Vedanta Resources Plc

Sustainability Governance System

Guidance Note GN33

Fall of Ground

Guidance Note – Fall of Ground

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Confidentiality

1. INTRODUCTION

1.1. Who is this Guidance Note aimed at?

This Guidance Note is aimed at all Vedanta subsidiaries, operations and managed sites with underground mining operations and other business where underground or excavations works may be undertaken, including new acquisitions, and to all new and existing employees and contractor employees. This Guidance Note is applicable to the entire operation lifecycle (including exploration and planning, evaluation, operation and closure).

1.2 What is the aim of this Guidance Note?

Falls of ground are one of the major contributors to fatalities within the underground mining industry. The aim of this Guidance Note is to outline the company requirements which Vedanta implements in order to ensure that all risks associated with ground control are eliminated or minimised within an acceptable level.

1.3 What issues does this Guidance Note address?

This Guidance Note presents the framework for the management of fall of ground risks to avoid untoward incidents within Vedanta operations. The focus of the Guidance Note is on the provision of preferred methods and outcomes rather than being prescriptive whilst at the same time representing a practical "how to" guide for all Vedanta operators.

It is however recognised that the different operations are at different levels of "maturity" with regards to the development of systems to manage the risk associated with falls of ground (FOG). With this in mind, the Guidance Note includes two approaches as set out in *Annex A*:

- *Prescriptive Approach.* This establishes specific requirements that are deemed mandatory and are indicated by the term '**shall**.'
- *Risk Based Approach.* This is less prescriptive and is driven from the site, acknowledging its specific mining methods, ground conditions and the competency of its personnel.

In reviewing this Guidance Note, the site needs to decide which approach to adopt using competent advisors. Some sites will already have mature systems in place and it is recommended that a combination of competent internal and external reviewers determines the level at which the site is currently operating. Where a site is deemed mature with competent resources, a risk-based approach is acceptable. Where a site is immature and/or has limited competent resources, the prescriptive approach is to be adopted and Group will require assurance such measures are being implemented.

Those requirements that are associated with '**shall**' statement are mandatory irrespective of site maturity.

1.4 How should this Guidance Note be used?

This Guidance Note is mandatory (as per instructions in Section 1.3 above) and is intended to provide a standard baseline and reflect good practice whilst providing the basis for continual improvement of sustainability issues across the Vedanta business. The need for flexibility at a site depending upon specific circumstances or regulatory specific requirements is also recognised. This Guidance Note is not designed to be definitive text, nor is it designed to provide prescriptive methods and procedures for undertaking tasks.

In most cases there will also be national and/or local regulatory requirements which address ground control issues and sites must ensure that these requirements are identified and complied with.

The guidance has been designed to be applicable for all Vedanta operations, but is focused on mining sites.

The successful implementation of this Guidance Note is expected to require several years of dedicated commitment from all of the Vedanta mining sites depending on their existing maturity and controls.

The following provides guidance on how this may be achieved. This is not a mandatory approach but an equivalent implementation programme must be designed where the guidance is not followed:

- Each site needs to appoint a Ground Control Manager who will drive its implementation and is supported by a top line manager with authority to approve new requirements and will be accountable for successful implementation.
- Once a Ground Control Manager is appointed an audit needs to be conducted with competent resources to determine the current status of the site with regard to the elements of this guidance; ideally this will use resources from across Vedanta sites to enable a peer review to be conducted and create a community of practice amongst champions.
- The results of this audit are to be used as the basis of an action plan to implement those aspects that are currently not in place.
- Once this process has been started, an annual progress review will be required to ensure implementation is on track.
- The Ground Control Managers from each site are encouraged to share experiences and build further competencies and internal capacity within the Vedanta Group.

This document has been developed as a collaborative approach with input provided from within the Vedanta businesses including Joe Burke of Lisheen, Ireland.

The remainder of this Guidance Note is structured as follows:

- Section 2 – What Do We Mean by Fall of Ground?
- Section 3 – Contributory Factors to Fall of Ground Incidents
- Section 4 – Overall Management Approach
- Section 5 – Analysis Hazards and Risks
- Section 6 – Ground Control Management Plan
- Section 7 – Mine Design and Planning
- Section 8 – Implementation
- Section 9 – Monitoring
- Section 10 – Review

Annex A: Suggested Fall of Ground approaches for new/immature and mature operations
Annex B: Ground Control Management Plan Example

2. WHAT DO WE MEAN BY FALL OF GROUND?

A Fall of Ground is a natural movement of rock to realign itself with the induced stresses generated by the mining process. This movement is unplanned and unexpected with the potential to injure or kill persons working in the area.

The integrity of a mine structure is greatly affected by the natural weaknesses and discontinuities occurring in any rock mass. Geological discontinuities including slips, joints, bedding planes, transition zones, faults as well as damage to roof and rib as a result of drilling/blasting all contribute to the ground conditions found underground.

Other factors contributing to the ground conditions include the chosen mining methods, hydrology, geometry and size of excavation and stress regimes.

Falls of ground can also be induced by seismic activity associated with underground mining operations in zones of high stress.

Falls of ground can occur in a number of ways but the most common are:

- Gravity-driven falls including wedges and toppling from walls (low stress conditions);
- Stress-induced falls including shear driven failure, spalling, and squeezing; and
- Falls resulting from time-dependent deterioration.

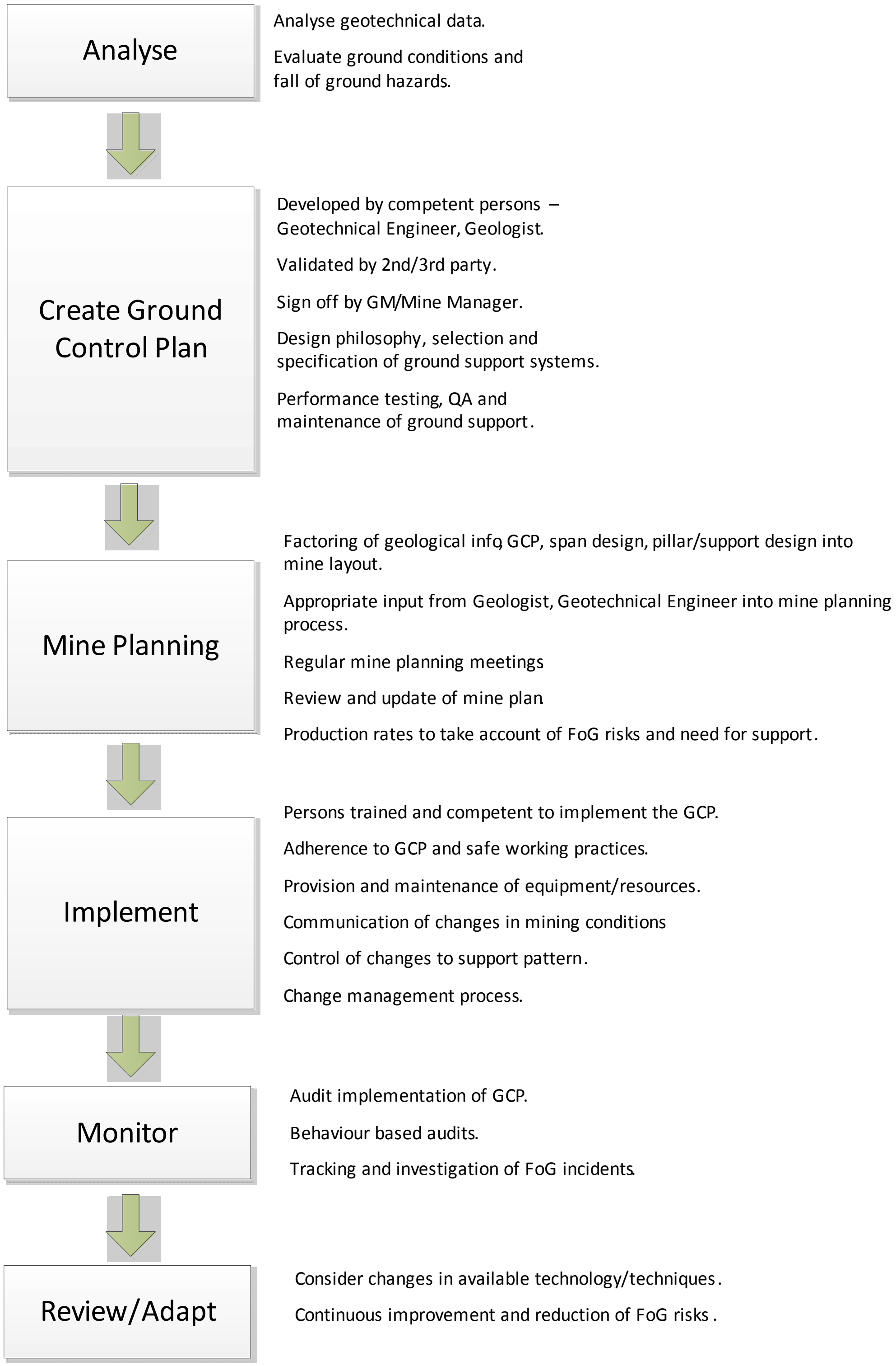
3. CONTRIBUTORY FACTORS TO FALL OF GROUND INCIDENTS

Industry experience has shown the most common causes or contributory factors to incidents involving fall of ground include:

- Inadequate knowledge of ground stability characteristics.
- Inadequate understanding of the in-situ and induced stress regime.
- Inadequate integration of support systems into the overall mine design.
- Inadequate control of applied ground support measures.
- Lack of monitoring of ground condition and support systems.
- Working under unsupported ground.
- At-risk barring and scaling down practices.
- At-risk installation of support practices.
- Carrying out remedial support activities.
- Failure of ground support systems.
- Poor hazard identification.
- At risk behaviour and non-adherence to standards.
- Non-compliant mining layouts including inadequate pillars, incorrect leads and lags, failure to overstope, and overbreak.
- Failure to identify and recognise the impact of geology.

4. OVERALL MANAGEMENT APPROACH

Every operation with underground mining activities should have a ground control management plan in place. This will typically analyse the ground conditions and recommend the appropriate level of ground support required, as illustrated in the following diagram.



Each of these phases is discussed in more detail in the following sections.

Annex A also provides an outline of the key requirements that should be considered as part of a Fall of Ground programme for new/immature operations and mature operations.

5. ANALYSIS OF HAZARDS & RISKS

A ground control management programme needs to be based on a thorough understanding of local and regional geology and rock conditions, including:

- Geotechnical aspects such as engineering geology, hydrology, soil mechanics, rock mechanics and mining seismology;
- Rock structure, including joints, faults, shears, bedding planes, foliation and schistosity (see Section 2); and
- Rock mass strength (influenced by many factors including rock type, compressive strength, mineralogy, condition, grade, groundwater, weathering etc.).

The programme should be based on methodologies established in recognised local and/or international guidelines and modified to represent local conditions. An example guideline is the Western Australian MOSHAB '*Geotechnical Considerations in Underground Mine*' Guidelines, 1997.

Code of practice/procedures should be established for the logging of cores, and databases maintained for the management of geotechnical and geological data. Data should be plotted spatially (i.e. in 3D), including calculated rock mass ratings.

Initial and on-going geotechnical analysis and assessment **shall** be an integral part of the mine design process and carried out by a competent person/s.

6. GROUND CONTROL MANAGEMENT PLAN

6.1 Scope & Basis for Development

A ground control management plan **shall** be developed for all underground mines with specific reference to the geological/geotechnical environment found at that mine. The ground control management plan should consider all the factors that are directly or indirectly responsible for the fall of rock.

All local legislative requirements should be used as a minimum standard for the ground control plan. In the absence of such a requirement, the ground control plan should be developed with reference to national or international best practice.

The ground control management plan is applicable to all areas of the underground operation. In addition to the active production and development areas this shall include:

- Permanent openings such as shafts, declines and inclines, haul roads, intake and return airways, workshops, crusher chambers, conveyor drives, main pump stations etc;
- Temporary openings such as stopes, stope access routes, drill drives, temporary raises, box holes etc.;
- Training areas and educational facilities;
- The influence of mining on surface infrastructure including paved roads, railways, pipelines, pylons and rivers etc; and
- The influence of adjoining mining operations on the current mining situation specifically with regard to blasting vibrations and underground water bodies.

Sufficient, suitably qualified, competent and experienced person/s should be involved in the integrated risk management process of design, planning and implementation of the ground control management plan.

The plan should be reviewed by an independent third party (to ensure objectivity) and signed off by the most senior manager at the operation (i.e. typically the General Manager or Mine Manager).

6.2 Ground Control Methods

The selection and consistent application of ground control methods is critical in protecting the people from falls of ground. The ground support should be appropriate to the ground conditions. Depending on the nature of the geology and identified fall of ground hazards, a variety of support systems may be used, often in combination.

Ground support tends to fall into two main types:

- Active local rock reinforcement/support systems such as pillars, packs, sticks, camloks, bolts and in-panel bolting; cabling, steel sets and backfill; and
- Passive support systems such as nets, mesh, straps, shotcrete and latex membranes.

The ground control management plan should describe the process for the selection, design and specification of ground support systems.

Design and selection of equipment and materials used in ground control applications should meet the requirements specified in the ground control plan and support performance specification. Selection of such equipment should be approved by a competent person (see Definitions).

The design of the mine support equipment should be capable of installing support as per the specifications of the ground control plan without necessitating modification of the ground control plan. In other words the ground control plan should be suitable to the support equipment.

Ground support requirements to deal with potential dynamic effects are a function of the seismic hazard. Areas of the mine where seismicity is expected to generate damage to excavation should take into account the potential dynamic effect from this seismic event.

Materials used in the ground support system should be designed and manufactured to audited standards to ensure they meet the required specifications of the ground control plan and performance specifications developed by the competent person.

Equipment used in the ground control system should be maintained and tested on a regular basis to ensure that it meets the ground control management plan requirements and performance specifications. A register and record of maintenance and testing by a competent person **shall** be kept.

Advances in worldwide ground control technology should be monitored, and appropriate engineering reviews should be conducted to determine whether new technology should be implemented or used.

Adequate contingency in ground control systems **shall** be provided by a multi-tiered ground support response plan.

In developing, implementing or altering any ground control system a geotechnical risk assessment process **shall** be undertaken and documented with a relevant level of sign off.

Documented procedures **shall** be in place to ensure the safe and effective installation of ground support.

No person should go beyond the area of secured ground except in specific emergency situations as declared by an appropriate level of supervision.

6.3 Equipment

Mining equipment design and use should incorporate removal or separation of the operator from unsecured ground, or the equipment **shall** provide a physical barrier to protect the operator in the event of an uncontrolled ground movement from hanging wall/roof or walls.

The mining equipment design should take into account the forceful ejection of material into the working areas by seismicity and/or fall from a significant height (i.e. energy absorption capacity).

6.4 Drilling/Blasting

Procedures and supervisory/monitoring arrangements should be in place to ensure that drilling and blasting is carried out in a way that achieves rock fragmentation with minimum damage to the adjacent rock mass.

Designs should be developed for use in drilling and charging in specific poor ground conditions. Appropriate drilling patterns, hole dimensions, lengths, charging densities and initiation systems and sequences must be developed to suit local conditions.

6.5 Scaling/Barring

Scaling (or "barring down") is necessary to remove loose rock from the sidewalls and the roof of mine roadways, particularly when rock and ore is removed by blasting. Those carrying out scaling are particularly at risk if they do not follow safe scaling practices.

Scaling can be carried out either manually using a hand-held pinch bar or mechanically (techniques such as high pressure water jetting have also been used in certain mining environments). Mechanical scaling generally provides the operator with a higher degree of protection as the person is normally enclosed in a protective cab, however there are many situations where manual scaling is the only viable option due to the working environment. Manual scaling should only be used to remove small scats (otherwise it shouldn't be undertaken) and it should be ensured that the person undertaking the activity is always located under supported ground.

Equipment to be used for barring should be appropriate and persons involved should be standing at a safe distance.

"Safe distance" needs to be determined from a specific risk assessment undertaken by a trained and competent person by considering the height of the excavation, the person doing the barring and the length of the barring tool being used.

The ground control plan should specifically address scaling/barring activities including methods, equipment and safe working procedures.

6.6 Monitoring of Ground Conditions

A process **shall** be in place for assessing that ground is secure.

Processes should be in place to monitor the behaviour of rock mass so that the effectiveness of controls can be assessed and warning provided of potentially deteriorating or unsafe conditions.

Systematic collection and analysis of data should be in place for the management of prevailing and predicted conditions and to assist with pre-empting changes to the physical conditions – such information should be communicated to all relevant personnel in advance of any change.

If the support system installed is not self-auditing then systematic and on-going monitoring **shall** be in place that assesses the implementation and effectiveness of the ground control system and integrity (from a geotechnical position) of the mining layout.

Where there is a potential for seismic, airblast or open pit blast damage to occur, seismic and/or vibration monitoring **shall** be carried out and where possible ensure that timely warning can be provided to all personnel.

6.7 Emergency Procedures

An emergency response plan to recover workers trapped under a fall of ground or isolated by a collapse should be in place at every underground operation, and practice drills/simulations undertaken on a regular basis. A "regular basis" timeline should be developed on the basis of a risk assessment taking into consideration the speed of mining and the turnover in production personnel. A register and records should be kept of such simulations.

7. MINE DESIGN & PLANNING

Ground control should be an integral part of the mine design process. The mining methods, development strategies (including production rates) and equipment selected should take into account the ground conditions.

When designing the mine layout, it is important that information relevant to fall of ground risks is taken into account, including:

- the ground control management plan;
- span design;
- ventilation requirements;
- auxiliary excavations;
- geological information;
- pillar and support design etc.

Similarly, the appropriate people/functions will need to have input into this process:

- survey;
- ventilation;
- geotechnical;
- geology;
- engineering.

The mine plan should take into account the ground control management plan and be adjusted accordingly.

As part of a change management process, a documented risk assessment should be undertaken prior to modification of the mine operation or design with specific consideration to the geotechnical impacts and signed off by a competent person.

8. IMPLEMENTATION

8.1 Roles & Responsibilities

Roles and responsibilities should be assigned to competent individuals for the implementation and maintenance of the ground control management plan.

8.2 Communication

There should be a process in place for the on-going communication between the geotechnical function, operations management and operators.

Shift change procedures should include the requirement to notify and document relevant personnel of changes to ground conditions and control.

The ground control management plan and related documents should be readily accessible by all employees as electronic copies for control purposes. Printed and unsigned copies should be treated as unauthorised copies.

8.3 Training & Competency

All personnel supervising the implementation of the ground control management plan should be trained and competent to do so.

All personnel working underground – and in particular face drillers and roof bolt operators - should be provided with training on fall of ground hazards and risk controls. This will normally include aspects such as:

- Identification of geological anomalies which contribute to weaker ground conditions.
- Support design principles.
- The ground control management plan.
- Placement and removal of supports.
- Recognition of indicators of change that may affect ground stability.
- On-the-job training and assessment.
- Requirements for reporting changes.
- Barring and scaling.

Competency and training requirements should be clearly defined in the operation's systems and procedures, and appropriate records maintained. Competency should be periodically assessed and refresher training carried out as appropriate. This is best determined on the basis of "planned task observations" (PTO's) and need to be conducted in a "mentoring" environment to give the most positive results.

9. MONITORING

9.1 Inspections & Auditing

Compliance to the ground control management plan should be ensured by:

- Recording and measurement of compliance to standards by the operators.
- Regular underground visits and inspection of compliance by line management.
- Regular underground visits and monitoring by the Rock Engineering Department.
- Regular underground visits by the Safety Department.
- Planned task observations.
- Periodic audits.

9.2 Reporting & Investigation of Fall of Ground Incidents

Clear procedures and processes should be in place for the identification, reporting and investigation of all falls of ground.

A mine site culture should be developed such that miners are willing to report all incidents without fear of retribution.

10. REVIEW

A formal, documented, periodic (typically annual) review should be carried out of the continuing adequacy and effectiveness of the ground control management plan and associated arrangements and practices for the management of fall of ground risks.

The review should:

- Take into account advances in mining methods and technology that could potentially be adopted to improve fall of ground risk control; and
- Include input by relevant technical specialists as well as senior mine management.

Based on the review, any necessary changes to the ground control plan should be identified and implemented.

RELATED DOCUMENTATION

A summary of the references and supporting documents relevant to this document is provided in the following table.

