Minerals Council of Australia

Industry Guideline for Rockfall Risk Management

UNDERGROUND METALLIFEROUS MINES

ACG

Australian Centre for Geomechanics

Safety and Health vision

"An Australian minerals industry free of fatalities, injuries and diseases."

Safety and Health beliefs

- All fatalities, injuries and diseases are preventable.
- No task is so important that it cannot be done safely.
- All hazards can be identified and their risks managed.
- Everyone has a personal responsibility for the safety and health of themselves and others.
- Safety and health performance can always improve.

Safety awareness

"The state of mind where we are constantly aware of the possibility of injury and act accordingly at all times."

Cover photographs courtesy of Newmont Australia Ltd, Bendigo Mining, George Fisher Mine and Kanowna Belle Gold Mine.

INTRODUCTION

ROCKFALL: "AN UNCONTROLLED FALL (DETACHMENT OR EJECTION) OF GROUND OF ANY SIZE THAT CAUSES (OR POTENTIALLY CAUSES) INJURY OR DAMAGE."

Rockfalls are a major hazard in underground mines, with consequences ranging from insignificant to catastrophic (fatalities). The risk to personnel and damage associated with rockfalls must therefore be managed. In particular, a step improvement in the overall safety record of the Australian mining industry will result from the elimination of rockfall injuries and fatalities.

This "Guideline for the Management of Rockfalls" aims at standardising the processes supporting mines' site specific systems and procedures for the management of rockfall risks. The guideline itself has been developed as a process illustrated by the flowchart in Figure 1. An effective rockfall management process must rely on an implementation strategy supported by all levels of the organisation, from top company executives to mine workers.

This guideline may be a component, or serve as the basis for a ground control management plan. It relies on techniques and methods that are seen as good practices in ground control.

CONTENTS

UNDERGROUND ROCKFALL RISK MANAGEMENT PROCESS

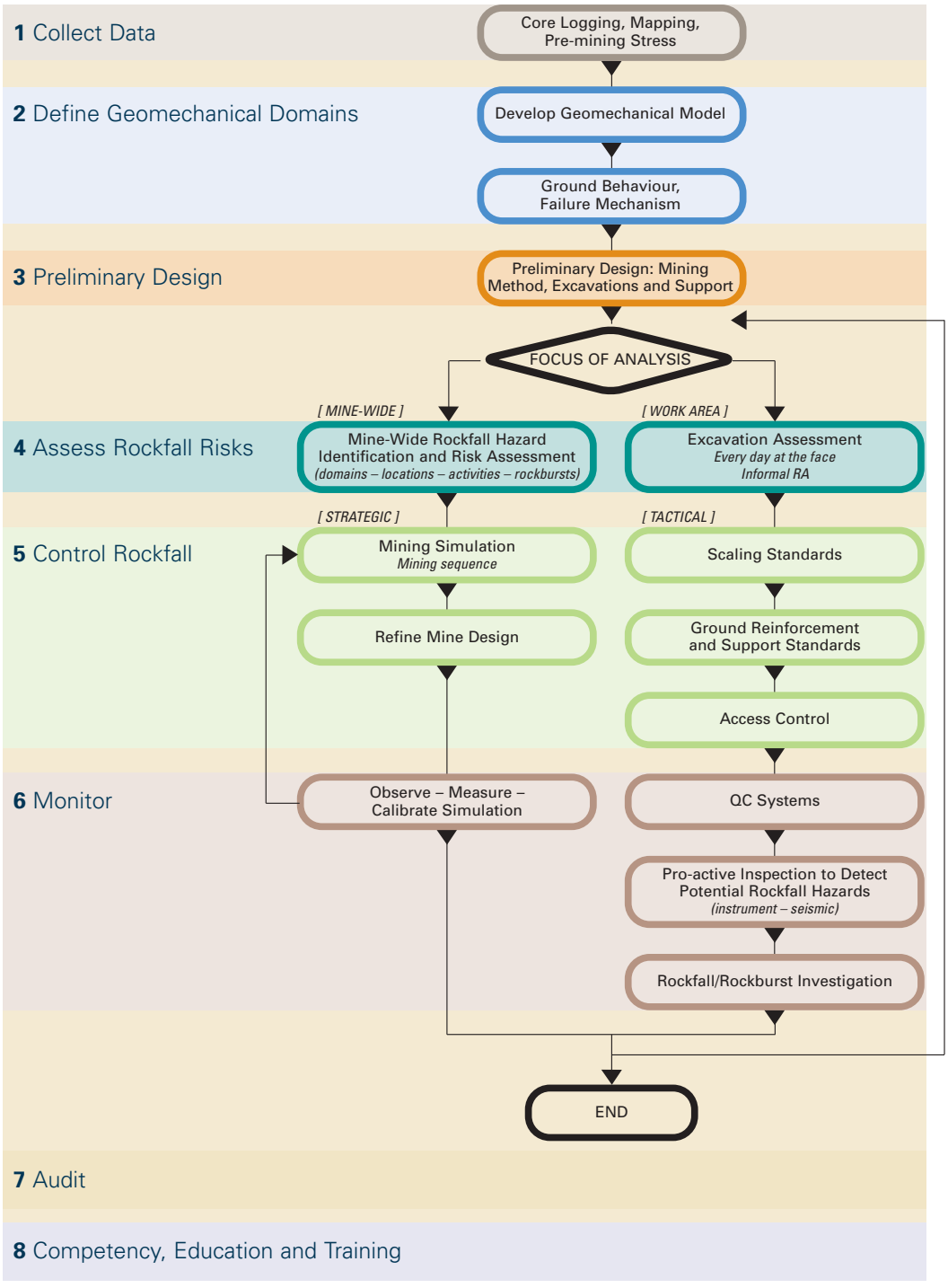
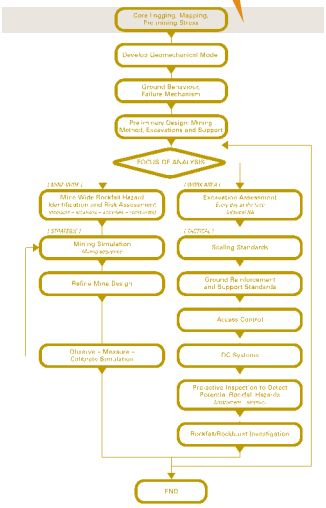


