geological interpretation of drill core (characterizing the ground).	3D Fault interpretation utilizing mapping and microseismic data by a structural geologist.	
	9. Geological Mapping of rock type and structures (drift mapping).	Regular, timely back mapping and 3D interpretation.	
	10. Ground Support design and adjustments based on actual geological rock type and structures as determined from ground observations.	Designed support for dynamic loading with high area coverage.	

	11. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication	
	12. Geotech drilling and structural geological interpretation of drill core (characterizing the ground)	Adequate coverage of data for the mine plan.		
	13. Instrumentation to monitor ground movement for gauging deformation and analysis.	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance	As per design
	14. Destress blasting practice where prescribed (local to the excavation).	Monitor effectiveness of destress and adjust accordingly		
	15. Keeping workers away from faces.	Use of jumbos, bolting units and other equipment designed for away from face.		

	16. Microseismic monitoring.	Array design for accurate location and quantification of seismic events.	
	17. Re-entry protocols.	Specific (e.g., Longer) re-entry protocols specific to fault slip events.	
	18. Closing off inactive headings	Minimize exposure to hazard.	
	19. Restricting access or barricading - ground control barricade warning of unstable ground.	Barricade with clear identification of hazard and communicated instructions for each.	Installing barricades and compliance.
	20. Equipment Design - ROPs/ FOPS, remote controlled equipment for non man-entry.	Minimize exposure to unsupported ground.	
	21. Procedural limits for access e.g., Minimum 5m “no-entry” limit demarcation from brow for a blasthole stope, 12m set-up for remote operation.	Minimize exposure to unsupported ground.	

	22. Emergency procedures.	Resourced and prepare procedure for timely response and to minimize exposure to responders.
	23. Secondary egress in mine design.	
Fall of ground - Ground Support Corrosion/ deterioration/ aging	1. Ground support design safety factors.	Higher safety factor for support degradation
	2. Ground support material selection for corrosion resistance.	Specific to the environment, monitor and adjust. Ground support evaluation - understanding/ addressing local corrosivity (e.g., methods to quantify corrosion rates).
	3. Periodic regular inspection of active and accessible areas, travel way audits (whole mine audits).	Scheduled
	4. Rehab support programs.	Planned “Pre-hab” prior to deterioration.

	5. Ground support installation practices.	Monitor and adjust.	
	6. Ventilation to reduce build up of humidity.	Sufficient air flow planned and monitored.	
	7. Grouting diamond drill holes (controlling unwanted water).	Water management plan.	
	8. Closing off inactive headings (barricading).	Minimize exposure to hazard.	
	9. Emergency procedures.	Resourced and prepare procedure for timely response and to minimize exposure to responders.	
	10. Secondary egress in mine design.		
Fall of ground - Mining induced changes to rock conditions, extraction rates or activities.	1. Ground numerical modelling analysis.	Array design for accurate location and quantification of seismic events.	
	2. Safe work practices for ground support installation.	Procedures to minimize exposure to unsupported ground.	

	3. Mine design standard for crossing faults and other problematic structures or rock types.	Cut across fault @ 90 degrees if unavoidable.	
	4. Ground support design and engineering design (span standards).	Design support for lifecycle of the opening.	
	5. Mine design - developing appropriate plan for extraction given the ground geological interpretation (undercutting).	Up to date peer reviewed design.	
	6. Drilling and blasting practices (avoiding excessive blast damage to opening and bad geometries.	Perimeter control techniques.	
	7. Top up backfilling (tight filling) - avoiding excessive stand-up time.	Engineered fill design and monitoring of fill quality.	

	8. Structural geological interpretation of drill core (characterizing the ground)	3D Fault interpretation utilizing mapping and microseismic data by a structural geologist.	
	9. Geological Mapping of rock type and structures (drift mapping).	Regular, timely back mapping and 3D interpretation.	
	10. Ground Support design and adjustments based on actual geological rock type and structures as determined from ground observations.	Iterative approach, regular adapting of design as mining progresses. Pre-support (e.g., Spiling) of next round.	
	11. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication

	12. Geotech drilling and structural geological interpretation of drill core (characterizing the ground).	Adequate coverage of data for the mine plan.		
	13. Instrumentation to monitor ground movement for gauging deformation and analysis.	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance	As per design
	14. Destress blasting practice where prescribed (local to the excavation).	Monitor effectiveness of destress and adjust accordingly		
	15. Keeping workers away from faces.	Use of jumbos, bolting units and other equipment designed for away from face.		
	16. Microseismic monitoring	Array design for accurate location and quantification of seismic events.		
	17. Re-entry protocols	Specific (e.g., Longer) re-entry protocols specific to fault slip events.		