Doc. Ref.	Document name
POL 06	HSE Policy
TS 06	Supplier and Contractor Management
VED/CORP/SUST/MS 1	Leadership, Responsibilities and Resources
VED/CORP/SUST/MS 3	New Projects, Planning Processes and Site Closure
VED/CORP/SUST/POL 5	Supplier and Contractor Management
VED/CORP/SUST/MS 6	Competency, Training and Awareness
VED/CORP/SUST/MS 9	Documentation and Records Management
VED/CORP/SUST/TS 10	Safety Management
VED/CORP/SUST/MS 11	Incident Reporting and Investigation
VED/CORP/SUST/MS 12	Auditing and Assurance
VED/CORP/SUST/TS 13	Emergency and Crisis Management
VED/CORP/SUST/MS 14	Management Review and Continual Improvement
GN 01	Incident Investigation
GN 07	Risk Assessment
GN 14	Health and Safety Management Systems

Annex A: Suggested Fall of Ground approaches for new/immature and mature operations

The objective of the approaches set out below is to eliminate the risk of fatalities and incidents resulting from falls of ground (FOG) in underground mining operations, including stockpiles, waste dumps, dam walls and trenches. The suggested approaches presented below set out the key requirements to be adopted for new/immature operations and mature operations.

1) Prescriptive approach - for implementation on new/immature operations

Plant and Equipment Requirements

- Mining equipment design and use **shall** incorporate removal or separation of the operator from unsecured ground, or the equipment **shall** provide a physical barrier to protect the operator in the event of an uncontrolled ground movement from hanging wall, roof or walls.
- The mining equipment design should take into account the forceful ejection of material into the working areas by seismicity and/or fall from a significant height (i.e. energy absorption capacity).
- The design of mine support equipment **shall** be capable of installing support as per the specifications of the ground control plan. In other words the ground control plan **shall** be suitable to the support equipment.
- The performance specifications of materials selected for the ground control system should take into account the possibility of seismic events and the potential dynamic effect of fall of ground incidents.
- Materials used in the ground support system should be designed and manufactured to audited standards to ensure they meet the required specifications of the ground control plan and performance specifications developed by the competent person.
- Equipment used in the ground control system **shall** be maintained and tested on a regular basis to ensure that it meets the ground control plan requirements and performance specifications. A register and record of maintenance and testing by a competent person **shall** be kept.
- Advances in worldwide ground control technology **shall** be monitored, and appropriate engineering reviews should be conducted to determine whether new technology should be implemented or used.
- Support systems should be “self-auditing” from an installed quality control perspective. Equipment to be used for barring **shall** be appropriate and persons involved should be standing at a safe distance. Various methods include mechanised, basket or jumbo scaling.

Systems and Procedural Requirements

- An underground ground control management plan specific to the commodity being mined **shall** be developed for all underground mines. This **shall** be approved by a competent person and signed off by the most senior manager of the operation.
- All mines **shall** have access to a competent person who has relevant understanding of the conditions at the mine.
- All local legislative requirements **shall** be used as a minimum standard for the ground control plan. In the absence of such a requirement, a generic ground control plan should be developed in consultation with national or international best practices.

- Any ground control system **shall** be designed as an integral part of the mine design process.
- Design and selection of equipment and materials used in ground control applications **shall** meet the requirements specified in the ground control plan and support performance specifications. Selection of such equipment **shall** be approved by a competent person.
- Initial and on-going geotechnical analysis and assessment **shall** be integral parts of the mine design process and **shall** be carried out by a competent person.
- As part of a change management process, a documented risk assessment **shall** be undertaken prior to any non-routine modification of the mine operation or design, with specific consideration to the geotechnical impacts, and **shall** be signed off by a competent person.
- In developing, implementing or altering any ground control system, a geotechnical risk assessment process **shall** be undertaken and documented, with relevant level of sign off.
- Adequate contingency for ground control systems **shall** be provided by a multi-tiered ground support response plan.
- A process **shall** be in place for assessing that ground is secure.
- No person **shall** go beyond the area of secure ground except in specific emergency situations as declared by an appropriate level of supervision.
- An emergency response plan to recover trapped workers (e.g. trapped under a fall of ground or isolated by a collapse) **shall** be in place at every underground operation and practice drills/simulations **shall** be undertaken on a regular basis. A register and records **shall** be kept of such simulations.
- Systematic collection and analysis of data **shall** be in place for the management of prevailing and predicted conditions and to assist with pre-empting changes to the physical conditions. Such information **shall** be communicated to all relevant personnel in advance of any change.
- If the support system installed is not self-auditing, then systematic and ongoing monitoring **shall** be in place to assess the implementation and effectiveness of the ground control system and integrity (from a geotechnical perspective) of the mining layout.
- Where there is potential for seismic, airblast or open pit blast damage to occur, seismic and/or vibration monitoring **shall** be carried out, and where possible, timeous warning should be provided to all personnel.
- Documented procedures **shall** be in place to ensure the safe and effective installation of ground support.
- A documented risk assessment **shall** be conducted before any remedial work is carried out to improve or regain stability, and appropriate risk reduction measures **shall** be adopted.
- All fall of ground incidents **shall** be reported and documented.

People Requirements

- The most senior manager of the operation **shall** authorise the ground control plan and **shall** be accountable for its implementation and on-going effectiveness in accordance with this Standard and with local regulations.
- Roles and responsibilities **shall** be assigned to ensure implementation and management of the ground control plan by competent persons.

- A staged competency-based training programme **shall** be in place and **shall** be cascaded to all underground operating personnel. The training programme **shall** include, but not limited to, the following criteria:
  - Identification of geological anomalies which contribute to weaker ground conditions;
  - Support design principles;
  - The ground control plan;
  - Placement and removal of supports;
  - Recognition of indicators of change that may affect ground stability;
  - On-the-job training and assessment;
  - Requirements for reporting changes; and
  - Barring and scaling.
- Sufficient, suitably qualified competent and experienced person/s **shall** be involved in the integrated risk management process of design, planning and implementation of the ground control and mining plan.
- A process **shall** be developed and maintained for on-going communication between the geotechnical function, operations management and operators.
- Shift change procedures **shall** include the requirement to document and notify relevant personnel of changes to ground conditions and control.
- Behaviour-based observations **shall** include work and tasks associated with ground control systems. Any need for additional specific retraining **shall** incorporate the results of these observations.

2) Risk-based approach – for application on mature operations

Requirements

Develop and maintain an approved ground control management plan prepared by a competent person. The plan must, as a minimum, address the following requirements:

- Establish equipment and mining methods to separate and protect personnel from unsecured ground and prevent personnel from proceeding beyond secure ground.
- Set standards for the quality of ground support materials and the means for assuring the integrity of their installation, including frequency of examination and methods of repair.
- Identify how planned and unplanned changes to ground conditions will be communicated to affected personnel.
- Set standards for the monitoring and analysis of ground condition data, excavation stability and the effectiveness of ground support.

Undertake an annual review of the ground control management plan. The review must include:

- Review of previous incidents within the Vedanta Group;
- Review on site incidents and identify trends, hazards and risks;
- Review and measure previous objectives and targets;
- Setting of revised objectives and targets; and

- Measure effectiveness of critical controls.

Annex B: Ground Control Management Plan Example

The following section includes an example document that could be used as the basis for a ground control management plan.

Lisheen Mine

Ground Control Management Plan

M-DPR-04.25

Implementation date : ***7th May 2014***

Revision date : ***7th November 2014***

Prepared by the following persons:

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1 INTRODUCTION

1.1 Objective

This document serves as a guideline to ensure that the management of ground conditions and the support of excavations employ the best measures possible to maintain stable and safe mining at the Lisheen mine.

It is designed for the specific conditions as found at the mine and to conform with the Irish Mines and Quarries act, 1965[1], the draft Safety, Health and Welfare at Work (Mines) Regulations 2010 Part 6[2] and the Vedanta Sustainability Governance System GN33 - Ground Control Management[3].

These guidelines are subject to change and continuous improvement. Non-standard practices can occur if the ground and/or mining conditions change. Therefore this document will be regularly updated and critically reviewed to maintain best practice while understanding that there is no single exact answer to best practice.[4]

The implementation of the ground control management plan is the responsibility of the mine manager and the geotechnical engineer. Personnel should be regularly informed and trained on all aspects essential in keeping the workforce safe.

1.2 Scope

The scope of this Ground Control Management Plan is:

- To outline the Irish Legal Framework on Support in Underground Mines and the legal requirements of all personnel involved with the Geotechnical Department
- To describe the minimum support required to minimise the risk of fatalities, injuries and incidents resulting from falls of ground
- To guide personnel in considering all aspects of ground control while designing the mine
- To serve as a support design manual for all ground control personnel
- To offer a step-by-step checklist for ground control personnel while performing area risk assessments
- To summarize the available ground control methods including installation procedures and necessary materials
- To outline the ground monitoring and quality assessment options
- To improve the operations management by outlining the available communication and reporting pathways

- To offer proof of regular personnel training

The Ground Control Management Process is summarized in the following process map:

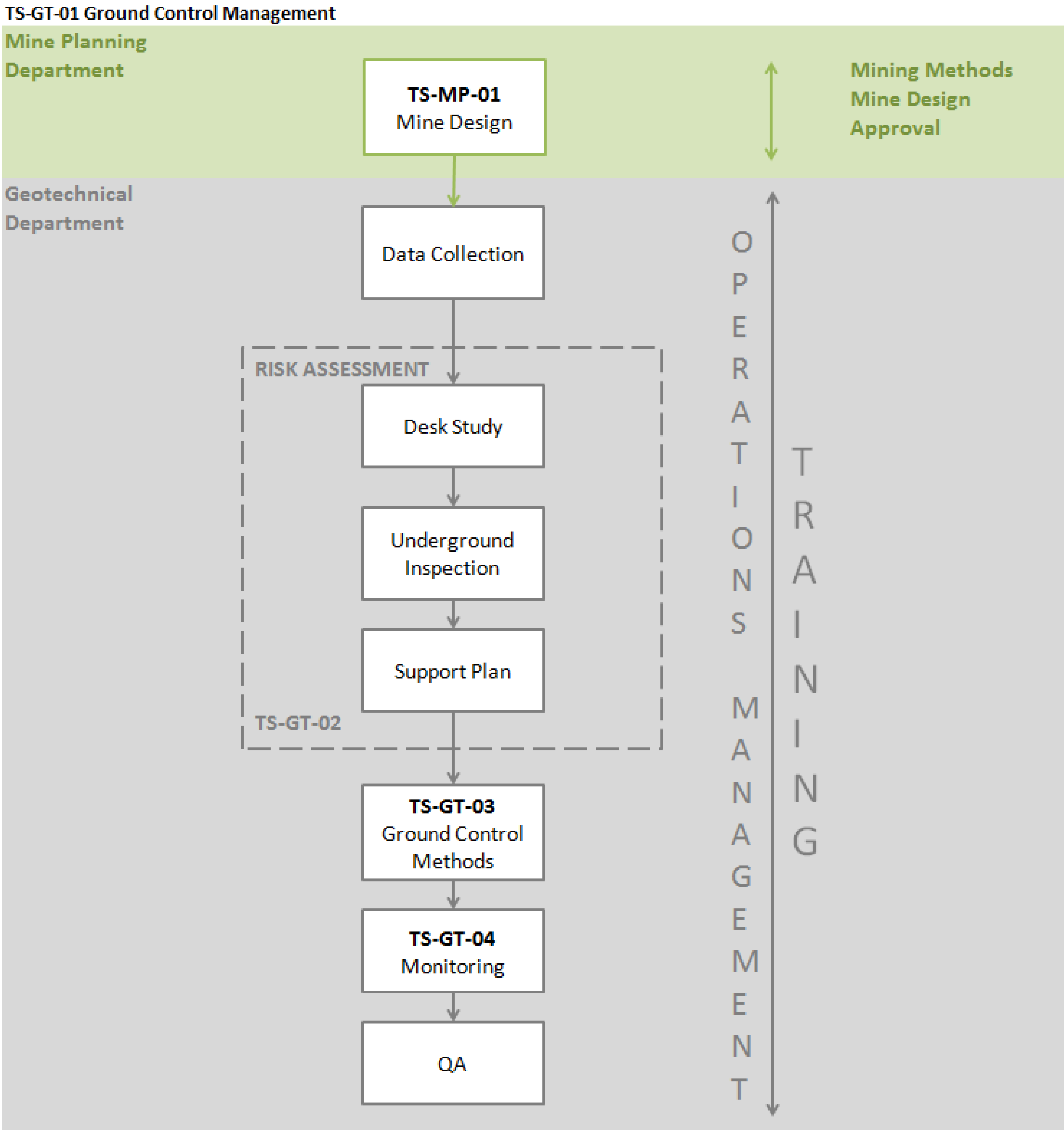


Figure 1: Ground Control Management Process (Process TS-GT-01)

1.3 Historical context[5, 6]

The Lisheen Mine commenced production in 1999. It is a high grade orebody currently mining ± 1.35 mtpa of 12% Zinc and 2% Lead. Mining methods are a combination of room and pillar, drift and fill and longhole open stoping (LHOS) at depths of between 70m and 230m below surface.

1.3.1 Locality

The Lisheen Mine (Zn, Pb) deposits are located in north County Tipperary approximately 150km south west of Dublin.

The mine is located in a rural area but connected with a well-established road network to the local towns of Thurles, Templetuohy and Urlingford and also to major cities of Dublin and Cork.

The concentrate is trucked by road to Cork port for shipment abroad for smelting.

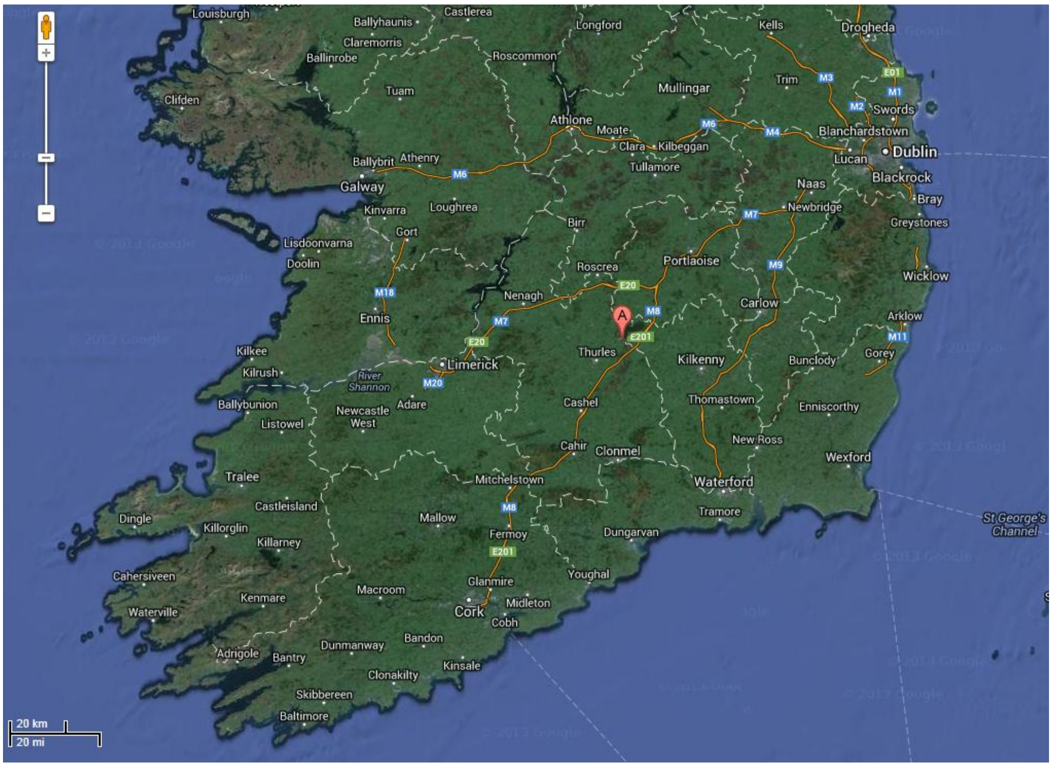


Figure 2: The Lisheen Mine, County Tipperary, Ireland[7]

1.4 Geological Setting

1.4.1 General Stratigraphy

The deposit is hosted in Lower Carboniferous hydrothermal breccias. These are developed at the base of a 200m thick, massive biomicrite limestone formation that has been extensively dolomitised.

This unit lies conformably above argillaceous bioclastic limestones (ABL) that form the lithological footwall to the mineralisation.

1.4.2 Structural Setting

The Lisheen deposit comprises four main economic orebodies, i.e. Main Zone, Derryville Zone, Island Pod and Bog Zone.

These orebodies are located in the hanging walls of northerly dipping echeloned extensional faults with displacements of the order of 200m. These are referred to as the Killoran, Derryville and Bog faults, respectively.

The faults are considered to be the primary control for the location of the orebodies. The ore is thickest in their immediate hanging walls, mineralisation is largely absent in the ramp-relay zones.

The detailed geometry of the deposit, however, is controlled by smaller displacement, low-angle faults and slides with short strike length. These faults appear to be confined to the Limestone - ABL contact zone.

1.4.3 Alteration

Two post-mineralisation structural episodes have significantly complicated the local orebody geometry.

A compressional event has inverted many of the pre-existing normal structures. Folds are commonly developed, centred on or sub-parallel to the smaller extensional faults. Larger compressional features are present where there has been buttressing against the footwall of early extensional structures. Here, thrusting has severely impacted orebody geometry and in Bog Zone East has duplicated the ore horizon.

A second episode produced sub-vertical, NW dextral wrench faults termed F-series with widespread associated NNW accommodation faults.

Most of these structures have minimal displacements and short strike length, although some can be mapped across the mine and can be up to 3m in width. They are typically filled with a coarse dolomite or a calcite gangue and are the main source of water inflow to the mine. These structures locally dislocate the orebody and are extensively karstified and severely impact geotechnical conditions.

Areas where these fault types coalesce are normally zones of intense disruption with very poor ground conditions over a large scale horizontally that tend to be cavernous.

The pervasive jointing is steeply dipping, sub vertical and sub parallel to the F-series faults. It is more intense in the hanging wall rocks and can be highly weathered.

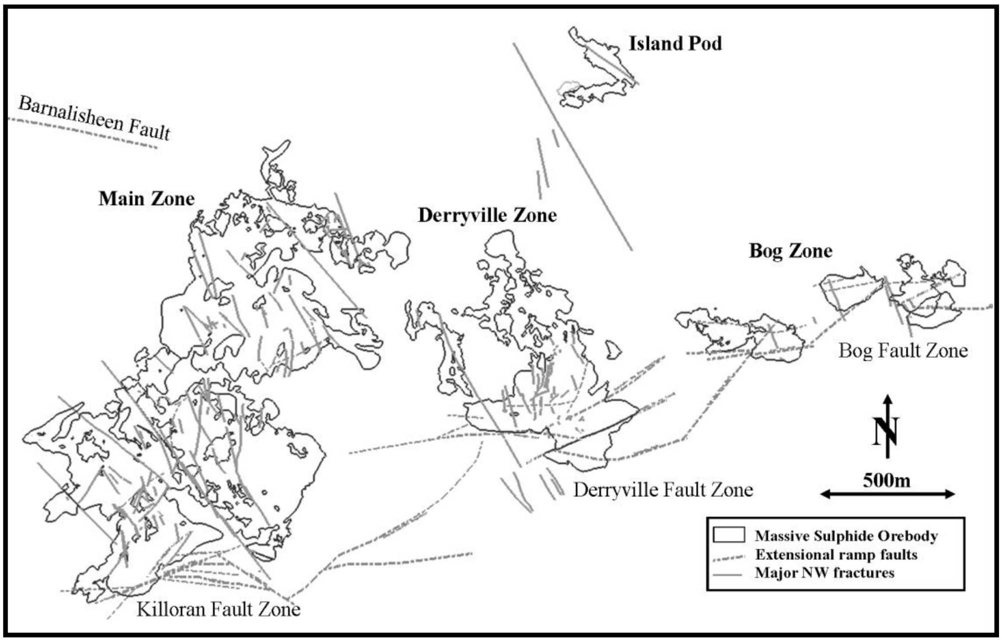


Figure 3: Plan showing orebodies and major structures

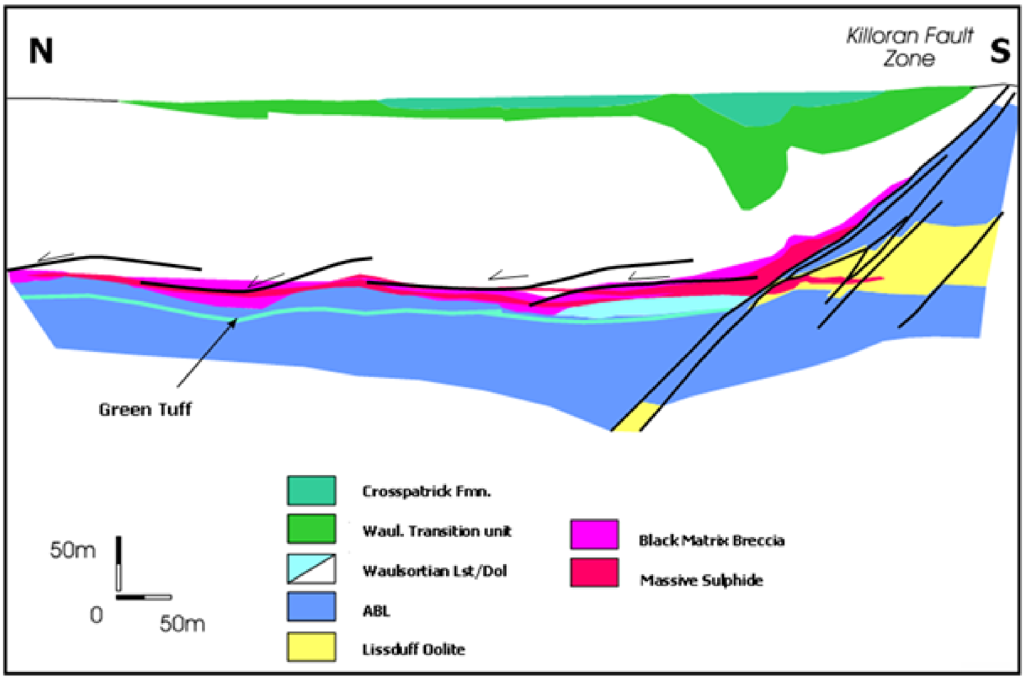


Figure 4: North-south cross section of the Killoran Fault Zone (Fusciardi, 2003)[8]

1.4.4 Stress Environment

The horizontal to vertical stress (K) ratio of 2.0 is extrapolated from orebodies in similar setting. The orientation of maximum principal stress is assumed to be NW-SE i.e. parallel to the F-series faults. The horizontal stress component normal to the principal is substantially lower given that many of the major structures have extensive cavity development.