Figure 1. Flowchart illustrating the Rockfall Risk Management process for Underground Metalliferrous Mines. Step 7 "Audit" and Step 8 "Competency, Education and Training" can be undertaken at any stage of the process. For clarity of the presentation, these two steps have been listed outside the process framework

Geomechanical Data Collection



1. Geomechanical Data Collection

Geomechanics field investigations, of a representative coverage, are required to understand ground conditions and identify rockfall hazards and appropriate controls throughout the mine.

Processes

- Log geotechnically diamond drill core
- Map geological structures, from underground or surface exposures
- Determine intact rock properties
- Characterise rock masses using classification systems
- Assess pre-mining stress
- Assess hydrological influence
- Assess regional geotechnical information

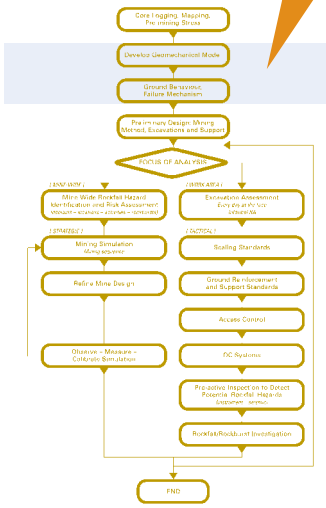
Timing

Undertake processes from pre-feasibility onwards and into mine operation. Some data may be extracted during the exploration stage.

Documents

- 3D geological model, including characteristics of major geological discontinuities, lithology, weathering, etc.
- Database of Rock Quality Designation (RQD) and/or linear fracture frequency
- Database of rock mass classification, structural data and/or structures shown on mine plans, stereonets
- Intact rock properties
- Magnitude and orientation of major, intermediate and minor pre-mining stresses, including depth gradient
- Hydrology reviews/studies
- Regional geotechnical data

Definition of Geomechanical Domains



2. Definition of Geomechanical Domains

Geomechanical domains are defined based on geomechanical characteristics, estimated or measured pre-mining stress levels and structural influence. The mine is divided into areas of expected similar ground behaviour.