	18. Closing off inactive headings	Minimize exposure to hazard.	
	19. Restricting access or barricading - ground control barricade warning of unstable ground.	Barricade with clear identification of hazard and communicated instructions for each.	Installing barricades and compliance.
	20. Equipment Design - ROPs/ FOPS, remote controlled equipment for non man-entry.	Minimize exposure to unsupported ground.	
	21. Procedural limits for access e.g., Minimum 5m “no-entry” limit demarcation from brow for a blasthole stope, 12m set-up for remote operation.	Minimize exposure to unsupported ground.	
	22. Emergency procedures.	Resourced and prepare procedure for timely response and to minimize exposure to responders.	
	23. Secondary egress in mine design.		

Fall of ground – Shaft event	1. Location selection of shaft and shaft design.	In concert with geological / engineering data. Geotech drilling and structural geological interpretation of drill core for shaft location selection (characterizing the ground), and numerical modelling. Pilot hole.
	2. Concrete lining/ support.	Specific to environment.
	3. Geological and geotechnical mapping of shaft.	Scheduled. Microseismic monitoring of sinking. Subsidence monitoring of soft rock shaft.
	4. Inspections for loose/changing conditions (shaft inspections weekly/yearly).	Scheduled
	5. Periodic inspection by Ground Engineers.	Scheduled

	6. Periodic inspection by structural engineer - to evaluate condition of steel work, timber shaft, concrete lining.	Scheduled
	7. Fixed plant conveyance inspections - shaft guide measurements to monitor alignment changes.	Scheduled
	8. Maintaining wet shaft (wood only).	Scheduled
	9. Ventilation control.	Specific to integrity of shaft integrity.
	10. Head cover design of conveyance.	In place
	11. Shaft brattice (isolation of compartments).	Scheduled maintenance.
Bench Failure / Brow Failure	1. Mine Design standard for span (width of the stope).	Specific to environment.

	2. Drilling and blasting practices (avoiding excessive blast damage to opening and bad geometries.	Pre-loading of rings to maintain 5m of distance from brow or bench		
	3. CMS audits (measuring cavity size).	Scheduled		
	4. Instrumentation to monitor ground movement for gauging deformation and analysis.	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance	As per design
	5. Ground support design.	Additional ground support prescribed in brow areas.		
	6. Worker tie-off work practices for working near open holes.	Procedure and design standard		
	7. Remote drilling	Procedure		
	8. Engineered bumper blocks/ barrier	Procedure and design standard		

Crown Pillar Failure	1. Ground numerical modelling analysis.	Array design for accurate location and quantification of seismic events.
	2. Ground support design and engineering design.	Span standards.
	3. Mine design - developing appropriate plan for extraction given the ground geological interpretation (undercutting).	Crown pillar study incorporated into the mine design.
	4. Drilling and blasting practices (avoiding excessive blast damage to opening and bad geometries).	Perimeter control techniques.
	5. Structural geological interpretation of drill core (characterizing the ground).	3D Fault interpretation utilizing mapping and microseismic data by a structural geologist.

	6. Geological Mapping of rock type and structures (drift mapping).	Regular, timely back mapping and 3D interpretation.		
	7. Ground Support design and adjustments based on actual geological rock type and structures as determined from ground observations	Iterative approach, regular adapting of design as mining progresses. Pre-support (e.g., Spiling) of next round.		
	8. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication	
	9. Geotech drilling and structural geological interpretation of drill core (characterizing the ground).	Adequate coverage of data for the mine plan.		

	10. Instrumentation to monitor ground movement for gauging deformation and analysis.	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance	As per design	
Uncontrolled Caving	1. Quality of Mine Design.	Span control			
	2. Ground support design and engineering design (span)	Ground control management plan.			QA/QC on support standards.
	3. Mine design - developing appropriate plan for extraction given the ground geological interpretation (undercutting).	Stope stability study - ground numerical modelling analysis			
	4. Drilling and blasting practices (avoiding excessive blast damage to opening and bad geometries).	Perimeter control techniques.			

	5. Structural geological interpretation of drill core (characterizing the ground).	3D Fault interpretation utilizing mapping and microseismic data by a structural geologist.	
	6. Geological Mapping of rock type and structures (drift mapping).	Regular, timely back mapping and 3D interpretation.	
	7. Ground Support design and adjustments based on actual geological rock type and structures as determined from ground observations.	Iterative approach, regular adapting of design as mining progresses. Pre-support (e.g., Spiling) of next round.	
	8. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication

	9. Geotech drilling and structural geological interpretation of drill core (characterizing the ground).	Adequate coverage of data for the mine plan.			
	10. Instrumentation to monitor ground movement for gauging deformation and analysis.	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance	As per design	
Fall of ground - Portals/slope/ bench failure	1. Ground numerical modelling analysis	Array design for accurate location and quantification of seismic events.			
	2. Ground support design and engineering design.	Ground control management plan.			QA/QC on support standards.
	3. Mine design - developing appropriate plan for extraction given the ground geological interpretation (undercutting)	Span control standards and Crown Pillar study.			