Table 1: Lisheen in-situ stress conditions

Principal Component	Magnitude	Stress as 100m depth	Orientation
$\sigma_1 = \sigma_H$	2 x σ_V	5.4 MPa	NW - SE
$\sigma_2 = \sigma_V$	ρgh	2.7 Mpa	Vertical
$\sigma_3 = \sigma_h$	σ_V	2.7 Mpa	NE -SW

1.4.5 Mining Environment

The orebody at Lisheen lies at the base of a heavily dolomitised Limestone unit. It is bounded on the southern side by a North-East trending main mineralising fault and is criss crossed by a series of en-echelon North-West trending structures. An Argillaceous Bioclastic Limestone forms the footwall unit.

The host rock is mostly massive and extremely strong in its intact state with strengths of up to 150 Mpa. However it is rarely un-affected by structure which reduces its rock mass strength to between 30 and 60 Mpa.

The sulphide rich mineralization process has "leached" large sections of the hanging wall and areas around structures giving rise to what can be sandy clay like material which is difficult to suppor. It is difficult to determine the exact location and extent of weathering that has occurred in a particular area.

The ore horizon itself is usually massive sulphide rich material. It tends to have a lower intact strength than the hanging wall material and is subject to similar degrees of structural damage and weathering. It is also subject to degradation by the oxidation of exposed iron sulphide rich ore which can cause geotechnical issues in longstanding and back areas. The more iron rich the horizon the greater the intensity of jointing which can cause brittle failure in high sidewalls or pillars.

The footwall unit is a thinly bedded argillaceous limestone unit which is relatively strong in compression but weak in shear due to the presence of shale bands between the thin narrow spaced beds. When flat laying this unit presents few problems geotechnically, but exposure of the unit allows slabbing to occur, causing swelling of the clay bands resulting in loss of cohesion.

Lisheen is a low in situ stress environment. However in the tertiary stages of mining with extensive spans high induced stresses occur, particularly in pillar areas.

A series of North West –South East trending structures known as F1-F10 have large zones of weathering surrounding them and barrier pillars have been used to increase confinement (particularly in F7 and F8).

Along with poor ground these major structures also carry with them large quantities of water. The mine is currently pumping c.90 million litres of water daily from underground, with 17 million litres of that total coming from one source. This can make supporting some of the major features even more difficult. The management of the water inflows is a major consideration in the design, support, extraction and backfill placement.

Figure 5: An example of the water make from a single source at Lisheen

The presence of such high volumes of water presents specific geotechnical hazards:

- Mud rushes in breccia filled features when exposed.
- Loss of cohesion on joints or faults.
- Lateral water pressures in well jointed massive sulphide ore.
- Lubricating the ABL / Limestone / Orebody contact to create sliding wedges.
- Undercutting high sidewalls or pillars with tectonised ABL base.
- Difficult to ensure adequate grouting of cablebolts.
- Difficult to achieve good adhesion of shotcrete on wet surfaces.

2 LEGAL REQUIREMENTS

Sections 49 to 55 of the Mines and Quarries Act, 1965 deal with the support requirements for mines and are applied at the Lisheen Mine for all excavations.

They are described in **Appendix A.**

2.1 General Rules

Based on Section 55, the following Manager's Support Rules have been developed:

"*(1) Support rules for a mine shall be made by the manager of the mine.* "

The Geotechnical Engineer on a continuous basis will ensure that the support types and systems are appropriate for the changing conditions brought about by mining. Specifications may be formally modified during the life of the mine with the approval of the Manager.

The current Support rules are described in **Appendix B.**

2.2 Competency of Personnel

Only personnel deemed competent are allowed to manage any ground control issues. It is the duty of the Mine Manager to ensure the competency of his personnel in the different departments. Experience in the relevant departments and the necessary qualifications are required of personnel before they can be allowed the responsibility to work independently. New staff will receive the necessary training by competent supervisors.

All mining plans and designs are reviewed by relevant supervisors before approval for publishing is given.

2.3 Roles and Responsibilities

Below are the support related responsibilities for the relevant staff. More detailed job descriptions can be found in **Appendix C** for these and other relevant members of the Lisheen staff.

2.3.1 Duties of the Geotechnical Department

The Geotechnical Engineers must ensure that:

- Geotechnical data sufficient to provide adequate input for mine design and sequencing is collected, analysed, interpreted and communicated.
- Timely advice is given to the Production and Technical teams for the purpose of mine planning, design and sequencing.

2.3.2 All Underground Personnel

The following requirements are mandatory for any employee or contractor conducting any work underground.

- No person shall travel under unsupported ground.
- All personnel working underground should ensure the ground conditions in their working area are safe. This is primarily done by regular 'check scaling' (or sounding the ground) and 'barring down' unsafe ground – never assume the ground has been assessed prior to your arrival.
- As ground condition hazards are identified during any task in the work cycle, scaling or other appropriate action must be taken immediately or the heading should be barricaded until other personnel make the area safe.
- Personnel shall not undertake ground control tasks unless they are assessed as competent to complete the task. The exception is that they can work under direct supervision of a competent person.
- Look for and obey the instructions implied by barricades.
- Look for loose rock between support elements.
- Inspect the previously installed ground support.
- Look for any signs of deteriorating or changing ground conditions. These may include:
    - New fracturing in backs and walls.
    - Cracks opening in the floor, walls and backs
    - Bulging mesh, cracked shotcrete
    - Failed or loaded rock bolts and cable bolts.
    - Rocknoise
    - Rock falls
    - Corroded support
    - Buckling of walls
    - Footwall heave
    - Drive closure and deformation
    - Deformed of squeezing rock
    - Presence of geological structures
    - Increase in water inflows.

Be aware that vent bags and services may obscure ground conditions hazards.

Any change in ground conditions must be reported to the shift boss /supervisor who must take immediate action and report it to the geotechnical department.

3 MINE DESIGN

In every step of the mine design process, ground control must be considered. It has a big influence on the choice of mining method (entry vs non-entry), the extraction sequence (primary, secondary and tertiary mining, pillar stresses,) and the production schedule (pre-support, back filling, etc). Therefore each step in the process requires the input and approval of ground control personnel. Sign-off procedures are in place for every design, plan or long-term schedule.

3.1 Pro-active Geotechnical Input for Effective Planning

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

Mine Design includes:

- Selection of suitable mining method, including backfill requirements.
- Optimisation of excavation size, shape and orientation within each rock domain and stress regime.
- Assess methods to control overbreak, including controlled blasting, presupport, systematic pillar and limiting spans.
- Define ground control requirements for each type of excavation, location and expected behaviour, as already outlined. This will be based on recognised and appropriate design approaches.
- Select the most appropriate ground control system(s), based on the requirements, exposure of personnel, life of excavation, mining induced stress changes, corrosion resistance, etc for the anticipated change in behaviour.
- Undertake ground control design analysis.

This work should be undertaken from pre-feasibility stages and completed before excavation commences. The process should be reviewed and improved upon periodically during the excavations operational life, to ensure it remains satisfactory.

An important part of managing ground control is to relate observations of excavation performance to planned mining and stoping.

Geotechnical input into preliminary development, stope and general mine design and sequencing will have a substantial impact on operating efficiency and business performance, as issues are best forecast and pro-actively managed rather than allowed to occur and re-actively managed.

3.2 Rock Material Parameters

The rock material physical properties play a major role in designing underground excavations. However in the later stages of mining with changes brought about by induced stresses the understanding of rock material behaviour at Lisheen is more critical.

A description of the main parameters is given in the following table:

Table 2: Lisheen Rock Parameters

Description (Zn, Pb, Fe)	Description of the geotechnical domain (average metal grades)
UCS	Uniaxial Compressive Strength
RQD	Rock Quality Designation index
RMR	Rock Mass Rating
Q	Rock Tunnelling Quality Index
DRMS	Design Rock Mass Strength
E_m(GPa)	Young's modulus
Nu	Poisson's Ratio
K(GPa)	Bulk modulus
G(Gpa)	Shear modulus
Behaviour	Site characteristic behaviour and potential failure mechanisms

The following table summarizes the rock material parameters and behaviour for each domain used in the design process:

ROCK TYPE	Description (Zn,Pb,Fe)	UCS	RQD	RMR	Q	DRMS	Em (GPa)	E (GPa)	nu	K (GPa)	G (GPa)	Friction	Cohesion	Density	Behaviour
Overburden WMB	Bedrock to ~120m. Rock intact but leached and vuggy with axial jointing. (0,0,0)	190	40	40	1-2	30	5.84	55	0.23	3.6	2.35	30	3.84	2740	Intact very strong, exposed controlled on structures.
Hangingwall BMB	120m to ore contact. Rock weathered, jointed with clay infills, wet. (2,0,4)	186	50	50	5	50	9.97	60	0.25	8.75	3.75	32	6.4	2700	Generally clean solid intact rock, jointed and weathered will have little shear value.
Massive High Grade	Massive blocky material with prominent vertical jointing closely spaced. (15,1,30)		75	60	10	38	25.56	65	0.30	25	9.6		8.96	4500	Very brittle under load - low residual strength, slabby sidewalls particularly if overheigh.
Massive Low Grade	Massive blocky material with little jointing random bedding horizons. (6,0,35)	176	85	70	15	70		80	0.25					4200	Poor contact surface with HW, can occur in hidden domes risky at turnouts.
Disseminated	Banded / erratic material usually with poorly defined HW and barren sections (10,1,10)		75	70	10	70		65	0.30	25	9.6	34	8.96	3200	Strong rock with structures defining behaviour. Once scaled and bolted - secured.
FW contact Tectonic Zone	Tectonic in immediate FW ~2-3m, dirty thin banded zone with calcite bedding. (0,0,0)		20	20	0.5	5		30	0.35	4	2.5	25	3	2700	Unfolds when unconfined, selfmines and undercuts ore/pillars weathers quickly in water.
ABL	Deeper into FW, more massive with wider spaced bedding. (0,0,0)	164	50	40	10	70	7.22	60	0.25	6	2.75	34	8.96	2700	As above if exposed, confined a well laminated rock that requires surface support.

Table 3: Summary of the rock material parameters used in the design of excavations and pillars

3.3 Mining Methods

The mining method selected in any area will depend on the orebody thickness, grade, orientation, geometry and ground conditions.

3.3.1 Long Hole Open Stoping

The subsequent steps are visualized in Figure 6.

Step 1

A 6m wide primary drift is developed on the footwall the full length of the stope (60-100m). It is supported as required with rebar, shotcrete and cables. In secondary stopes the drift is developed alongside the backfilled stope with a slender pillar on the opposite sidewall. The support design will follow procedure M-DPR-4.17 for mining alongside or through paste. This is discussed in more detail in Sections 6.6.4 and 6.6.4.4.

Step 2

Where poor ground has been identified, either in the orebody or in the hangingwall, pre-support in the form of long bulbed cables are drilled through the orebody and anchored (grout encapsulation into at least 5m of solid hanging wall material).This support is to assist interlock the hangingwall beam and provide confinement. It **DOES NOT** provide support for the stope and the resulting void **remains a no man-entry excavation.**

Step 3

Once the development is complete the production drilling starts.

Step 4

The stope is retreated on a ring by ring basis and remote mucked from a distance. Some of the stopes can be up to 30m high, 25 m wide and 100m long with individual blasts of between 2,000T and 10,000T and in exceptional cases larger.

The stope void is backfilled as soon as possible to minimise the risk of roof failure, deteriorating sidewalls and surface subsidence.

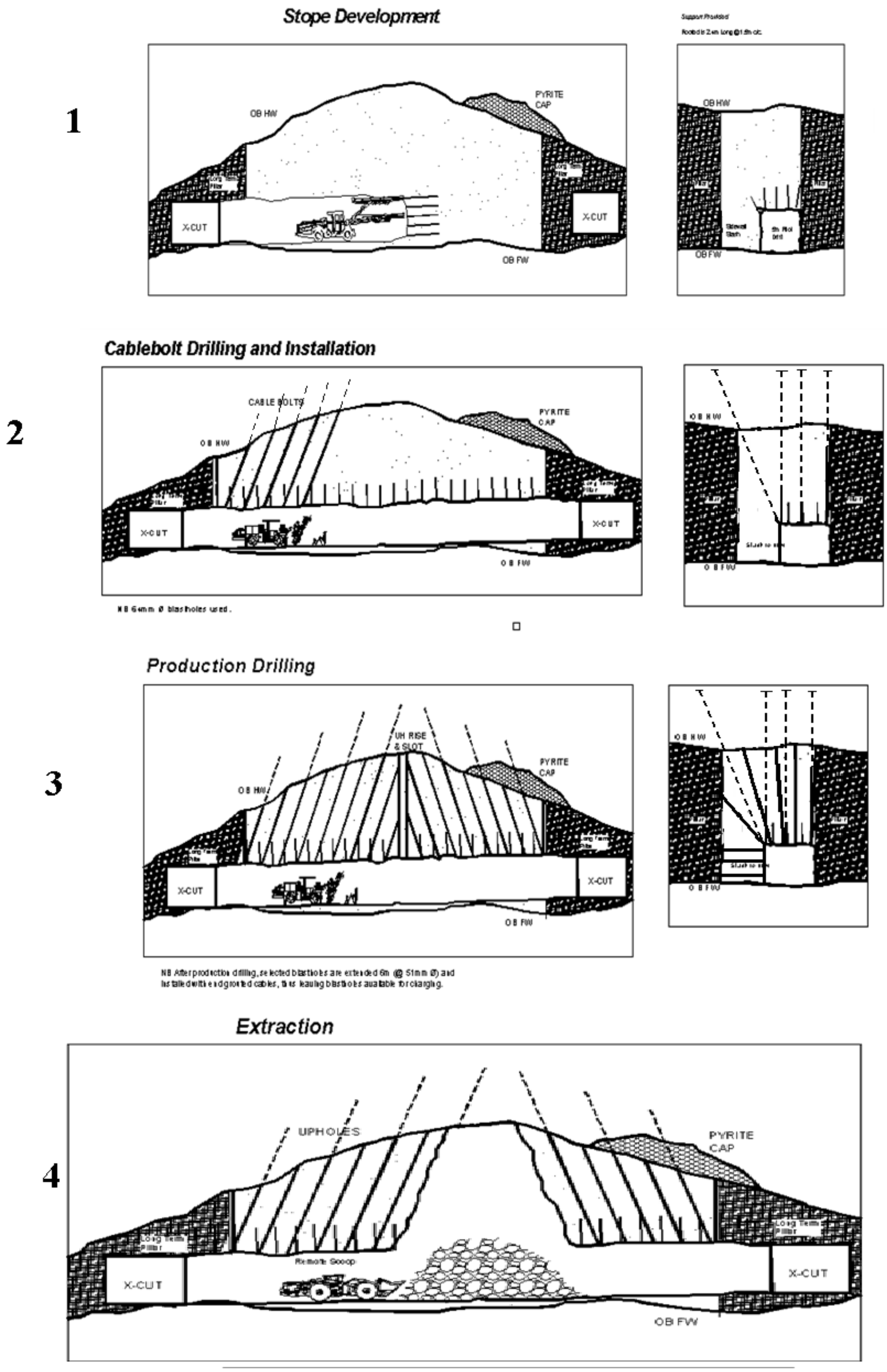


Figure 6: Long Hole Open Stoping

3.3.1 Drift and Fill

Drift and fill mining is used in areas where the ore is less than 8m thick of an extent and grade to allow full extraction.

A 6m wide primary drive is driven on the hangingwall contact to its planned limit (40-100m). A 4m wide slash is developed at the end as a hammer head. Any remaining ore is then benched in the floor.

A 4m wide slash is then predrilled using a longhole rig over the length of the drive. This slash is blasted in increments as required and mucked on remote. Small pillars can be designed and left to control spans or provide local support as required. The drift is then backfilled.

The following figure shows a plan view of the drift and fill mining method.

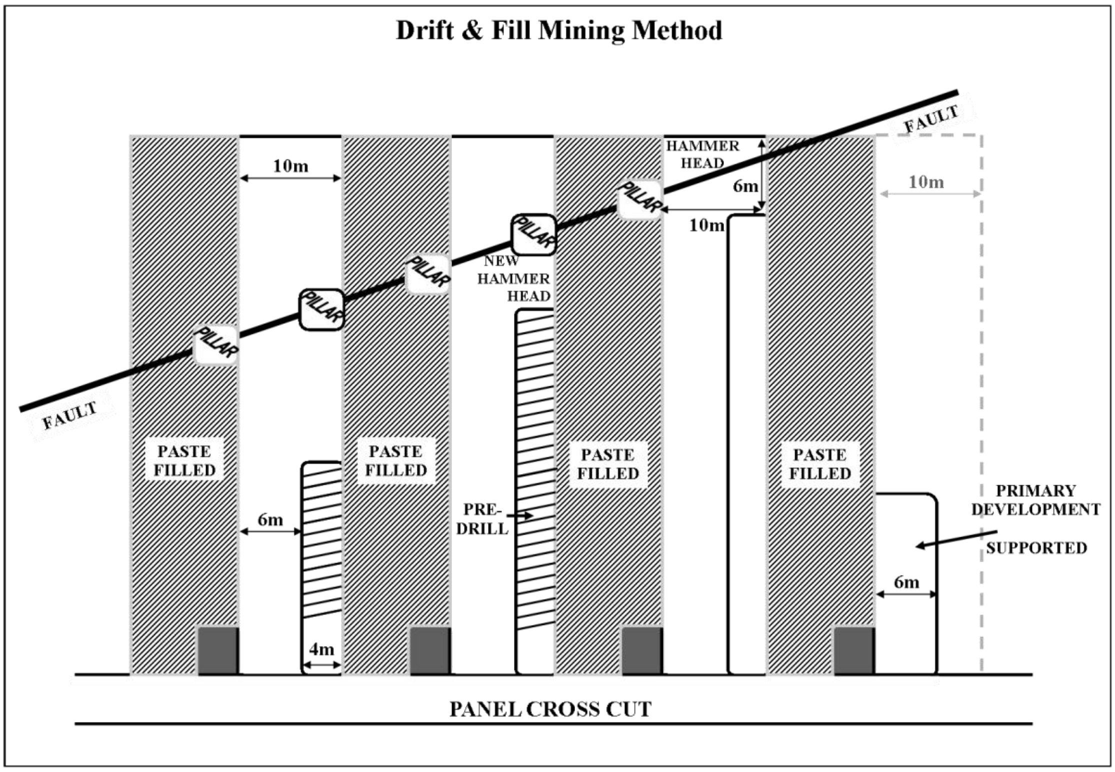


Figure 7: Drift and Fill Mining

3.3.2 Room and Pillar

Where the ore is thin and multi levelled with poor ground conditions a room and pillar technique aimed at maximising extraction is used. Sacrificial yield pillars may be left for regional stability if necessary. Pillars are monitored for changes in condition throughout the extraction sequence and can be sacrificed or the extraction sequence accelerated should the need arise.