Processes

- Develop a geomechanical model of the mine and define geomechanical domains
- Assess the overall rock mass response to mining, seismic versus non-seismic, time dependant, highly deformable, etc.
- Catalogue typical ground behaviour categories including potential failure mechanisms

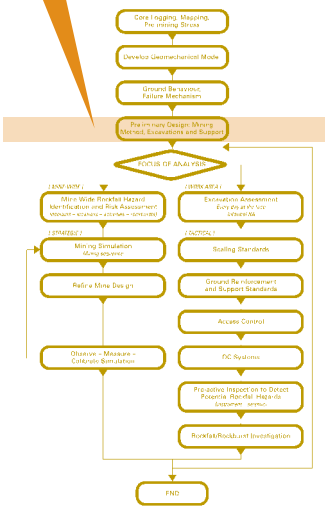
Timing

Undertake processes from pre-feasibility onwards and into mine operation.

Documents

- Description of the geomechanical model of the mine, comprising the geomechanical data collected in Step 1
- Geomechanical domains clearly identified and justified with relevant information on expected ground behaviour within each domain
- Catalogue of probable ground behaviour (failure mechanisms) with key features and hazards clearly identified which may include photos and sketches

Preliminary Design



3. Preliminary Design

A mining method and development layout suitable to the expected ground behaviour and production requirement are selected. Excavation design parameters such as size, shape and ground control methods are defined.

Processes

- Select suitable mining methods, including fill requirements
- Determine optimum excavation size, shapes and orientation, for all types of excavations, major access and infrastructure, drives, cross-cuts, intersections, stopes, etc., within each domain and stress regime
- Assess methods for controlling overbreak, control blasting of the excavation perimeter
- Define ground control requirement including length and displacement demand, for each type of excavation, location and ground behaviour, as catalogued. This will be based on recognised and appropriate design approaches
- Select the most appropriate reinforcement and surface support system based on assessed demand, equipment available, frequency of travel, longevity of the excavation equipment and personnel exposure during installation, anticipated stress changes (increase or decrease), need for corrosion resistance, etc., for each excavation type and ground behaviour as catalogued
- Perform ground reinforcement and support design analysis

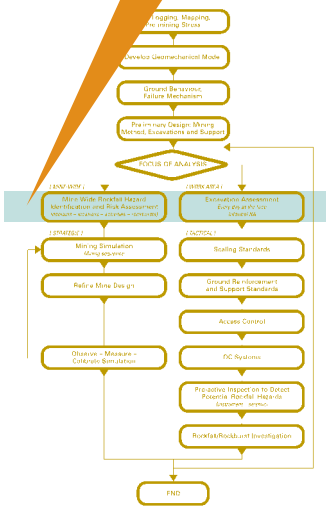
Timing

Start during the scoping or pre-feasibility study to be completed before the start of production. Once in production, update periodically or when there is a significant change in operations.

Documents

- Mining method selection criteria, including fill requirement
- Overbreak control method(s)
- Report on excavation size, shape and orientation analysis, including ground reinforcement and support requirement

Identification of Rockfall Hazards and Assessment of Rockfall Risks



4. Identification of Rockfall Hazards and Assessment of Rockfall Risks

The risk of rockfall is formally assessed on a mine-wide scale, leading to the implementation of strategic controls as well as on a specific work area scale, leading to the implementation of tactical controls. The level of residual risk deemed tolerable by the organisation must be clearly defined.

4.1 MINE-WIDE RISK ASSESSMENT

Processes

- Identify potential for major mine collapse
- Identify locations and activities where the rockfall risk is high
- Perform risk assessment, using standard techniques, for all significant rockfall hazards and implement action plan

Timing

High level assessment before mine development starts. During mining, formal risk assessments to be performed at regular intervals and when there is a significant change in operations.

Documents

- Tolerable level of residual risks to personnel
- Risk assessment document
- Communication to personnel

4.2 WORKING AREA RISK ASSESSMENT

Processes

- Develop and implement heading, or work area assessment process including:
  - Identify ground behaviour category according to catalogue
  - Identify ground related hazards
  - Identify how these hazards will be controlled
  - If required, notify supervisor and/or other relevant personnel and document

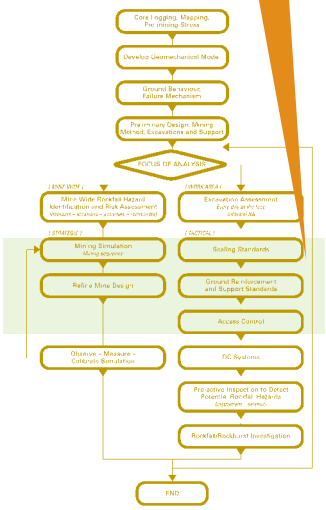
Timing

Apply standard procedure for assessing the ground every time anyone is entering a work area.