	4. Drilling and blasting practices (avoiding excessive blast damage to opening and bad geometries)	Perimeter control techniques.		
	5. Geological Mapping of rock type and structures (drift mapping).	Regular, timely back mapping and 3D interpretation.		
	6. Ground Support design and adjustments based on actual geological rock type and structures as determined from ground observations.	Iterative approach, regular adapting of design as mining progresses. Pre-support (e.g., Spiling) of next round.		
	7. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication	

	8. Geotechnical drilling and structural geological interpretation of drill core (characterizing the ground).	Adequate coverage of data for the mine plan.		
	9. Instrumentation to monitor ground movement for gauging deformation and analysis	Sufficient instrumentation, reading data, interpreting data, and maintaining devices.	Proper installation and maintenance.	As per design
Fall of ground – Blast Induced	1. Mine design - blast design, proximity of openings design practice (sequencing).	Central blast.		
	2. Ground support designed to withstand blasting.	Rehab of failed ground.		

	3. Ground observation reports - monitor to verify ground reaction or performance as expected; ground support installed as prescribed.	Ground control communications plan.	Timely communication
	4. Control personnel access.	Central blast or guarding where appropriate	

Appendix C: Example hazard/risk register templates

Hazard and Operability Study (HAZOP) Template

Project:				Node:			Page:	
Node Description:							Date:	
							Drg. No:	
Team Leader:		Team Members:				Minutes By:		Pages:
Guideword	Possible Cause(s)	Consequence	Safeguard (existing)	Rec#	Recommendations	Accountability	Action	Action Ref#

Failure Modes and Effects (FMEA) Analysis

<table>
<tr><td colspan="3">Project No:</td><td colspan="3">Component:</td><td colspan="2">Page:</td></tr>
<tr><td colspan="6" rowspan="2">Component Description:</td><td colspan="2">Date:</td></tr>
<tr><td colspan="2">Drg. No:</td></tr>
<tr><td colspan="2">Team Leader:</td><td colspan="3">Team Members:</td><td colspan="2">Minutes By:</td><td>Pages:</td></tr>
<tr><th rowspan="2">No</th><th rowspan="2">Failure Mode</th><th rowspan="2">Detection Method</th><th colspan="2">Equipment Affected</th><th rowspan="2">Safety Systems Reponse</th><th colspan="2" rowspan="2">Comments</th></tr>
<tr><th>Identification</th><th>Effects</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
</table>

Failure Modes, Effects and Criticality Analysis (FMECA) Template

Project No:			Component:				Page No:		
Drg Nos:			Team Leader: Team Members: Minutes:				Date: Reference No.:		
No.	Component Description	Failure Mode	Effects on			Probability	Consequence	Criticality	Control
			Other item	System	Safety				

Human Error Analysis (HEA) Template

Project No:				Key Task:			Page ___ of ___	
Task Description:							Date:	
Team Leader:		Team Members:				Minutes By:	SOP References:	
No	Sub-task or element	Potential human error	Possible root cause(s) of error	Possible contributory factors	Existing mitigating factors	Additional safeguards proposed	Agreed action	Accountability

What If...? Template

<table>
<tr><td colspan="3">Project No:</td><td colspan="2">Section:</td><td colspan="2">Page No:</td></tr>
<tr><td colspan="5">Description and Purpose:</td><td>Reference Documents:</td><td>Date:</td></tr>
<tr><td colspan="3">Team Leader:</td><td colspan="2">Team Members:</td><td>Minutes By:</td><td>Drg No:</td></tr>
<tr><td>No</td><td>What If...?</td><td>Concern</td><td>Safeguards</td><td>Additional Safeguards Proposed</td><td>Action Required</td><td>Accountable</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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Workplace Risk Assessment and Control (WRAC) Template

<table>
<tr><td colspan="4">Project No:</td><td colspan="5">Project Title:</td><td colspan="2">Page ____ of ____</td></tr>
<tr><td colspan="6">Operation Description:</td><td colspan="3">Documents:</td><td colspan="2">Date:</td></tr>
<tr><td colspan="3">Team Leader:</td><td colspan="3">Team Members:</td><td colspan="3">Minutes By:</td><td colspan="2">SOPs</td></tr>
<tr><td rowspan="2">No</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td>G</td><td rowspan="2">Agreed Action</td><td rowspan="2">Accountability</td><td rowspan="2"></td></tr>
<tr><td>Step in Operation</td><td>Potential Incident/ Accident</td><td>Probability</td><td>Consequence</td><td>Risk Rank</td><td>Current Controls</td><td>Recommended Controls</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Preliminary Hazard Analysis (PHA) Template

Project:				Section:		Page:
Description of Scope Boundaries					Drawing Nos:	Date:
					Design Status:	
Team Leader:			Team Members:		Minutes By:	
No	Hazard	Cause	Major Effect	Hazard Category	Corrective Action/ Preventative Measure	Accountability