Primary development is carried out using a conservative pillar strength design to give a factor of safety greater than 2. This is verified by modelling and close observation of the development. Panels are designed around the orientations of major structures and ground conditions. A suitable hydraulic radius would be designed for the panel that could vary from 5 in poor ground to a maximum of 25 in very good ground. A strict protocol for ensuring that total extraction of the panel is used that includes pre-drilling pillars, remote mucking, monitoring of both the roof beam and pillar behaviour, strict adherence to individual pillar removals and partial filling if required.

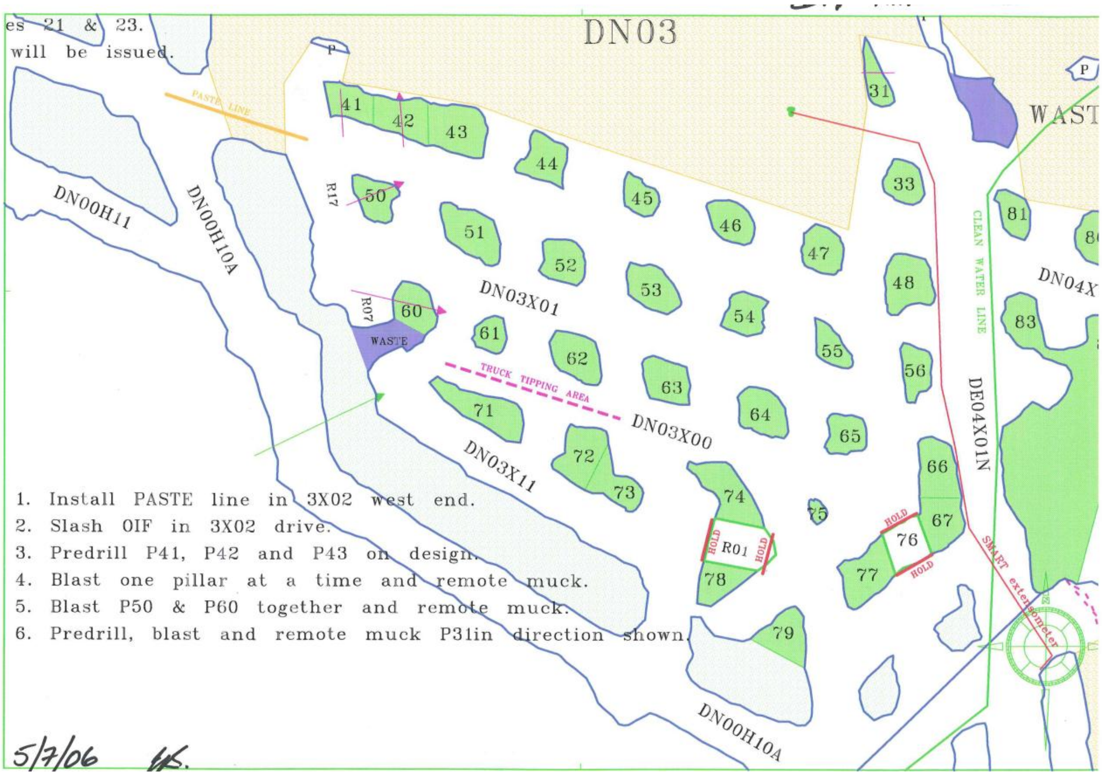


Figure 8: Example of Room and Pillar Mining at the Lisheen Mine

3.4 Approval

Each mine plan (development, stoping or pillar mining) is designed, taking into account ground conditions and in discussion with ground control personnel.

Final plans are reviewed by all relevant parties and plan execution is only possible when the plan is signed off by the geotechnical engineer.

Formal sign-off procedures are in place for all major tasks in every department. An example of such a sign-off certificate is given in **Appendix D.**

The following plans are reviewed and signed off by the geotechnical staff:

- Mine Designs or "Noddy Plans"
- Final Design Revisions
- Diamond Drilling Plans
- Reserve Estimations

The following procedures require **input** as well as approval from the geotechnical engineer:

- Paste fill Clearance: Type of backfill, strength of fill, degree of tight fill required and future exposure.
- Long Hole Design sign off: Review of plan, assessment of existing support, discussion of geotechnical risks and special roof and/or sidewall support, instalment of instruments, reporting of ground conditions and cable bolt requirements (see example in **Appendix D**.
- Pre-support Plans
- Room and pillar firing sequence

4 GEOTECHNICAL DATA COLLECTION

A systematic approach to the collection, analysis and interpretation of geotechnical, geological and hydro geological data is used. The main source of this data is diamond drilling, and data collection is ongoing during mining operations.

This includes logging of diamond drill holes, underground mapping, cavity monitoring, visual inspections of ground behaviour and critical examination of all ground movement incidents.

All information is kept on a database that can accessed by planning, geotechnical, drill and blast and scheduling for design and tracking purposes.

4.1 Geological Core Logging

Surface and underground diamond drilling is undertaken to investigate the geological, geotechnical and hydrogeological site characteristics. To date approximately 4,100 underground holes and 2,200 surface drill holes have been drilled

The diamond drill cores record structures, cavities, zones of weathering and significant changes in lithology. A systematic geotechnical log is done on all ore intersections and immediate hangingwall and footwall contacts. A less detailed form of geotechnical logging is done on the remainder of the diamond drill core. The logging is done with a wide range of parameters that can be utilised to obtain several classifications. The specific ground conditions at the Lisheen mine necessitated a site modified RMR system.

Geological logs are available for detailed description of the lithology and mineralisation of the cores.

Drilling Diamond drilling is regularly used to confirm ground conditions, probe paste contacts or identify water bearing structures.

4.1.1 Core Photos

Photographs such as in Figure 9 are kept for all surface and underground boreholes and can be viewed electronically to verify the presence of large cavities, structures and weathering.

The core photos can be found HERE.

4.1.2 Rock Properties

Rock property testing was done on cores to obtain values for the uniaxial compressive strength, tensile strength, deformation modulus, point loading , permeability and shear of all rock domains.

The values of the most critical parameters are given in Table 3 above.

4.2 Geological Face Mapping

All development faces are mapped to assess their geological characteristics. The differences in lithology and grade are recorded as well as a qualitative description of the ground conditions and structures.

Geotechnical information regarding hazards, structures, water, support requirement and ground behaviour is also recorded and forms the basis for the geotechnical daily visits.

Figure 9: Diamond Drill Core Photo (Class 4 ground)

5 RISK ASSESSMENT

Despite being in the tertiary stages of extraction with extensive mining in all area, the karstic nature of the ground still makes it difficult to predict the exact location of major structures and the extent of weathering and poor ground associated with them.

The effects of mining induced stress and displacement, the impact of overbreak, increased spans and effectiveness of backfill on such ground need constant evaluation.

In all mining both stoping and development the planning engineers will develop a concept design which is then risk assessed by the geotechnical section but with involvement from all technical services and production supervisors.

A preliminary assessment based on a site modified Bieniawski RMR system is used to evaluate the mining risk. Ground falling into classes 1 (RMR >60), do not require further assessment, unless previous mining history or planned mining geometry suggests otherwise. In poorer ground conditions (Class 2 to 4 RMR < 60) further assessment is undertaken. An example of the site modified RMR system is given in **Appendix E**.

Secondary and tertiary mining areas are assessed using a mining rock mass rating (MRMR, Laubscher, 1990) to take into account blast damage, backfill exposure and geometry. Excavations to be developed in poorer ground (RMR <60) or through structures, alongside paste fill or with large spans are fully assessed utilising a formal process spreadsheet.

Prior to design approval the geotechnical department must accumulate a list of predetermined data and evaluate these in order to prepare for entry into a stope, panel, development drive or remnant pillar area.

These area assessments form the basis of a risk assessment for all planned mining areas. An example of the checklist used for these area assessments is given in **Appendix F**. The assessments are compiled under the following headings:

5.1 Desk Study

A desk study is conducted by compiling as much of the information about the area as possible namely:

1. **Predicted Ground Conditions**
   A database was constructed using geotechnical logs of boreholes for the first 2m above the hanging wall and a category assigned to the ground conditions based on the logs. The ground classifications are site specific and based on the critical parameters that influence the ground conditions at Lisheen namely RQD, fracture frequency and degree of alteration. These are divided into 4 categories:

   - Class 1 Ground Conditions have an RQD of between 61 and 100 and usually feature an intact or near intact rock mass with little or no weathering.

Class 1 ground is usually supported using a standard resin grouted rebar 2.4m long on a 1.5m X 1.5m pattern.

- Class 2 Ground Conditions have a RQD of between 41 and 60, normally poorly jointed with slight weathering or minor fractured rock mass. This ground is usually supported using a combination of standard rebar and occasionally shotcrete where necessary.
- Class 3 Ground Conditions have a RQD of between 21 and 40 and usually feature an intense degree of jointing, would be moderately weathered and may have significant structures or water. This ground is supported with a mixture of bolting, shotcrete, cable bolts and mesh or straps.
- Class 4 Ground Conditions have an RQD of between 0 and 20 and is usually associated with the worst ground conditions at Lisheen. The ground is highly weathered and fractured and may have large cavities or clay/sand pockets. It is supported with a mixture of bolting, shotcrete, cable bolts, long cable bolts, pressure grouting and spiling.

NOTE: Area ground conditions can change in time due to mining operations in the area and should be regularly reviewed and updated accordingly

2. Diamond Drilling Surface and Underground

The relevant geotechnical and geological logs of surface and underground diamond drilling are scrutinised for indications of major structure, zones of weathering and significant changes in lithology.

3. Local Structure

The mine plans are scrutinised to determine if any of the structures encountered before can be found in the area being assessed and the possible impact on both development and stopes.

4. Core Photos

Photographs are kept for most of the surface boreholes and can be viewed electronically to verify the presence of large cavities, structures and weathering.

5. Face Sheets

The face sheets of surrounding development contain geological information as well as a qualitative description of the ground conditions.

6. Pyrite Hazard

An assessment of the presence, the depth, thickness and condition of massive pyrite in the roof of excavations.

7. Existing Support

Support that is in place currently, its condition and how it is performing.

8. Recent Mining

Any mining that has been conducted in the area and its influence on the roof beam and stress transfer, the history of the nearby excavation, overbreak, water make and stability.

9. Span to be created

This involves the maximum span that will be created at any stage during mining. A stability graph method is used to design an appropriate span for given ground conditions. In areas of uncertainty numerical modelling is also used.

10. Pillar Height to Width Ratio

The existing height to width ratio of the existing pillars or the height- width ratio to be created at any stage during mining to evaluate the changing stress loading of pillars to be created is evaluated to ensure that any stress changes can be accommodated using either the Tributary Theory formula or numerical modelling.

11. Paste Backfill Exposure

If there is paste exposed in any of the excavations the quality and condition of that paste, the degree of tight filling, the presence of voids and the strength of the fill is reviewed. Any possible unfilled areas are also investigated along with the possible presence of water.

12. Extraction sequence

Review the planned extraction sequence and ensure that it is appropriate for the ground conditions in the area. This will optimise the safe drilling and throw of muck for ease of recovery.

5.2 Underground Inspection

Confirmation of the findings of the desk study is undertaken by an underground visit to evaluate:

13. Stability Assessment

A visual assessment of the stability of the area, slabbing, falls of ground, deterioration of sidewalls or pillars is carried out.

14. Support Assessment

An evaluation of the support requirements and the existing support and its suitability and performance. The effect of corrosion and the influence of any new spans on the existing support is evaluated.

15. Pillar Assessment

A description and classification of the condition of the pillars in the mining area based on a visual assessment.

16. Risk Assessment

A chronological list describes potential future issues and in which order they are likely to arise. This allows the geotechnical section to deal with and prevent issues before they are expected to occur and prioritizes specific issues during the different stages of mining.

In areas where a higher level of risk is present a detailed integrated risk management format is used involving all stakeholders to identify and put in place measures to manage the risks.

A copy of the format and completed risk assessment is attached in **Appendix G**.

17. Further Geotechnical Investigations

A list of any recommended further actions required to be conducted in order to gain a better understanding of the ground conditions. This may be additional diamond drilling, probes or remodelling.

5.3 Actions Required

A list of recommendations for the area in question

18. Additional support required.

Support plans and instructions all completed, breaker lines of cables, bullnose support, shotcrete arches etc.

19. Instrumentation Required

Does the area require physical monitoring activities such as stressmeters, extensometers, telltales or stress disks.

20. **Communication required**

Who needs to know this information and how do we communicate this information to them. In high risk areas where information must be constantly communicated a board is erected at the entrance and updated as required.

21. **Follow up summary on completion of the mining area.**

What are the learnings that have arisen as a result of the mining of the area? What would we have done differently with the benefit of hindsight? Also includes closure instructions for the panel. I.e. waste/ paste filling.

The assessments allow for the prediction of the ground behaviour in a particular mining area before mining commences thus allowing the introduction of mitigation measures through support, monitoring, change in design or simply communication which will allow the maximum extraction in the safest possible conditions as a result of mining in poor ground.

The assessment is discussed with the planning engineers and production officials prior to commencing of the stoping.

All assessments are archived in their designated folders and are available for examination. All areas being worked are reviewed weekly by the geotechnical engineer to ensure that the assessment remains valid and update if necessary.

The digitized area assessments can be found HERE.

5.4 Tips of stockpiles

Surface stockpiles are generally not used at Lisheen. Where used, (i.e. Galmoy ore) the stockpile is monitored by the Geotechnical Department.

A geotechnical appraisal is performed on the stability of this stockpile and the stability of the planned future extension. For this the 2008 quarry regulations were used.

Guidance is given on the area extent, bench heights and face angle. Monitoring of water settlement and ramps is put in place, operators are trained as to tipping, dozing and undercutting benches.

Procedures are in put in place to ensure that these safe conditions are maintained at all times.

5.5 Lagoons and dams

The Tailings Management Facility (TMF) is managed and monitored by the mill staff who have employed a consultancy services company to advise and guide.

6 GROUND CONTROL METHODS

6.1 Classes of Support

The support specifications given below for the different types of ground represent the minimum support that must be installed. Any employee may recommend additional support in the interests of safety and such support may be installed with the authorization of a Shiftboss or higher official.

6.1.1 Minimum Support Levels

In the absence of a non-standard support specification, a 1.5m diagonal pattern of 2.4m long rebar must be installed by default. All excavations must be supported.

6.1.2 Guideline Support Table

Table 4: Guideline Support Table

ROCK CLASS	Class 1 GOOD	Class 2 FAIR	Class 3 POOR	Class 4 Very Poor
ROCK MASS RATING	80 - 61	60 - 41	40 - 20	<20
SUPPORT TYPE				
Pattern bolting (1.5m diag.)	********	*******	****	
Pattern bolting (1m square)			****	*******
Shotcrete 50mm (Plain)		***	***	
Shotcrete 75mm (Fibre)			****	*******
Cable bolts			****	*******

6.1.3 Primary support

Primary support will be a systematic rockbolting pattern and will be installed to stabilize the ground and ensure safe working conditions.

Support will be installed to within 1.5m of the face following scaling and before any further work. All hammerheads, breakthroughs, holings or 'last round' ends must be supported.

Support will only be installed following scaling of the excavation. Any changes in ground conditions must be reported to the geotechnical department.

6.1.4 Secondary support

Secondary support will be installed in poor ground to provide for longer term stability or anticipated changes in conditions. Detailed Non-Standard-Support plans with support design and installation instructions will be issued as required. An example of such a plan is given in **Appendix H**.

6.1.5 Very poor ground

In areas of known poor ground conditions bolting will be carried to within 1m of the face. If necessary spiling and pressure grouting may be used to consolidate the ground. In a "poor ground round" the use of smooth blasting would be advised. In cases where additional support measures are required a Non Standard Support request will be issued and details specified in the Heading Status Report.

6.1.6 High areas

Excavations that exceed 6.5m high will be mined in two passes. The roof and shoulders will be supported with either mesh or shotcrete, and the sidewalls bolted to within 4m of the floor.

6.2 Support Procedures

The following are the critical support Standard Operational Procedures

Scaling	see M-DPR-04.7	Manual Scaling.
Scaling	see M-DPR-04.13	Mechanised Scaling.
Rockbolts	see M-DPR-04.9	Mechanised Rockbolting.
Shotcrete	see M-DPR-04.3	Shotcreting using Spraymec machine.
Cable bolts	see M-DPR-04.10	Cable bolt installation (Manual).
Cable bolts	see M-DPR-04.18	Cable bolt installation (Mechanised).
Mesh	see M-DPR-04.15	Roofbolting with mesh.

6.3 Support Installation

Detailed procedures describing every installation step are available for each support type as referred to above and these are used to train and guide the operators. An example is given in **Appendix I** for the mechanised roof bolting procedure.

6.3.1 Roofbolt pattern

A systematic 1.5m diagonal pattern will be used in the installation of all bolts both in roof and sidewalls where required.

The bolts will be installed in rows with alternating rows staggered, maximum spacing between bolts (within a row and diagonally between rows) is 1.5m.

Unless stated otherwise bolts to be 2.4m long.

In poor ground the pattern may be tightened to 1m square by the bolter operator or Deputy (Shiftboss). This must be recorded on the bolters report.

6.3.2 Shotcrete

The type of shotcrete (plain or fibre reinforced) will be advised by the geotechnical section.

Unless specifically instructed the application thickness must be 50mm for plain shotcrete or 75mm for fibre shotcrete.

A minimum re-entry time of 8 hours is required between shotcrete applications.

6.3.3 Cables

The type of cable, length, pattern and angle of cable installations will be advised by the geotechnical section.

A minimum re-entry time of 8 hours is required following the installation of cables and before they can be plated or tensioned.

6.4 Standard Ground Control Measures

6.4.1 Scaling

Every blasted heading is first mechanically scaled, bolted and then hand scaled to clear the area of loose rocks. Scaling gives the operators a good indication of the ground conditions and may lead to a non-standard support request.

6.4.1.1 Jama Scaling

Machinery and Equipment

Jama Scaler SBU 800 / Jama Scaler SBU 8000

Figure 10: Jama Scaler SBU 8000[9]

Description

Initial scaling is done mechanically to allow the operator to scale the back, sidewalls and face from a safe distance. A hammer with high impact rate and impact power is installed at the end of a long boom and used to sound the roof to assess the presence of loose and to knock down any loose found.

The full procedure M-DPR-04.13 can be found in the database here: CLICK .

6.4.1.2 Manual Scaling

Machinery and Equipment

Manitou MT 1440 Teleporter / Caterpillar TH414

Scaling Bar	1.8m length, 22mm diameter round steel, Straight, Point end and chisel end, sharp, heel square, hand grips, rubber guard

Description

After the face is bolted and before it is prepped for drilling, one or two operators hand scale the area. They do so from the basket of a telescopic handler driven by a third operator. If ground conditions dictate a special canopy basked should be used to provide overhead cover for the scalers. This is to be decided by the operators themselves.

During the course of a working shift routine checks are carried out in all working areas by all operators and especially the prep crew by inspecting or sounding the back, face and sidewalls. Regular check-scaling is required on all main travel ways on a weekly basis and organised by the zone shift bosses.

The full procedure M-DPR-04.7 can be found in the database here: CLICK **.**

6.4.2 Resin Grouted Rock Bolting

Machinery and Equipment

Atlas Copco Boltecs

Rockbolts	2.4m x 25 mm diameter T grade deformed steel bar except as otherwise specified with 100mm square domed plate and M24 spherical nut
Resin	450mm x 25mm capsules Fast set – 30 sec. Slow set – 120sec.

Description

Standard mechanised rebar bolting "to the face" is performed for each blasted heading. The adoption of a resin bonded non yield rebar was necessary due to the wet nature of the hanging wall rock. The bolts are fully grouted to avoid corrosion.

The Boltecs drill a 33mm hole to the required pattern. The resin installation nozzle shoots the required number of resin capsules (6) into the borehole. The bolt is tensioned immediately after the fast set resin has cured. Any bolts which cannot be tensioned or properly installed are replaced with a bolt adjacent to the failed bolt. The quality of the bolt installation and the condition of the hanging wall is recorded on the bolter's shift report and may lead to non-standard support.

The full procedure M-DPR-04.9 can be found in the database here: CLICK .

6.5 Non-Standard Support

6.5.1 Shotcreting

Machinery and Equipment

Spraymec 1050 WPC sprayer /Normet remixer 5m^3/ Fermel remixer 5m^3 / Dux remixer 3m^3

Shotcrete As specified dependant on ground conditions and purpose:

- Sealing against weathering Plain Shotcrete
- Very poor / fractured 5kg/m3 of Koyto. 48 synthetic fibre

Description

The shotcrete type will be decided by ground conditions and anticipated behaviour. As a general rule, 50mm of plain shotcrete is applied to seal intact ground that is prone to weathering (ABL, Paste).

A 50-75mm layer of fibre reinforced shotcrete is normally used for highly fractured or stressed ground where some deflection is expected.

The full procedure M-DPR-04.3 can be found in the database here: CLICK .