Documents

- Standard procedure for entering and working/operating in work areas
- Where relevant, in particular in areas with no surface support, excavation assessment forms could be used by underground personnel and routed to geomechanics office
- Communication system for unusual events or ground control issues
- Field book describing generic ground behaviour and rockfall hazards
- Where required, hazard plans of work area

Control Rockfall Risks



5. Control Rockfall Risks

The risk of rockfall is strategically controlled at the mine-wide scale by eliminating, modifying or monitoring the hazard and reducing it to a tolerable level. At the work area scale, the risk is controlled tactically by modifying, monitoring and protecting.

5.1 STRATEGIC CONTROL

Processes

- Optimise mining strategy and regional mine support using relevant simulation models (stress, personnel exposure) to minimise rockfall risks and to reduce likelihood and/or exposure
- Refine and modify preliminary design including extraction sequence, stope and pillar dimensions, fill, automation, mine layout, etc., based on simulations

Timing

Undertake processes from pre-feasibility onwards and into mine operation.

Document

- Report on simulations, eg., numerical modelling analysis, including possible recommendations for changes in design
- Benchmark good practices when considering changes in design

5.2 TACTICAL CONTROL

Processes

- Scaling standards
  - Develop and implement a standard procedure for hand scaling, including an auditable check scaling management system. All active areas of the mine that are not surface supported must be check scaled periodically on the basis of a risk assessment
  - Develop and implement a standard procedure for mechanised scaling
- Ground reinforcement and support standards
  - Develop and implement ground support standard installation procedures
  - Develop and implement a procedure for deviation from standard ground support, when unusual, or uncatalogued, ground behaviour is encountered
  - Define approach for rehabilitation of ground support, based on risk assessment
- Access control
  - Develop a standard procedure for controlling the entry of personnel to areas where exposure to rockfall hazards is higher than normal conditions

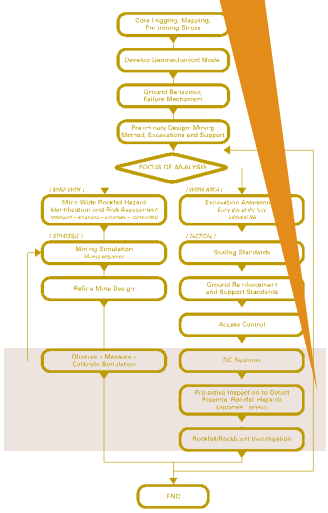
Timing

Before mine development starts and update periodically, or when there is a significant change in operations.

Documents

- Scaling standards
  - Hand scaling standard procedure, including check scaling management system
  - Mechanised scaling standard procedure
  - Safe work instructions for hand and mechanised scaling
- Ground reinforcement and support standards
  - Ground reinforcement and support standards
  - Safe work instructions for ground reinforcement and support
  - Deviation from ground reinforcement and support standard
- Access control
  - Access control standard

Monitoring Rockfall Risks



6. Monitoring Rockfall Risks

Monitoring may be used strategically as a feedback step in the design process or tactically as a warning system to control hazards or simply as a tool for quality control.

6.1 STRATEGIC MONITORING

Processes

- Observe and monitor stress change, rock mass deformation, seismicity, excavation volume/profile, reinforcement deformation, etc., to assess and document rock mass response to mining
- Compare encountered and predicted ground conditions and support performance. Analyse monitoring data and calibrate models, simulations and designs

Timing

During mine development and operation.

Documents

- Filing system or database of underground observations with possible use of data visualisation techniques
- Rock mass monitoring records and analysis

6.2 TACTICAL MONITORING

Processes

- Quality Control (QC) system
  - Implement a QC system for all reinforcement and support systems used (supply, testing, training, installation procedure, etc.) to ensure complete adherence to ground support standard
- Pro-active inspection to detect potential rockfall hazards
  - Perform systematic inspections periodically, for rockfall hazard identification and rehabilitation requirements, including assessment of the adequacy of ground reinforcement and support
  - Develop and implement a procedure which may involve report cards or white board posting, shift change discussions, etc., to communicate signs of potential rockfall hazards including rock noise, seismic data, ground movement, support deterioration, etc.
  - Monitor rock mass, using geotechnical instrumentation "as a warning system" and assess changes in rockfall hazards such as stress change, deformation, seismicity, weathering, etc.
- Rockfall investigations, records and analysis
  - Develop a procedure to initiate an investigation and implement a risk mitigation strategy when a rockfall occurs
  - Document all rockfalls and actions taken to control exposure to a similar rockfall hazard
  - Compile, analyse and communicate rockfall reports periodically
  - Review and modify excavation design and support procedures as required

Timing

Prior to, and during operations and when there is a significant change in operations.