Figure 11: Shotcrete application with Spraymec

6.5.2 Cable Bolting

Machinery and Equipment

Atlas Copco LC2 jumbos

- modified with a basket and shorter slide to serve as a multipurpose support platform installing cablebolts, mesh, spiles, split sets, drill probes and install instrumentation.

Tamrock DS 420 automatic cable bolter

- utilised primarily for pre-support of the hangingwall of stopes with long cables and in areas where bolting alone is not adequate to support the excavation

Cable Bolts

- Birdcage style cable c/w grouting and tensioning capabilities, 6m long, 15.2mm diameter with 38mm continuous bulbs
- ‘Garford’ style cables, 15.2mm diameter with 28mm bulbs at 0.5m spacings

Figure 12: Installing cables with the Tamrock DSC-420

Description

The manually installed cablebolt is a 15.2mm Birdcage with a nominal cage size of 38mm and a bearing capacity of 250kN. The bolt length can vary but the standard is 6m long. Most cables are face tensioned. This type of cable is very suited to the soft ground conditions allowing a weaker water cement ratio of 0.45 to be used to obtain a better bond strength and fill all cavities and cable cages.

The automatic cable bolter is used to deal with the increasing requirement for pre-support of the hangingwall of poor ground stopes. In addition it is used to remove the man from installation risk in poor ground conditions. The rig uses 15.2mm diameter 28 mm bulbed 'Garford' style cable with a grout ratio of 0.28, a bearing capacity of 250kN and is capable of installation lengths of up to 25m.

Where man access is required the cables are plated with a 150mm square plate and tensioned at 5t using a Surelock barrel and wedge.

In some cases breaker lines of double cables are used to prevent possible brow failures.

The full procedure M-DPR-04.10 can be found in the database here: CLICK .

6.5.3 Meshing

Machinery and Equipment

Atlas Copco LC2 cable bolters

Weld Mesh Sheets or rolls with 100mm apertures of 10g bar, galvanized

Description

Welded wire mesh sheets are installed in an overlapping pattern in combination with other types of support to provide extra protection against falls of small rocks or to control open fissures. The mesh is often used together with a sealing layer of shotcrete to assist surface restraint.

The full procedure M-DPR-04.15 can be found in the database here: CLICK .

Figure 13: Meshing of vent raise 9

6.5.4 Strapping

Machinery and Equipment

Weld Straps	Mesh Support Straps 2.4m Long X 400mm Wide B503 Mesh Size 100mm X 200mm X 8mm

Description

Straps can be installed in combination with other types of support to extend the area of coverage of the rock bolts and to restrain relatively large blocks. They are also used to support bullnoses and failing pillars.

6.6 Other Support Methods

Other support may be installed as required, specific designs will be issued by the geotechnical department with material and installation instruction. These methods are specifically designed for the ground conditions and detailed instructions are issued for each case.

6.6.1 Shotcrete Arch

Shotcrete arches are regularly used as a means of reinforcing brows in longhole stopes. This is particularly the case where narrow pillars of paste form the sidewalls in secondary stopes.

They are constructed using a tight pattern of bolts to support a mesh frame which is shotcreted into place to form a complete arch across the excavation.

The arch allows for a higher load capacity and transfers the loads from the backs into the legs of the arch and into the walls.

6.6.2 Spiling – post grouting

Spiling is used to reinforce the ground ahead of development. A pattern of drill and forget steels are installed at the face and extended to the required length.

Following drilling a grout is injected through the tubes and traverses back down the length of the spile on the outside grouting them in place.

This grouted spile pattern provides overhead reinforcement that allows the face to develop with careful blasting and timely installed support.

6.6.3 High pressure grout injection

In extreme cases where post grouted spiles are not sufficient to reinforce the ground ahead of development (weathered sands/clays) it may be necessary to consolidate the ground.

Utilising the drill and forget spiles a micro cement/cement mixture is injected under pressure using a colloidal mixer and pump until the void is either filled or the desired volume is reached.

Figure 14: High pressure grout injection

6.6.4 Support for mining alongside or through paste

During secondary and tertiary mining paste is encountered alongside the development drifts of stopes. Reliance is placed on small pillars and the quality of paste. A set of standard procedures are in place for supporting these areas.

6.6.4.1 Footwall drive exposing paste on one side

The drifts require a clean paste contact, careful blasting is needed to avoid leaving slabs of ore alongside the paste or blasting into the paste. A systematic cablebolt pattern is installed on the paste side to support the additional span and any potential wedges. The paste sidewall itself is bolted and fibre shotcreted.

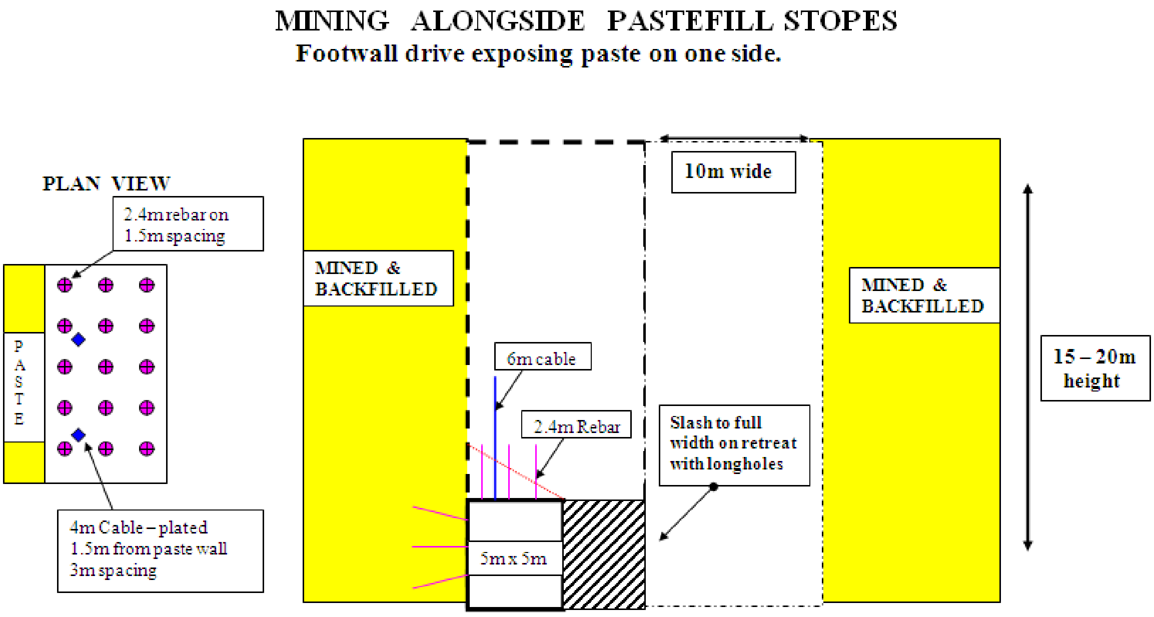


Figure 15: Support design for mining alongside pastefill stopes

6.6.4.2 Footwall drive exposing paste on both side

If both sides of the stope to be extracted are pastefilled then the pillar sidewall will be bolted as well.

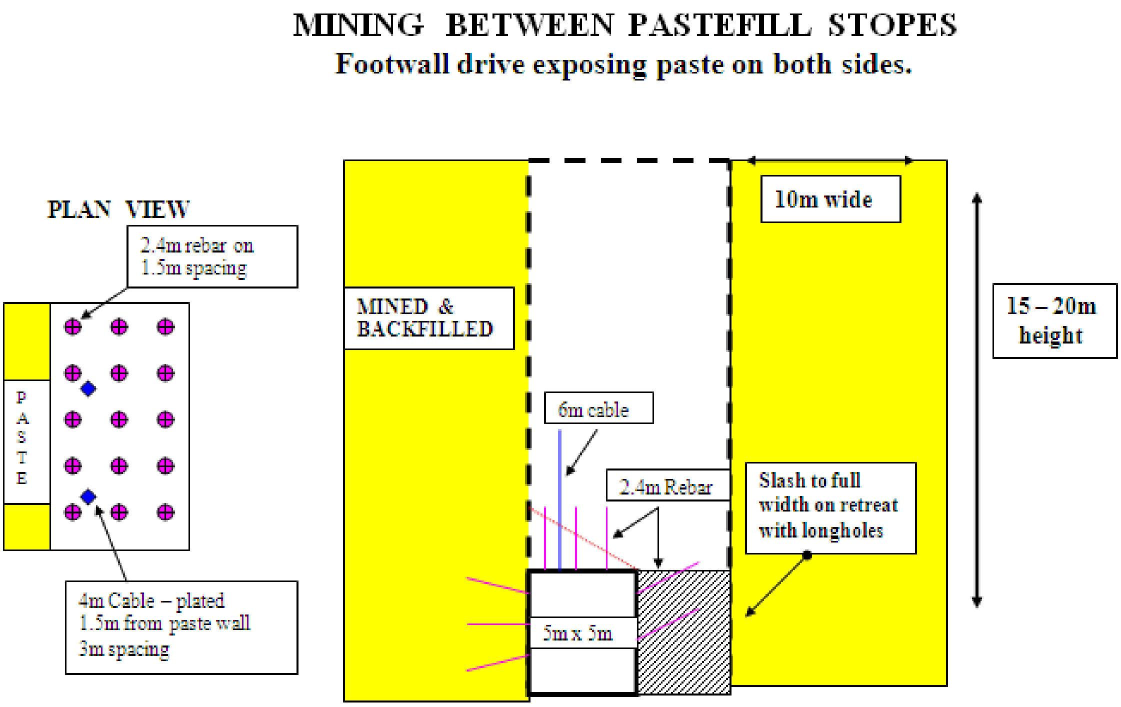


Figure 16: Support design for mining between pastefill stopes

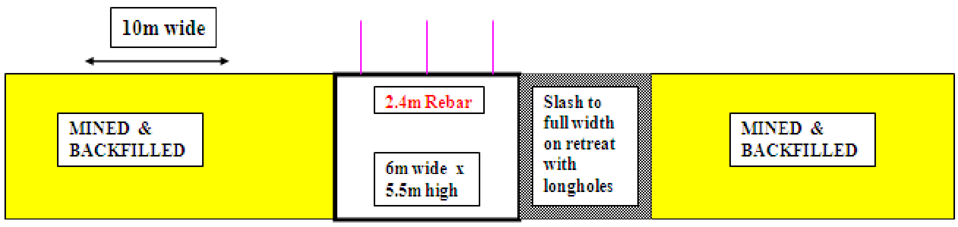
6.6.4.3 Drift and Fill mining alongside paste

In a Drift and Fill operation the support will depend on:

- **The quality of the paste** - which will require bolting and shotcreting.
- **The degree of tightfilling** - The geotechnical engineer will decide whether it will require paste top-up breaker lines of cables or pillars to control the resultant span.
- **Future benching** - of the area would require overheight support as per standards.

MINING ALONGSIDE PASTEFILL

SINGLE CUT



1. Blast to paste contact – DO NOT leave a slab of ore alongside paste.
2. Support each round - as per standard to within 1.5m of face PRIOR to drilling the face. (1m from sidewalls at 1.5m spacing)
3. The exposed paste sidewall is to bolted then shotcreted ONLY if paste quality is poor – Mine Captains call.
4. If paste not tight filled – cablebolts may be required depending on possible span – call Geotechnical Engineer.
5. Where floor is to benched in excess of 5.5m – over height support standards apply, bolt sidewalls and shotcrete roof and walls
6. BEWARE of shotcrete overhangs.

Figure 17: Single Cut mining alongside pastefill

6.6.4.4 Support for mining through paste

Occasionally it is necessary to drive an excavation through paste. Every excavation is different with the required methodology of developing and supporting depending on:

- Overhead thickness of paste
- Contact of paste with solid hangingwall
- Quality of paste
- Likely stress changes
- Usage of excavation

The following figure works as a guideline for mining through paste:

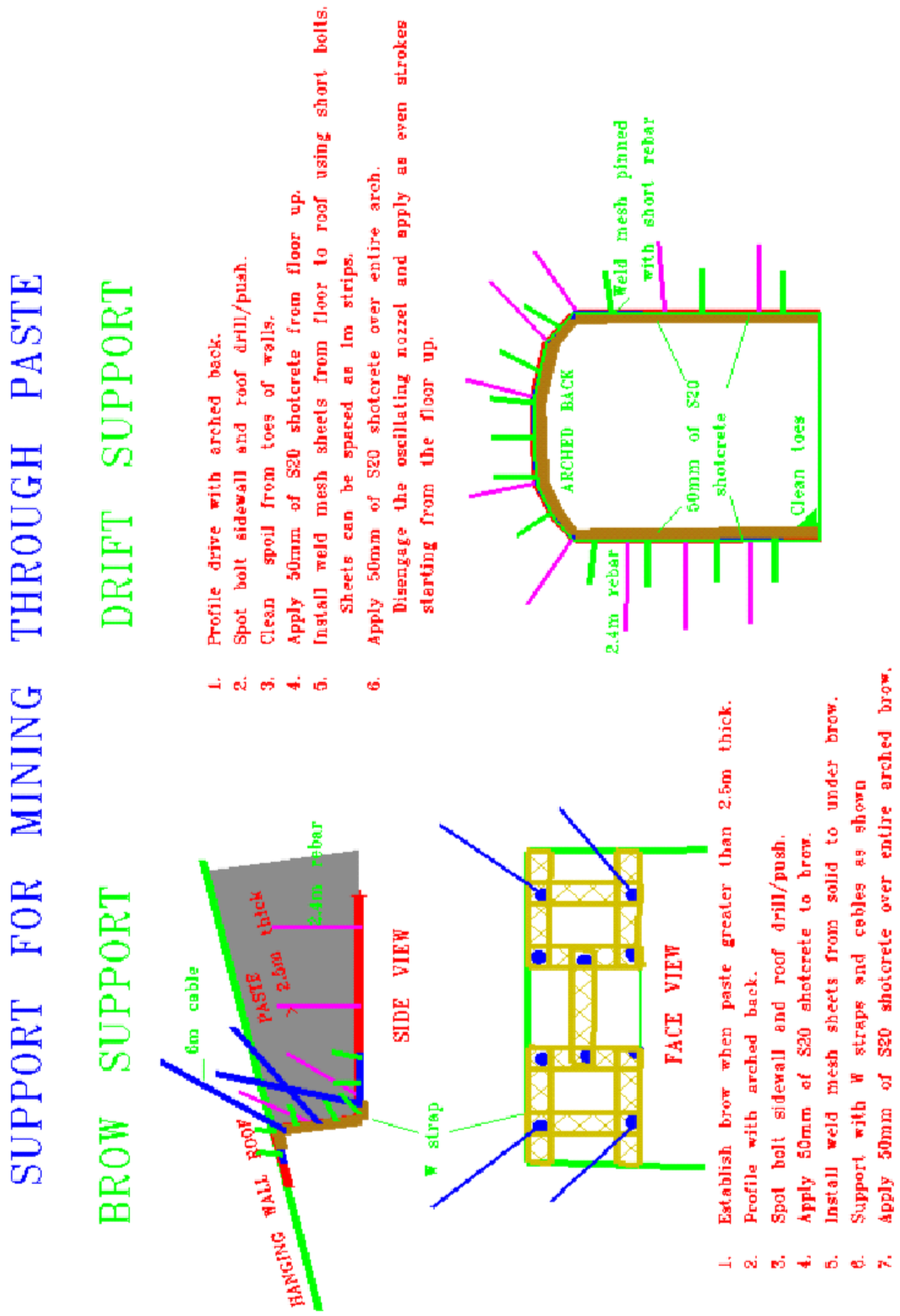


Figure 18: Support for mining through paste

6.6.5 Support for Specific Areas

Specific standards exist for specific areas and conditions that occur throughout the mine. An example of such standards applies to the mining of the Bog Zone where ABL contacts occur in pillars alongside pastefilled stopes. The ABL will be bolted and shotcreted. When the ABL contact is steeply dipping a breaker line of cables must be installed every 2-2.5m alongside the paste filled stope and at least 1 cable anchored in the rock sidewall through the ABL contact spaced 2-2.5m apart.

These support instructions are issued with the risk assessment and design plan and are monitored as development takes place.

6.6.6 Negotiation of features using Truss Cables

Large fissure type faulting, 0.5 - 3m wide, near vertical and normally infilled with sand, clay and water occur throughout the mine ("F"-structures). These fissures tend to occur as singular discontinuities with competent ground on both sides and when intersected these have proved difficult to traverse.

Truss cables are used to deal with these open fissures.

After the fissure and the brows have been safely scaled and shotcreted as much as possible, the 10m long truss cables with bulbed ends are installed and grouted into the brow past the fissure for 2.7m. Standard 6m cables are installed ahead of the fissure and are plated with two way locking barrels. The long truss cables are threaded through a sheet of mesh covering the void and brows. The standard cables are tensioned with the ends of the truss cables fitted through the two way locking barrels. As many polystyrene blocks as possible are placed on top of the mesh into the fissure void before the truss cables are tensioned. Finally the mesh will be secured in place with W straps. Bolts are used to deal with any loose areas.

This support design is demonstrated in detail in the following figure:

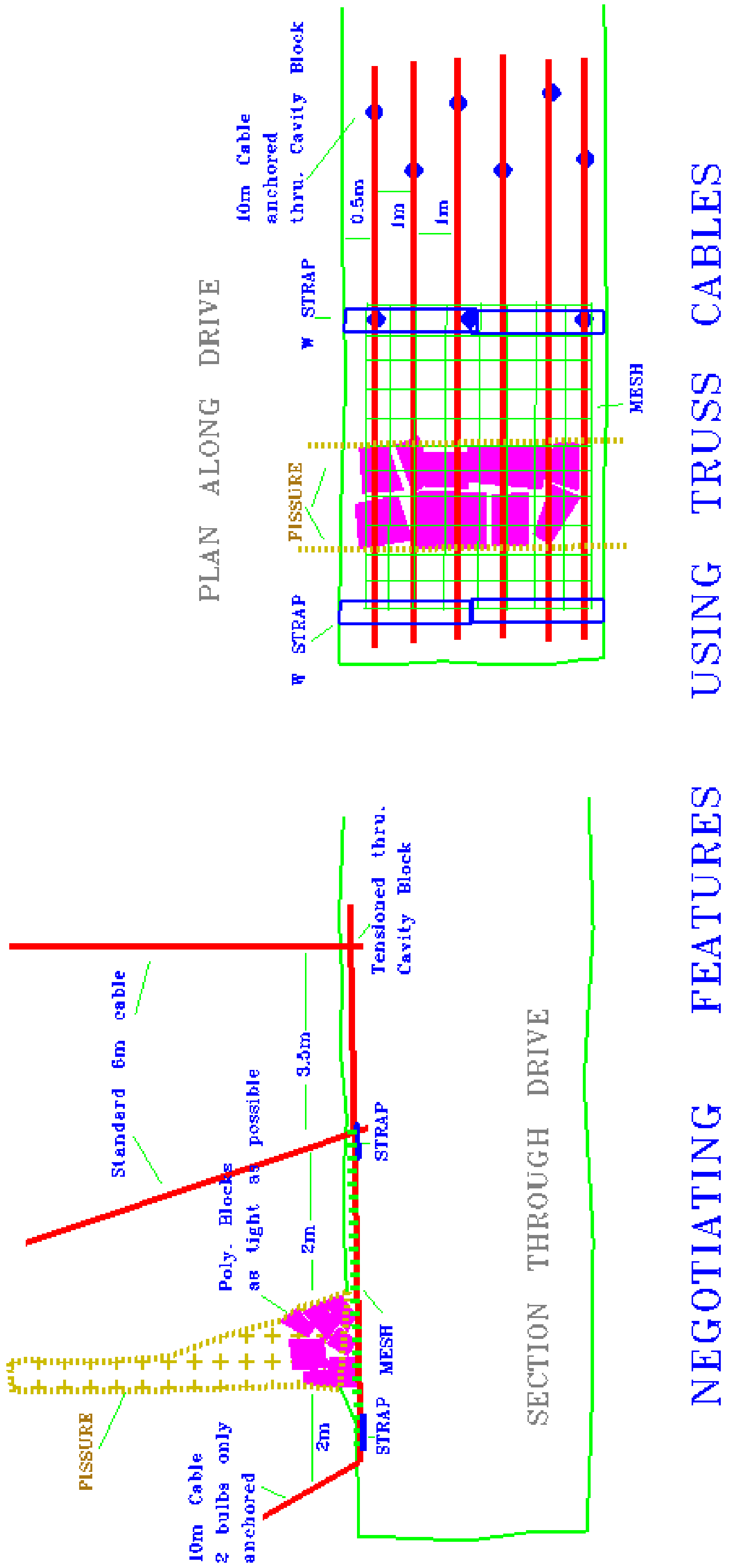


Figure 19: Negotiation features using Truss cables

6.7 Pillars

Most of the development at Lisheen mine was within the orebody. This necessitates the leaving of large sections of the ore as pillars to safeguard access, limit span and control subsidence.

6.7.1 Regional

The shallow depth below surface, the near tabular nature of the orebody and the high extraction rate means that the risk of significant surface subsidence is high. To control the amount and behaviour of the subsidence a combination of regional pillars and backfill are used.

The regional pillars to be effective are designed to be permanently stable and are therefore designed with a W:H of not less than 4. In most cases waste or low grade areas are utilised but where the pillar will be ore a sequence of pillar cutting using paste backfill as confinement is used. A confinement factor of 33% is utilised which allows an effective reduction in pillar size ie. W:H ratio of 2.6.

The pillars are used to control the roof span and are located in areas of poor hangingwall ground where the effectiveness of tight backfilling is not certain.

6.7.2 Haulage/ X cut

Pillars to protect access to stope panels or areas are designed as squat pillars having a W:H ratio of >2. If a mined out span of greater than 50m is opened on any side of the pillar it is immediately backfilled to increase confinement.

6.7.3 Yield

All Room and pillar areas are designed as squat pillars with a factor of safety of 2.2 on the first pass. Due to the panel spans being almost equal to the depth below surface the Tributary Area Theory is used to calculate the average pillar load. The strength of these pillars is calculated using the empirically derived Hedley's Formulae with the K factor changed to reflect the local lithology.

The first pass development is designed as drifts and rib pillars with holings only where ventilation, mucking or geometry make them necessary. On reaching the designed length the pillars are retreated on a strictly controlled sequence. In areas of poor ground, local structures or unfavourable geometry yield pillars are left in place to carry the immediate hangingwall span. These pillars are designed with a factor of safety of 1.

6.7.4 Bracket

Where large geological features occur that extend into the deep hangingwall bracket pillars are regularly left on both sides to contain Horst type failures. In most cases these pillars are designed with a factor of safety of 1.6 and confined by paste. A strictly enforced methodology is in place to incrementally mine up to these structures ensuring that only limited exposures are made.

6.8 Backfilling

Backfill is an integral and essential part of the mining and support process. It allows for the extraction of secondary stopes, maintaining pillar stability, preventing surface subsidence and minimising the disposal of tailings on surface.

6.8.1 Backfilling procedure

Operating Parameters

60-100kg of binder per m^3 of paste is used for backfilling and the binder consists out of Ground Granulated Blast furnace Slag (GGBS) and Ordinary Portland Cement (OPC). The GGBS:OPC ratio is usually set at 60:40 or 0:100, depending on strength required underground, type of stope to be filled and oxide levels in the tailings.

OPC is used more when a quick setting time is required to allow for mining to commence quickly in surrounding areas. GGBS allows for a better long-term strength. Oxides in the tailings effect the GGBS so when the oxide levels are high, the 0:100 GGBS:OPC ratio is preferred.

Backfilling process[10]

Tailings are supplied to a Deep Cone Thickener (DCT) where the tailings are thickened to and recirculated at the base of the thickener to eliminate flocculation effects. The pastefill is then pumped to a Siemens twin shaft continuous mixer. The GGBS and OPC is drawn from their respective silos. The combined binder is then mixed in a high intensity Colloidal shear mixer with water to produce a thick paste. This binder mortar is pumped to the Siemens mixer and is mixed with the tailings to produce the high slump paste backfill. The cemented pastefill is delivered by gravity to one of two Putzmeister HS250 pumps. The pumps deliver the paste to a steel pipeline which runs horizontally on surface which then enters the mine portal running down hill at 1:7 grade for a further 1,500m before the pipelines spread to the different parts of the mine. A simplified flow diagram is shown in Figure 20.

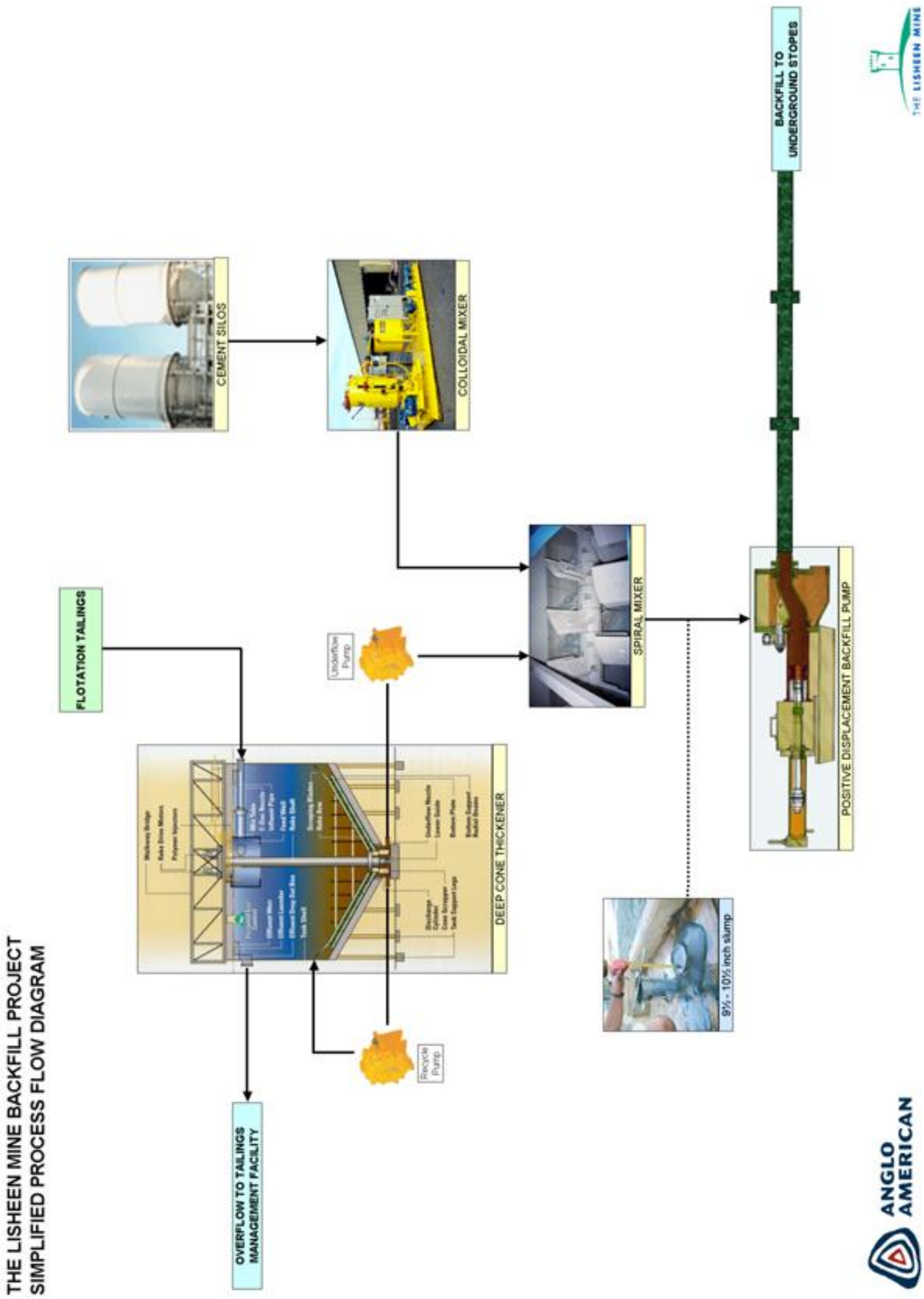


Figure 20: Simplified backfill process

6.8.2 Backfill Management

The Backfill Mine Captain and the Senior Engineer at Lisheen manage the backfill schedule. Good communication between the planning engineers, the diamond drillers, the backfill plant, the geotechnical department and the shiftbosses is vital in this process. The backfill availability severely effects the stability and productivity of the mine and is closely monitored and scheduled.

6.8.3 Stope Closure

To handle the closure of a stope properly and to ensure that the backfill requirements are met, a Stope Closure Certificate is circulated through all the relevant departments. This certificate is illustrated in **Appendix J**. The backfill requirements are assessed depending on whether or not the fill will be re-exposed and the regional stability requirements. The following two parameters are essential:

- **UCS strength**: The depth stress of the stope determines the UCS strength required of the paste to allow the paste to remain freestanding when mined next to. This stress is defined by the density of the paste and the height of the stope. The depth stress also determines the required thickness of the shotcrete barricades. Paste samples are taken daily for short and long term UCS tests.
- **Degree of tightfilling**: The difference between the stope height and the achievable pastefill level determine how tightfilled a stope is.
  A high degree of tightfilling is required to avoid leaving cavities and avoid the risk major hanging wall collapses due to large exposed spans.
  The biggest limit to tightfilling is the height of the pour points.

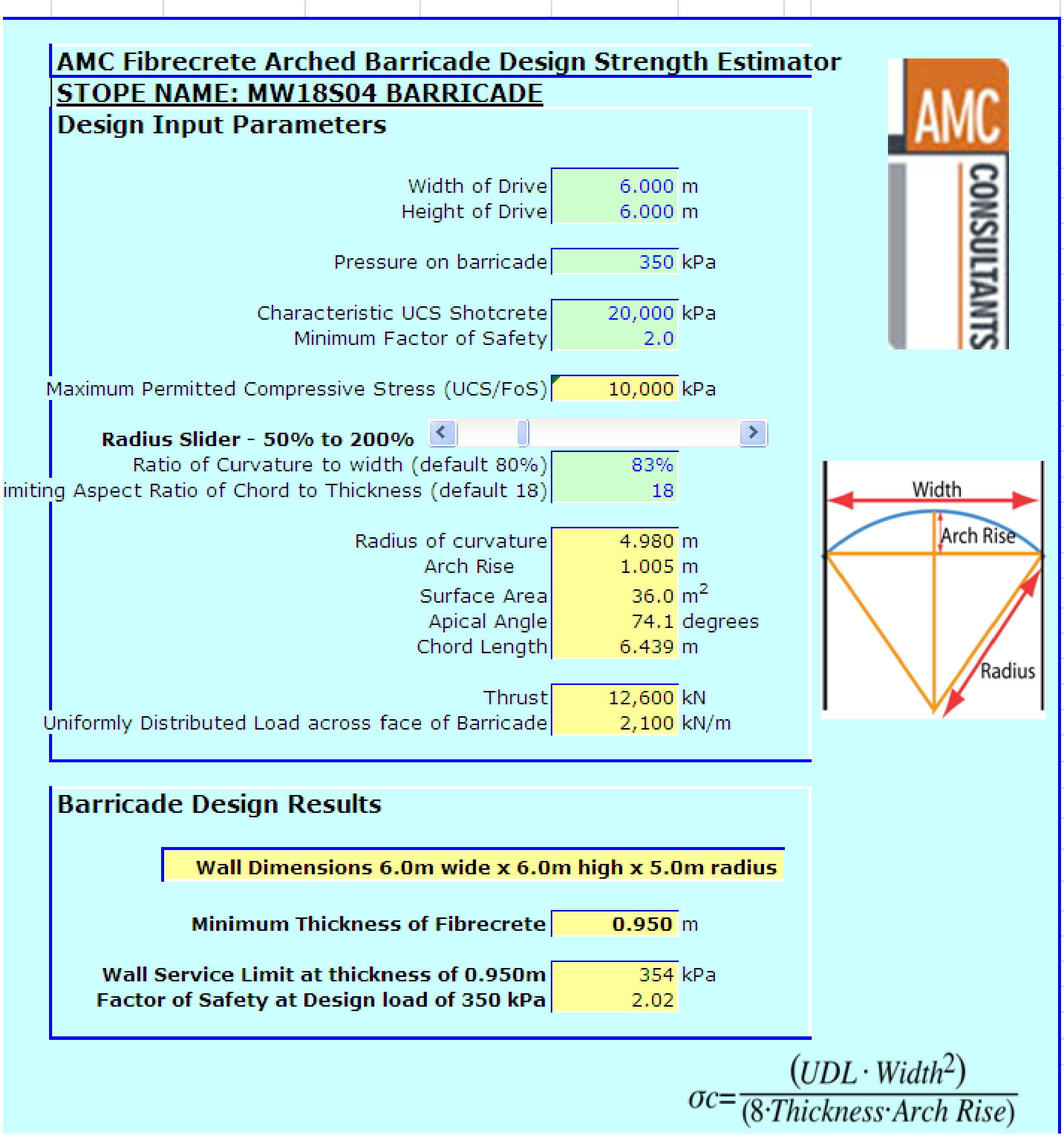
6.8.4 Pour Points and Barricade Construction

A pour point in a stope is achieved by drilling holes into the highest possible level in a stope. These holes are necessary for the feeder and breather pipes. The first pipe allows for the feed of paste into the stope and the breather pipe is installed to avoid high pressure build-ups in the stope and pipes.

A system is also in place to allow for the water to be drained while the stope is being filled. This is usually a race between water and paste and often water is left in the stope at the point of stope closure.

Optimal barricade design and construction is essential in the backfill process.
The barricade design is dependent on the future pressure on the barricade and a safety factor of 2.

The required barricade dimensions result from the following AMC created template:


AMC Fibrecrete Arched Barricade Design Strength Estimator
STOPE NAME: MW18S04 BARRICADE

Design Input Parameters

Width of Drive	6.000	m
Height of Drive	6.000	m
Pressure on barricade	350	kPa
Characteristic UCS Shotcrete	20,000	kPa
Minimum Factor of Safety	2.0	
Maximum Permitted Compressive Stress (UCS/FoS)	10,000	kPa
Radius Slider - 50% to 200%		
Ratio of Curvature to width (default 80%)	83%	
imiting Aspect Ratio of Chord to Thickness (default 18)	18	
Radius of curvature	4.980	m
Arch Rise	1.005	m
Surface Area	36.0	m^2
Apical Angle	74.1	degrees
Chord Length	6.439	m
Thrust	12,600	kN
Uniformly Distributed Load across face of Barricade	2,100	kN/m

Barricade Design Results

Wall Dimensions 6.0m wide x 6.0m high x 5.0m radius

Minimum Thickness of Fibrecrete	**0.950**	m
Wall Service Limit at thickness of 0.950m	354	kPa
Factor of Safety at Design load of 350 kPa	2.02	

$$\sigma c = \frac{(UDL \cdot Width^2)}{(8 \cdot Thickness \cdot Arch\ Rise)}$$

Figure 21: Barricade Design Parameters

Following the backfilling of a stope the Stope Closure Certificate is returned to the Geotechnical Department. The area filled, the volume placed and the paste strength are recorded as well as areas where tight fill was not achieved. This information is transferred to a digitised database on the planning software (Vulcan) and is used in designing further stopes.

At the present stage of retreat mining, backfill is becoming more important concerning both production and especially ground control. Priority is given to areas of potential instability or safety concerns, the control of large spans is vital in managing surface subsidence and uncontrolled caving along features is strictly monitored.

7 GROUND MONOTORING

An ongoing monitoring of ground conditions is carried out on several levels. This is utilised to understand the ground behaviour, spot trends and identify hazards.

It is also used as a quality control on the effectiveness of the excavation design and installed support. It allows for a timely review of the support methods in place and aids in the continuous improvement of the ground control management process.

A combination of observation, report backs and instrumentation is used. The principle ones are as follows:

7.1 Daily Face Examinations

Each blasted heading leaves a fresh face which is assessed for its geological characteristics. The face is mapped out on a face sheet. The geotechnical department review these sheets on a daily basis to review the heading dimensions and to record any significant differences in lithology and/or structures.

7.2 Daily Support Operator Shift Reports

The geotechnical department reviews the shift reports of the bolters, cablebolters and shotcrete installations on a daily basis to assess the quality of the installed support. If the operator was not able to install the support up to an adequate level, the department will take necessary actions to compensate for this. Specific training is given to support operators to recognize geotechnical hazards and read the ground.

7.3 Pillar Assessment

Each pillar panel area is continually evaluated for its pillar stability using visual inspections and managed with a dedicated spread sheet. They are assessed for signs of scaling, dog earring and stress loading and then classified according to their level of spalling, yielding or failing. This classification system is visualised in Figure 22.

The pillar strength is compared with the pillar stress it has to carry to assess its level of safety. In general, an empirical method is used with a high safety factor to assure pillar stability even in the worst case scenarios. The method applied is based on the Tributary Theory for the stress calculation and on Hedley and Grant 1973 for the pillar strength. A simplified template sheet used for these calculations is shown in Figure 23.

Numerical modelling with either Phase2 or Map3D can also be applied to assess the stress distribution throughout a pillar on a smaller scale.

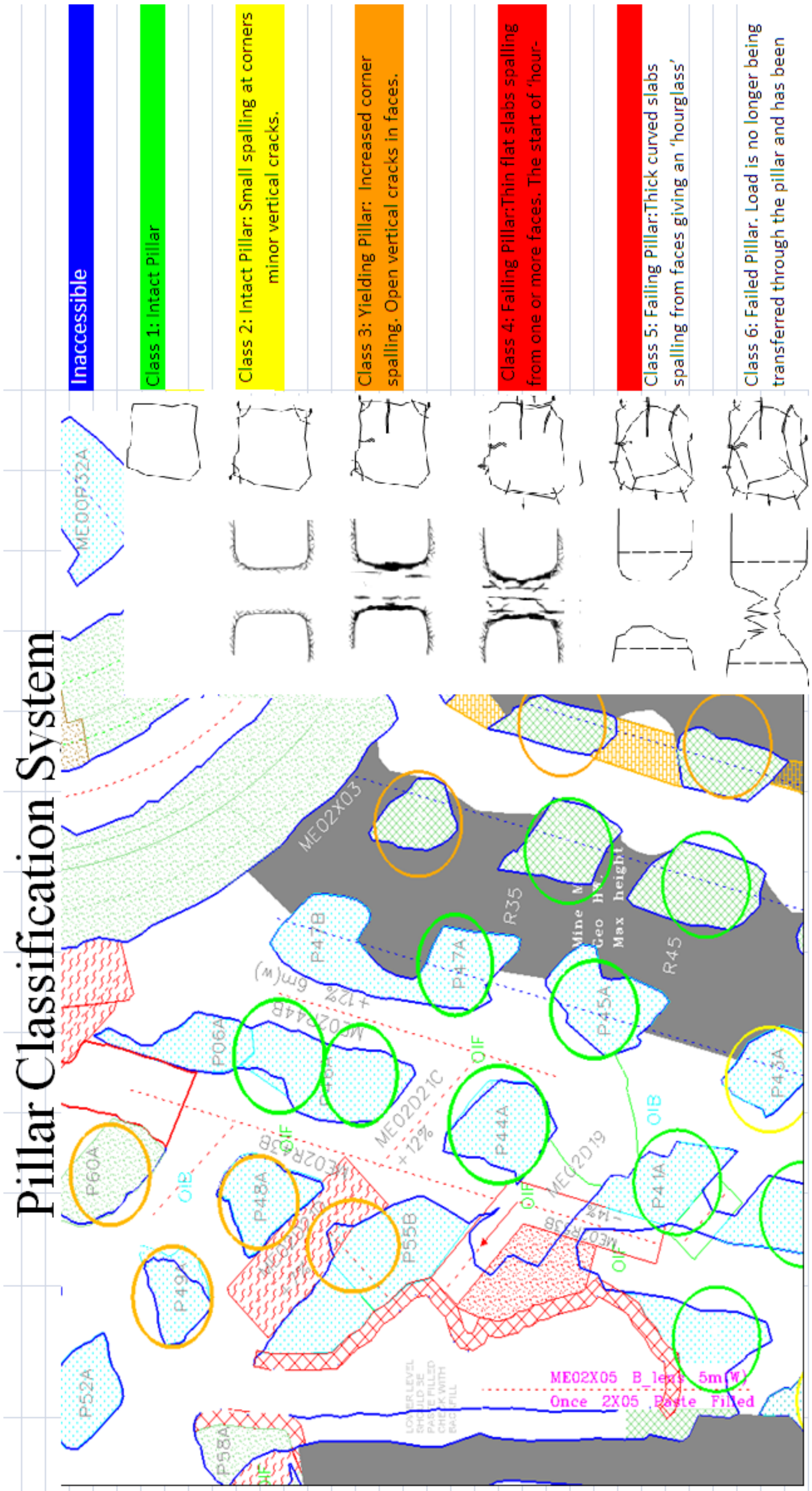


Figure 22: Pillar Classification System

Overburden Density	2,700	kg/m3
Gravity	9.81	ms-2
Depth	0.08	km
w_1	6	m
w_2	6	m
b_1	15	m
b_2	15	m
rock constant	86.46	Mpa
width $_{effective}$	6	m
Pillar height	6	m

Pillar Stress	
26	MPa
Pillar Strength	
53	MPa
F.O.S.	
2.05	

Factor of Safety should be 1.6 or greater.