Documents

- Quality Control (QC) system
  - Manufacturer's specifications of ground reinforcement and support products
  - Standard procedures to test reinforcement component performance
  - Specifications for support and reinforcement performance
  - Criteria for triggering action plan for poor reinforcement performance
  - Test records

- Pro-active inspection to detect potential rockfall hazards
  - Rock mass monitoring records and analysis
  - Inspection records
  - Procedure to communicate rockfall hazards
- Rockfall investigations, records and analysis
  - Procedure to initiate rockfall investigation
  - Rockfall reports, including what could be done to avoid re-occurrence
  - Rockfall database, photos, rockfall statistics, charts, etc., posted for the workforce
  - Report "analysis of rockfalls"

7. Audit

Audits can be performed at any stage of the rockfall management process. An audit can be either an independent assessment or a self assessment. External or independent audits may be required at appropriate time intervals.

Process

- Assess the implementation of design versus practices
- Check list to assess the level of implementation of this guideline
- Audit process to evaluate the effectiveness of the systems and procedures in place for rockfall management at the mine
- Audit data, interpretations, analysis, application and design
- Audit compliance with mine standards

Timing

At any time during the rockfall management process.

Documents

- Check list and audit records
- Backlog list of remedial action plans and requirements

8. Competency, Education and Training

The definition of competency and the requirement for education and training is relevant to every step of the rockfall management process. Site specific requirements for education and training are better defined after completing a risk assessment, Step 4 of the process.

Processes

- Induction and workplace standards awareness training for all personnel
- Basic geotechnical training for all underground orientated staff
- Define the geomechanics competencies required to understand and identify ground hazards for each relevant job that may be exposed to potential rockfalls (e.g. ground support crews, jumbo operators, geomechanical engineers, geologists, front line supervisors, managers, etc.)
- Develop and implement training and education programs for relevant personnel to acquire the geomechanics competencies, with periodic refreshers

Timing

At all stages of the rockfall management process.

Documents

- Geomechanics competencies for each relevant job
- Training records and demonstration of competencies

Minerals Council of Australia Disclaimer and Copyright

The Minerals Council of Australia, and its authors, editors and other consultants accept no liability (including liability in negligence) for and gives no undertakings concerning the accuracy, completeness or fitness for the purpose of the information provided. The Minerals Council of Australia takes no responsibility for any loss or damage which the user of this publication or any third party may suffer in relying on the information provided when making a decision affecting their interests.

Before relying on the material in any important matter, users should carefully evaluate its accuracy, currency, completeness and relevance for the purposes, and should obtain any appropriate professional advice relevant to their particular circumstances.

ISBN 909276935

Minerals Council of Australia
PO Box 363
Dickson ACT 2602

Mining Industry House
216 Northbourne Avenue
Braddon ACT 2612

Telephone 02 6279 3600
Facsimile 02 6279 3699

From November 2003:
Walter Turnbull Building
44 Sydney Avenue
Forrest ACT 2603

Telephone 02 6233 0600
Facsimile 02 6233 0699

Internet www.minerals.org.au

ABN 21 191 309 229
ACN 008 445 141

The Industry Guideline for Rockfall Risk Management was developed by the Australian Centre for Geomechanics for the Minerals Council of Australia.

Australian Centre for Geomechanics, The University of Western Australia Disclaimer
The information contained in this publication is for general educational and informative purposes only. Except to the extent required by law, The University of Western Australia makes no representations or warranties express or implied as to the accuracy, reliability or completeness of the information contained in this publication. To the extent permitted by law, The University of Western Australia excludes all liability for loss or damage of any kind at all (including consequential loss or damage) arising from the information in this publication or use of such information. You acknowledge that the information provided in this publication is to assist with you undertaking your own enquiries and analysis and that you should seek independent professional advice before acting in reliance on the information in this publication.