N.B. Based on Tributary theory (stress) and Hedley and Grant 1973 (strength)

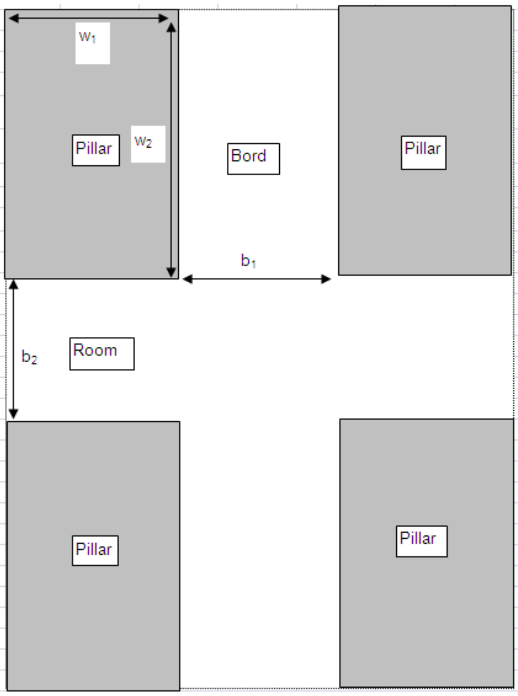


Figure 23: Pillar stability calculations

7.4 Instruments

7.4.1 Tell Tales

In areas where the roof is intensely bedded or suspected wedges may be formed, Tell Tale instruments may be installed. (see Figure 24) These provide a visual check to monitor ground movement. It is anchored and tensioned up to 8 meters into the roof. The centre probe is suspended independently of the surrounding base and it retracts upwards as the roof moves downwards. Each colour section on the probe represents 5 mm of movement. After >5mm of movement the red LEDs start to flash. When this occurs, the operators remove themselves from the area, chain the area off and inform their shiftboss and await geotechnical area assessment.

Figure 24: Tell Tale

7.4.2 FOGLight

Where ground conditions allow (dry and class 1 & 2) a FOG Light tell tale can be installed. These provide a highly visible LED light on a continuous basis and are more useful in high area or where the Tell Tale becomes covered with dust. The movement range is set at 3mm after which an amber light will continue to flash.

7.4.3 Multi Point Borehole Extensometers (MPBX)

Extensometers are used to monitor any movements of the hanging wall. The instruments have six anchor points and are fully grouted into a borehole which is 15m long and should penetrate the hanging wall deeply enough. Using a digital read-out box, the displacements are recorded on a software package that graphs movement. These are placed in some pillar extraction areas where the removal of the pillars causes sudden large span increases. Production supervisors are trained to take the readings on re-entry into the panels and at regular intervals during the shift. Trigger levels are issued and set responses are instructed.

7.4.4 Multi Point Borehole Contractometers (MPBC)

The Contractometers are modified extensometers that read compression movement. They are installed into the paste to monitor fill loading caused either by hanging wall loading when adjacent pillars/stopes are taken or paste ingress to adjacent stopes.

7.4.5 Vibrating Wire Stress Meters

The Geokon Model 4300 Vibrating Wire Borehole Stressmeters measure stress changes in rock and are used to monitor stress redistribution. These are installed in pillar boreholes and wedged stuck. Changes in rock stress cause a related change in the resonant frequency of vibration of the tensioned wire. This provides an output which is read by the Model GK-403 Readout Box. The changes are visualized in a graph and allow for the monitoring of pillar stress changes during retreat mining.

7.4.6 Collapsible Tension Indicator

These are machined sleeves designed to fail at predetermined loading. They are used to give early warning of loading of pillar sidewalls and are set at 5 and 10 tonnes.

Figure 25: Collapsible Tension Indicator

7.4.7 Pressure Cells

Pressure cells are installed on the floor of a stope prior to backfilling. They are used to measure the loading of the paste as filling progresses. Longer-term they are used to measure any supercharge of collapse on the paste fill. Backfill curing factors influence the early readings so care has to be taken when analysing the graphs. The quality of the measurements is directly dependent on whether the stope is fully tight filled.

7.4.8 Borehole Camera

A borehole camera is used to inspect and log boreholes internally underground. This allows for a better determination of the ground conditions. The push rod cable indicates the travelled distance into the borehole and therefore pinpoints the location of the camera in the borehole. They are used to identify fractures or poor ground conditions ahead of development ends. They are also used to evaluate the condition of stress induced damage to pillars.

7.4.9 Remote Levelling Equipment

A remote sensing total station is used to monitor the stability of critical access ways. The Leica TS30 robotic total station surveys the drives by using reflective prisms. These are monitored on a continuous basis with the station itself being changed as the concentration of mining moves from zone to zone.

Figure 26: Leica TS30 Total Station

Figure 27: Remote levelling

7.5 Surface Subsidence

The tabular nature of the orebody, its thickness and shallow depth below surface make the occurrence of surface subsidence inevitable. As a worst case scenario the mine was modelled with total extraction and no backfilling. A magnitude of 500mm subsidence was obtained above the western section of the main zone.

The presence of large near vertical structures, deep kastic weathering and the dewatering of the mine all contribute to making predictions regarding subsidence very difficult. The control of extraction sequencing, the timely tight backfilling of all voids, control of caving and positioning of regional support pillars are used to manage the rate and magnitude of surface subsidence.

Quarterly surface levelling measurements, mine wide modelling of extraction and monitoring of hangingwall behaviour is used to predict potential future subsidence. An extensive network of precision levelling stations are installed on surface and used to measure the surface elevation levels and to calculate the difference between these and the previous measurements to record the movement. The results are analysed by the geotechnical department to confirm predictions and identify any anomalies that indicate whether mining sequences need to be altered, additional pillars left or higher strength backfill placed.

To record the potential for progressive caving above areas of known large scale, stope roof unravelling Time Domain Reflectometry (TDR) are installed. A coaxial TDR cable is fully grouted into a borehole from the surface to the roof of the stope. Voltage pulses are sent along the cable using a predetermined Velocity of Propagation (VOP) and reflections are generated by cable deformations at known locations. Cable deformations caused by ground movements alter the VOP and therefore the reflections at the known locations and allow for the interpretation of the movement rate at these specific locations. Where limited access is available for surface levelling 50m long contractometers have been installed from surface.

The data and analyses of the instrument readings can be found HERE.

7.6 Back Analysis

The data gathered from the stressmeters, the extensometers and the surface subsidence monitoring is also used by the geotechnical engineer to calibrate the numerical models.

These models are useful tools to help decide the optimal lowest-stress extraction sequence in room and pillar areas or to control the hanging wall displacements in stopes.

The 3-dimensional Map3D code is most commonly used. This program creates linear elastic models which are used to predict the near mine stress field and the ground behaviour in and around extraction zones.

Linear elastic models however are not optimal for surface subsidence prediction which should take into account all previous ground displacements and their influence on the rock properties. Figure 28 shows an example of the stress modelling with Map3D.

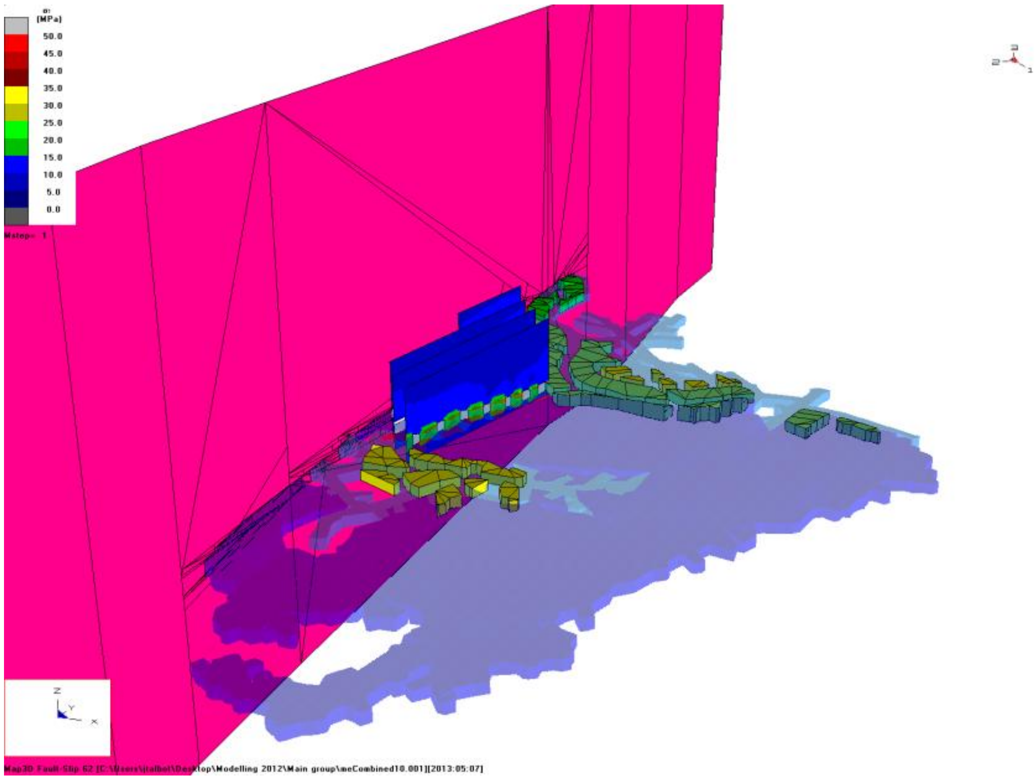


Figure 28: Map3D model

Phase2D, a 2-dimensional program is also used particularly for simpler geometries. This finite element analysis software can model progressive deformation as shown in an example in Figure 29 which shows the effect of the removal of the BE03S03 semi permanent pillar on the near mine stress field, the near mine subsidence behaviour and the surface subsidence behaviour.

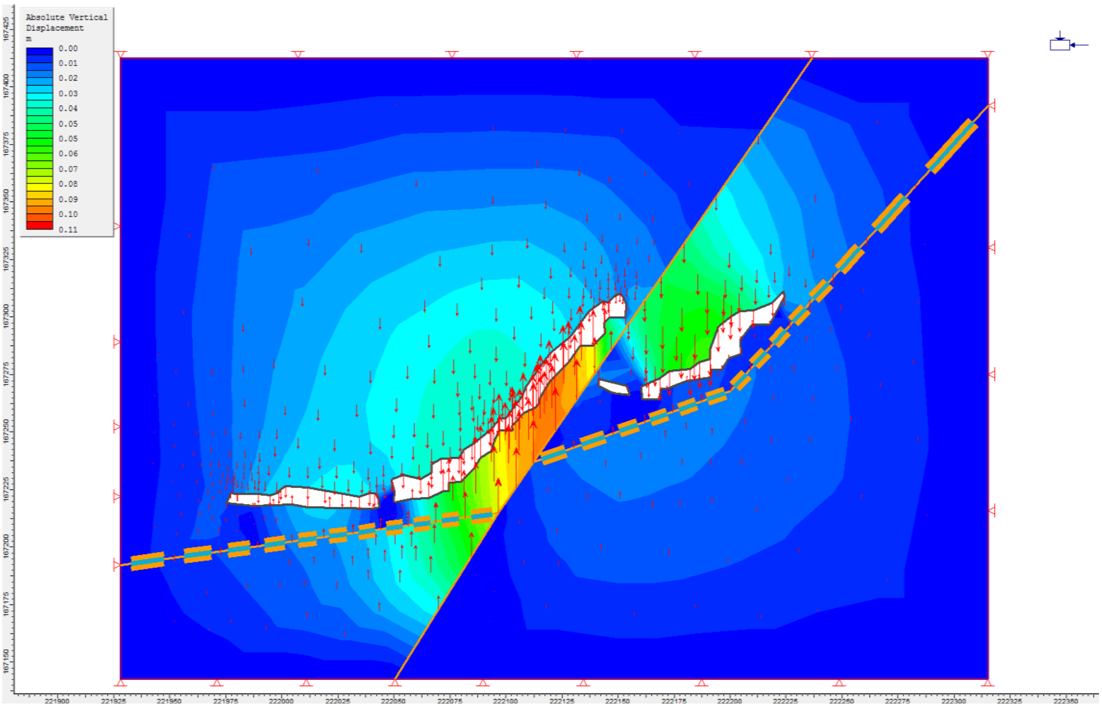


Figure 29: Phase 2D model of BE03S03 around the Bog Zone Thrust Fault

A Life of Mine Map3D Model is now available to examine any mining scenario or change in extraction sequence. This model will be updated at quarterly intervals to verify the stress distribution, highlight areas of concern and check alternative sequences. All information about the models and the models themselves can be found HERE.

8 QUALITY ASSURANCE

All materials used for ground control undergo thorough testing on a regular basis.

This happens at the manufacturer's factory as well as on site. The manufacturer delivers a certificate of quality together with the order. The following table summarizes the tests performed by the Geotechnical Department on the different ground control materials:

Table 5: QA on Ground Control Material

QA	
Material	**Tests**
Shotcrete	(For more details see HERE)
	Slump Testing
	Cube Testing
	Depth Checks
	Dose Rates
	Early Strength Testing
	Round Panel Tests
Bolting	
	Resin Testing
	Bolt Testing
	Pull Tests
Cable Bolting	
	Grout Testing
	Pull Tests
	Tensioner
	Barrels/wedge
Paste	
	UCS Strength Tests

Results of the Quality Assurance tests can be found HERE.

9 OPERATIONS MANAGEMENT

The following controls are in place to ensure that all stakeholders contribute to and understand all mining designs, excavation sequences and the relevant risks.

9.1 Communication

Mine plans or "Noddy Plans" are a simplified plan with all relevant information displayed and a sequence of actions listed. These are fully discussed with all relevant departments, the risks are explained and measures to counter are emphasised prior to being signed off.

Mine plan **design revisions** must undergo a "change of management" examination and if necessary a complete revision of the design along with a new assessment and sign-off process.

Weekly and monthly **meetings** are held with all technical services departments to discuss and communicate changes.

Information is made available for all personnel in the form of plans, notice boards and electronic on the HSR (heading status report).

An **Incident Reporting** system is in place to allow all personnel to report ground control incidents and expect feedback and closure.

A **Ground Conditions Hazard Reporting** system is in place to allow all personnel to report ground control hazards and recieve feedback and closure. The hazard report sheet is given in **Appendix K**.

All **Near Misses** have to be reported and are subsequently analysed and summarized for all underground personnel to learn from.

9.2 Ground Failures

A detailed multi-disciplinary investigation organized by the safety department investigates all Fall of Grounds (FOGs) and High Potential Incidents (HPIs) and issues recommendations.

9.2.1 Fall of Ground (FOG)

At Lisheen a fall of ground is defined as

"A failure within the ground control system such that an unplanned movement of ground occurs which affects safety, has the potential to affect safety, affects production or has a business cost. "

Each FOG incident is reported and investigated by the geotechnical department. A systematic data recording/reporting sheet is used to analyse the fall and identify learning points to help prevent future occurrences.

9.2.2 High Potential Incident (HPI)

This occurs when there is no loss regarding injuries or property damage. However it could have resulted in a Major Incident under slightly different circumstances such as incidents where people would have been exposed to unsupported ground (not scaled, not supported, not barricaded).

9.2.3 Potential Incident (PI)

These differ from HPI's in that no people or equipment was directly at risk. An example would be bolts being incorrectly installed but this being picked up immediately after installation before further work was started.

9.2.4 Failure to follow instructions (FFI)

Usually a design infringement that impacts on ground stability or safety such as benching without overheight support.

9.2.5 Hazard Report

These are reports on ground conditions or behaviour from underground personnel. The may be very minor but may indicate trends or provide a warning. They are used to ensure that the entire workforce is involved in hazard recognition and assessing their own risks. An investigation is undertaken and feedback given to the person who reported the incident.

Ongoing records are kept and analysed with periodical reviews as necessary if unfavourable trends are identified. This could lead to changes in practice, design modifications or refresher training.

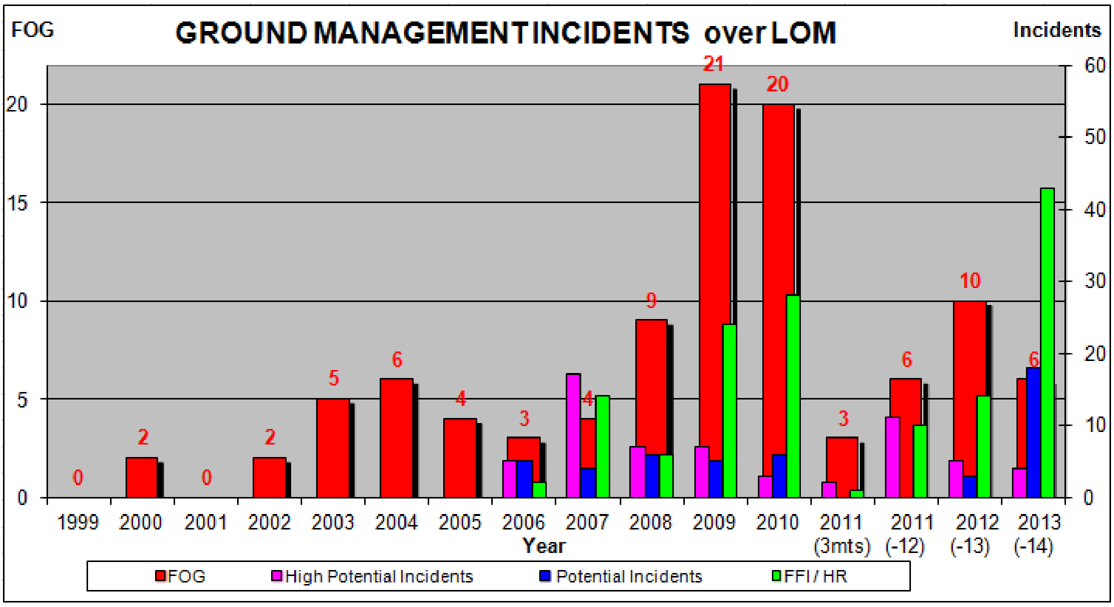


Figure 30: Ground Management Incidents over LOM

10 TRAINING

10.1 Continuing Workplace Intervention

Supervisors and workmates have a responsibility to identify hazardous practices or dangerous situations.

If a need for further training is identified on the job, the shift supervisor is responsible to ensure that the unsafe practices immediately cease and that the need for further training is conveyed to the underground line management. The underground line management will arrange the further training.

10.2 Ground Conditions Safety Themes / Canteen Talks

The Geotechnical Engineer will develop and present a session (or sessions) discussing geotechnical hazards at the Mine or arrange for such a session to be given on an as needed or request basis.

The talk will consist of the following as a minimum:

- Basic training covered by the generic and other inductions relevant to rock hazards and ground control.
- A pictorial discussion of rock hazards.
- Additional hazards that have been identified since the last rock hazard toolbox talks.
- Feedback to employee questions related to rock hazards.

It is intended that these talks will act as a reminder for all underground employees of geotechnical hazards at the mine.

10.3 Hazard Information Sessions

When new geotechnical hazards or changes in mining conditions or practices related to geotechnical issues are identified in the mine, the Geotechnical Engineer and the Mine Management will arrange a suitable means for communicating the issues related to these hazards to the entire underground workforce.

This would normally be in the form of a presentation, designed to teach the workforce:

- How to identify the hazard.
- What needs to be done to deal with the hazard.
- What will be done to manage the hazard.

10.4 Induction Training

New underground employees are placed under close personal supervision for a 4-6 week period. During this period they become familiar with the underground environment and their workplace.

A Planned Task Observation/Visibility Felt Leadership exercise is carried out by the geotechnical section before the employee is allowed to work on their own. This involves an understanding of ground hazards, the recognition of various ground conditions, support performance, examination of excavations, understanding the Take 5 and the reporting system.

10.5 Ground Awareness

A ground awareness refresher course is run every year for all underground personnel that covers hazard recognition, face examination, a review of major ground incidents and an awareness of any changes either in ground behaviour or mining methods.

10.6 Specialist Training

Production supervisors, technical service and geology personnel are regularly briefed and trained in how to recognise, support or design for any geotechnical hazards or high risk mining areas.

10.7 Yearly Refresher

All Technical Services staff and underground personnel undergo a yearly retraining on the following subjects:

- Lisheen Mine Transport Rules
- Underground Safety rules
- Scaling
- Manual Handling
- Self Rescuer
- Take 5 Risk Assessment
- CAS System
- Other

During the retraining, time is taken to discuss all relevant incidents during the previous year.

10.8 Bolter

Bolter operators are regularly (at least quarterly) reassessed on reading the ground, understanding support plans, installation of rebar and management of both machine and consumables. This is carried out using a PTO and used as feedback for any potential improvement or corrections in procedures.

10.9 Cable Bolter

Cablebolt operators are regularly (at least quarterly) reassessed on reading the ground, understanding support plans, installation of cables, split sets, mesh and straps and management of both machine and consumables. This is carried out using a PTO and used as feedback for any potential improvement or corrections in procedures.

10.10 Shotcrete Operators

The shotcrete nozzle men undergo training under guidance by Normet and are qualified to EFNARC standards. Regular PTO and Normet master sprayer audits are used to assess the effectiveness of the shotcrete application. All nozzle men have attended the ITA sprayers course at Hagerbach in Switzerland.

10.11 Spile/Injection

A core of people has been trained in the installation of spiles, post grouting and high pressure grouting. They have also attended the Grout Injection course at Hagerbach in Switzerland.

Spiling and pressure grouting is not considered a standard operation and is closely supervised and monitored by an experienced geotechnical personal.

10.12 Ground reading

The nature of the ground at the Lisheen mine means that a high degree of individualised support design is used. The ability of operators to understand and install the support as designed is critical and even more so to read the ground and adjust the design if necessary. All non-standard designs are discussed and explained to the operators on site encouraging input and feedback.

10.13 Toolbox talks

The Safety, Health & Environment department draws up and distributes toolbox talks. Any important safety subject, near miss or incident can be discussed in a Toolbox talk. The Shiftboss will organise for these subjects to be discussed by the crew before the shift starts.

10.14 Take 5 – cards

Every operator is required to perform a "Take 5" of the working area before commencing work. This assists the operator in carrying out area risk assessments and promotes their ground awareness.

10.15 Planned Task Observations

Regular Planned Task observations are carried out on all support operations to ensure that machine, consumables and men are able to perform the operation as required.

The exercise is used to assess all aspects of the job and conditions it has to be carried out in. Shortcomings in any aspect are immediately addressed and operators are encouraged to offer input.

The content of the training courses is constantly updated and improved based on new experiences. The ground awareness courses are updated based on new findings and they are adjusted to the stage of mining the mine is at. The latest ground awareness course can be found HERE.

11 CONTINUOUS IMPROVEMENT

11.1 Stability Graph Open Stope Design

Lisheen is evaluating the use of the harmonic radius in addition to the hydraulic radius for determining the hangingwall stability of a mining area. This method is more suitable for large room and pillar areas and factors in the presence of pillars, brows, raises, major structures and the effect of large backfill spans in particular on secondary extraction. A back analysis of all or a large portion of Lisheen's previous mining areas to determine the stability number and hydraulic/ harmonic radius/ radius factor will be undertaken. This will be used to develop a Lisheen specific stability graph which can then be used to determine the likelihood of large scale hangingwall failure in remaining mining areas.

11.2 Shotcrete Fibres

A new type of shotcrete fibres was trialled recently following satisfactory applications and random panel laboratory tests. The Concrix fibres are bi-component polymer fibres that consist of an inner core with a very high strength and E-modulus while the shell with structured surface offers better binding to the shotcrete. The main advantage is the enhanced post failure behaviour which exhibits considerably better binding of the fibres allowing the failed shotcrete to stay in place and be re-sprayed if recognised.

11.3 Resin

Currently Lisheen sources its resin supplies from a single monopoly and would prefer to have an alternative source for such a critical item. The Jennmar J Lock Rockbolt Resin is currently being tested. There is also a potential cost improvement.

11.4 Geotextile Mesh

A geotextile mesh has recently been introduced. This mesh is used to retain waste/paste sidewall material by being pinned with split sets and shotcreted into place. It cannot be used to replace weld mesh as a support system.

11.5 'Garford' style cable bolts

An alternative supplier was approached to develop a bulbed 'garford' style cablebolt. A local source was required to alleviate management of stock of this consumable in the final stages of operation. The cable is presently on trial and is performing well. Final embedment and pull out trials have still to be undertaken.

11.6 Collapsible Tension Indicators

A batch of these was sourced to assist in monitoring stressed pillars. They consist of a hollow tubing with an engineered groove that collapses at a given load. When fitted at the collar of a rebar installation they provide warning of pillar/sidewall failure by collapsing at a predetermined load. This will assist in taking the subjectivity out of assessing the degree of failure in pillars.

11.7 Paste voids

The irregular geometry of the stoping at Lisheen, combined with factors such as access to filling points, caving and unfavourable dips make the achievement of tight backfilling a challenge. Significant backfill voids create a risk to either development or subsequent stope extraction and need be topped up.

Greater care is being taken to ensure all voids are filled as tight as possible if not identified, and measures are put in place to negate the possible effects such as stand off pillars or breaker lines of cables if suitable.

A foaming grout using Rheocell 10 a liquid additive to a sand/cement mixture is being trialled to ensure tight filling of the paste in areas where pastefill top-up is not possible.

11.8 Outby Examinations.

A procedure has been developed and is now been trialled to assist in ensuring the stability of all roadways, infrastructure and less frequented areas. The scattered nature of the tertiary mining will cause shakedown in back areas that require regular examination and in some cases resupport.

11.9 InSAR / Areal Imagery

Both InSAR and Areal Imagery were recently used over the mine site with the purpose of assisting in developing a structural / hydrological model for the surface site.

The short term aim is to locate potential karstic expressions that may be activated by mining to allow more focused monitoring of them. The results will also be examined to identify the progressive effect of mining and mine dewatering on the ground and be compared to the current monitoring techniques and model.

Longer term, there is the potential for utilising InSAR for post-closure monitoring.

12 CONCLUSIONS

This document describes all aspects of the Geotechnical Department at the Lisheen Mine. It explains the requirement for compliance with the Irish law concerning support and will serve as a guideline for Lisheen's ground control management system.

Each mine design takes into account a long list of geotechnical parameters and before the design is approved it undergoes a thorough step-by-step risk assessment by the geotechnical department. A broad range of data is available to aid the assessments and monitoring steps are in place to allow for an even better understanding of the ground conditions post extraction and to manage any current or future hazards.

Standard support protocols are in place for areas in good ground and non-standard support requests can be made by any employee. Non-standard support measures such as shotcreting, cablebolting, meshing and strapping are available for poor ground. Other support may be installed as required and specific designs will be issued by the geotechnical department with material and installation instructions.

The ground control installations, such as bolts, cables, etc. undergo regular testing to assure the quality of the ground support measures and efforts are constantly made to improve the support designs and methods.

The geotechnical department actively pursues any techniques, methodologies or opportunities internally or externally to improve the stability of the excavations, minimise the ground control risks or increase the knowledge of the ground behaviour. This approach is complemented with rigorous ground awareness training, an effective communication system and an empowerment of all personnel to act on any ground condition.

Given the rapidly changing ground conditions at Lisheen this document must be reviewed and updated every six months.

The next date of review is 07/11/2014

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14 APPENDICES

A. SUPPORT – Mines and Quarries Act, 1965

Duty to secure safety of roads and working places.

49.—(1) It shall be the duty of the manager of every mine to take such steps by way of controlling movement of the strata in the mine and supporting the roof and sides of every road or working place as may be necessary for keeping the road or working place secure.

(2) It shall be the duty of the manager of every mine to secure that he has at all material times all information relevant for determining the steps necessary to discharge efficiently the duty imposed on him by subsection (1).

Systematic support in mines of coal and other stratified minerals.

50.—(1) Subject to this section, in every mine of coal or other stratified mineral there shall be provided and maintained systematic support for the roof and sides of—

(*a*) every place where any mineral is worked;

(*b*) every roadhead;

(*c*) every junction of two or more lengths of road through any one of which vehicles or a conveyor run or runs; and

(*d*) every length of road in which persons work otherwise than occasionally or for short periods.

(2) (*a*) If an inspector is of opinion that systematic support for the roof and sides (or either of them) of any other length of road in any such mine ought to be provided and maintained, he may serve on the manager a notice specifying the length of road, stating his opinion and requiring the provision, before the expiration of a specified period, and maintenance of such systematic support.

(*b*) The provisions of section 146 as to references upon notices served by inspectors shall apply to a notice served under this subsection.

(3) Regulations may require or empower inspectors to require systematic support for roofs or sides, or both, to be provided and maintained in mines of a class to which this section relates in such cases (not being cases falling within subsection (1)) and to such extent as may be prescribed.

(4) Regulations may provide for exempting from this section any prescribed class of mine or any prescribed class of place where mineral is worked, or of roadheads, junctions or roads, and an inspector may, by

notice served on the manager of a particular mine, exempt from this section that mine or any such place, roadhead, junction or road therein.

(5) Such systematic support as is required under this section shall comply with a system specified in support rules being a system consistent with the proper control of movement of the strata in the mine.

(6) Nothing in this section shall be construed as preventing a workman from setting in his working place any additional support which he considers necessary to secure the safety of himself or another.

Power to require systematic support in other mines.

51.—(1) Regulations may require, or empower inspectors to require, systematic support for roofs or sides, or both, in mines other than of coal or other stratified mineral to be provided and maintained in such cases and to such extent as may be prescribed.

(2) Such support shall comply with a system specified in support rules, being a system consistent with the proper control of movement of the strata in the mine.

Supply of materials for support.

52.—(1) Subject to any prescribed exceptions, all materials for support shall be provided by the owner of the mine.

(2) No charge shall be levied upon any workman in respect of the provision of materials for support.

(3) It shall be the duty of the manager of every mine to secure that a sufficient supply of suitable materials for support is at all times readily available, for use at the place where he is actually working, to each workman who needs them.

(4) Where such a supply is not so available, the workman shall withdraw to a place of safety and forthwith report to an official of the mine that he has done so.

(5) Where it appears to the person for the time being in charge of a part of a mine that such supply is not so available to a workman employed there, that person shall cause the workman to withdraw to a place of safety.

(6) Where, on any occasion, a workman has, in pursuance of either of the foregoing subsections, withdrawn from the place where he was actually working, the person for the time being in charge of that part of the mine shall not permit the workman to return to it until that person is satisfied that such a supply of materials will be so available.

Withdrawal of support.

53.—(1) No person shall withdraw support from the roof or sides of any place in a mine otherwise than by a method or device by which he does so from a position of safety.

(2) Where it is part of the system of work to withdraw from the waste or

from under the roof adjoining the waste support provided in compliance with this Act, no person shall withdraw such support except in accordance with a system specified in support rules.

Duties of deputies in relation to support.

54.—It shall be the duty of every deputy to ensure to the best of his ability that all support rules are executed and enforced and that any additional supports which appear to him to be necessary are duly set.

Provisions as to support rules.

55.—(1) Support rules for a mine shall be made by the manager of the mine.

(2) Support rules shall comply with such requirements as may be prescribed, and may impose upon persons employed at the mine such duties and prohibitions as the manager of the mine thinks proper to secure compliance with the provisions of this Part relating to support.

(3) (*a*) If an inspector is of opinion that support rules require modification in any particular, he may serve on the manager of the mine a notice specifying the modification that, in his opinion, ought to be made, and requiring the manager, within a specified time, to modify the rules in accordance with the tenor of the notice.

(*b*) The provisions of section 146 as to references upon notices served by inspectors shall apply to a notice served under this subsection.

(4) A support rule which is inconsistent with the provisions of any regulation shall, to the extent of the inconsistency, be of no effect.

(5) A copy of all support rules shall be kept at the office at the mine or at such other place as may be approved by an inspector. A copy of such rules as are applicable to a district delimited under paragraph (*d*) of subsection (1) of section 17 shall be supplied by the manager to the deputy in charge of the district and shall be kept posted at the entrance to the district so as to be easily seen and read by the persons employed in the district.

(6) It shall be the duty of the manager of every mine for which support rules are for the time being in force to supply to every person employed at the mine whose duties consist of, or include, the setting of supports in accordance with a system specified in the rules, a document explaining either verbally or diagrammatically, or partly in the one way and partly in the other, the effect of the rules so far as they concern him.

B. Support Rules For Underground Excavations – Lisheen Mine

In accordance with Section 55 of the Mines and Quarries Act, 1965, the Support Rules described below will be applied at Lisheen Mine for all excavations.

1. INTRODUCTION

Specification of support is carried out as a function of the following;

a) The nature of the rock mass at a particular location

b) The stress to which the excavation is subjected

c) The size and nature of the excavation

d) The use and duration for which the excavation is required

e) The anticipated stress changes caused by mining.

Information on (a) and (b) will be collected on an ongoing basis by the Geotechnical Engineer. Ranges of support for different conditions are given in Section 6 and the above appointee will determine which of these is appropriate in different areas. Specifications may be formally modified during the life of the mine with the approval of the Manager.

2. RESPONSIBILITIES

2.1 Geotechnical Engineer

1) To determine the appropriate support for each excavation on an ongoing basis.
2) To ensure that the Services Mine Captain is advised in writing of the ground conditions and relevant support specifications for the different areas.
3) To ensure that audits are carried out on installed support to determine its effectiveness.
4) To define a testing program and undertake such tests on the different elements of support as required.
5) To undertake regular examinations of underground excavations and issue a report on the findings and remedial actions required.

2.2 Mine Captain

1) To ensure that written advice of the support designs and associated support specifications is up to date.

2) To ensure that Deputies (Shiftbosses) and supervisors are aware of the support requirements on a shift by shift basis as shown on the support plans.
3) To ensure that both primary and secondary support has been installed correctly and timeously in all excavations.
4) To request assistance from the Geotechnical Engineer where ground conditions raise questions about the optimum means of support

2.3 Deputy (Shiftboss)

1) To make himself familiar with his responsibility, which will be clearly defined on a plan (attached).
2) To confirm what class of support is required in each area of the mine for which he is responsible.
3) To ensure that the specified support is correctly and timeously installed.
4) To bring to the attention of the Mine Captain, ground conditions where technical advice should be sought.
5) To carry out on a monthly basis an inspection of all haulages and cross cuts in his area of responsibility. The inspection to include sidewalls, backs, roadways and all services. Any unsafe condition found must be fixed on the spot **or** the area closed off by a chain barricade and signed 'No – Entry' Time and date of inspections must be recorded and signed off by the relevant shiftboss.
6) To ensure that all blasted development headings are scaled to at least 20m back from the face

3. SUPPORT MATERIALS

3.1 Rockbolts 2.4m x 25mm diameter T grade deformed steel bar c/w 100mm square domed bearing plate.

3.2 Resin 450mm x 25mm capsules Fast set - 30 sec., Slow set - 120 sec.

3.3 Shotcrete As specified dependent on ground conditions and purpose.

1. Sealing against weathering - Plain shotcrete
2. Very poor / fractured - Fibre shotcrete

3.3 Weld mesh Sheets or rolls with 100mm apertures of 8g bar, galvanized.

3.4 Cable Bolts Birdcage **–** 6m long x 15.2mm x 38mm continuous cage.

Bulbed – various lengths x 15.2mm x 28mm bulbs at 0.5m centers.

150x6mm domed bearing plate c/w Surelock (5t) barrel and wedges.

4. INSTALLATION

4.1 Timing

4.1.1 Primary support

Primary support will be a systematic rockbolting pattern and will be installed to stabilize the ground and ensure safe working conditions.

Support will be installed to within 1.5m of the face.

Support will only be installed following scaling of the excavation.

4.1.2 Secondary support

Secondary support will be installed in poor ground to provide for longer term stability or anticipated changes in conditions. Detailed plans with support designs and installation instructions will be issued as required.

4.1.3 High areas

Excavations that exceed 6.5m high will be mined in two passes. The roof and shoulders will be supported with either mesh or shotcrete, and the sidewalls bolted to within 4m of the floor.

4.2 Support Procedures

4.2.1 Scaling	see M-DPR-04.7	Manual Scaling.
4.2.2 Scaling	see M-DPR-04.13	Mechanised Scaling.
4.2.3 Rockbolts	see M-DPR-04.9	Mechanised Rockbolting.
4.2.4 Shotcrete	see M-DPR-04.3	Shotcreting using Spraymec machine.
4.2.5 Cable bolts	see M-DPR-04.10	Cable bolt installation (Manual).
4.2.6 Cable bolts	see M-DPR-04.18	Cable bolt installation (Mechanised).
4.2.7 Mesh	see M-DPR-04.15	Roofbolting with mesh.

5. SUPPORT CODES

An explanation of the support codes given in Section 7 below is as follows:

5.1 Roofbolt pattern

A systematic 1.5m diagonal pattern will be used in the installation of all bolts both in roof and sidewalls where required.

The bolts will be installed in rows with alternating rows staggered, maximum spacing between bolts (within a row and diagonally between rows) is 1.5m.

Unless stated otherwise bolts to be 2.4m long.

In poor ground the pattern may be tightened to 1m square by the bolter operator or Deputy (Shiftboss). This must be recorder on the bolters report.

5.2 Shotcrete

The type of shotcrete (plain or fibre reinforced) will be advised by the geotechnical section.

Unless specifically instructed the application thickness must be 50mm for plain shotcrete or 75mm for fibre shotcrete.

A minimum re-entry time of 8 hours is required between shotcrete applications.

5.3 Cables

The type of cable, length, pattern and angle of cable installations will be advised by the geotechnical section.

A minimum re-entry time of 8 hours is required following the installation of cables and before they can be plated or tensioned.

6. CLASSES OF SUPPORT

Support specifications given below for different type of ground represent the minimum support that must be installed. Any employee may recommend additional support in the interests of safety and such support may be installed with the authorisation of a Deputy (Shiftboss) or higher official.

6.1 Minimum Support Levels

In the absence of a support specification, roofbolts on a systematic 1.5 diagonal pattern must be installed by default.

6.2 Guideline Support Table

ROCK CLASS	Good	Fair	Poor	Very Poor
ROCK MASS RATING	80 - 61	60 - 41	40 - 20	<20
SUPPORT TYPE				
Pattern bolting (1.5m diag.)	********	********	****	
Pattern bolting (1m square)			****	********
Shotcrete 50mm (Plain)		***	***	
Shotcrete 75mm (Fibre)			****	********
Cable bolts			****	********

A range of support designs is provided to cater for these ground conditions and each excavation is monitored and managed to ensure that the appropriate support and design is applied.

7. CLASSIFICATIONS OF GROUND CONDITIONS

A rock mass classification system is used to characterize the ground conditions (Appendix 1). Using diamond drill holes, rock material testing and underground exposures a rock mass rating (RMR) range has been developed identifying three rock classes.

1 Good RMR range 61 – 80 blocky, hard rock, smooth and extensive fractures spaced 0.3 – 1m apart, dry – damp, favorable – fair orientation

2 Fair RMR range 41 – 60 hard rock, smooth extensive fractures spaced less than 0.3m damp – dripping, fair – unfavorable orientation.

3 Poor RMR range 21 – 40 hard rock fragmented by fractures spaced less than 50mm dripping – flowing, unfavorable – very unfavorable.

4 Very Poor RMR range 0 – 20 weathered, cavity, clay filled no structure, wet – flowing, very unfavorable orientation.

The support design issued will allow for variations in the dimension and orientation of the excavations.

Where possible, secondary support to allow for benching, junctions and breakaways will be included in the initial design.

Regular examinations will provide opportunities to reassess the design and modify accordingly. Support for structural anomalies i.e. block stability, laminated bedding of faulted areas will be designed separately and a recommendation issued as a Non Standard Support request.

The secondary support will be designed to cater for the mining–induced stresses anticipated by secondary mining and presupport of open stoping areas.

_____________________	_______________________
Brendan Morris	Joe Burke
Acting Mine Manager	Senior Geotechnical Engineer

DISTRIBUTION:

Underground Superintendent	Mine Captains
Safety Officer	All Shift Supervisors
Technical Services Engineer	Geotechnical Notice Board

C. Roles and Responsibilities for the Lisheen Mine Staff

Who?	Role and responsibility
Senior Geotechnical Engineer	• Maintain health, safety and environmental standards in compliance with the systems adopted on the mine namely ISRS and ISO14001. • Act as the Excavation Support Engineer for the Lisheen Mine as stipulated in the 'Support Rules for Underground Excavations' and ensure that the responsibilities within this section are fulfilled. • Act as liaison with suppliers and consultants specialising in, or related to, all geotechnical matters. • Assist in formulating procedures for the installation of all ground control measures at the Lisheen Mine. Initiate and oversee quality assurance testwork with a view to ensuring ground control procedures are both suitable and cost effective. • Provide timely verbal and written geotechnical advice on all new mine designs. • Assist in the annual preparation of the Ore Reserves Statement. • Recommend, initiate and oversee geotechnical monitoring programs as required. Including surface subsidence monitoring of the on the land above the mining activities. • Provide ongoing geotechnical and ground control awareness training to the Mining Department. • Provide ongoing technical input to ensure geotechnicaly safe implementation of grade control and sampling procedures. • Other duties as may be required by the Technical Services Department. • Review underground support requirements and make recommendations as to the necessary equipment to fulfil the support requirements.

Who?	Role and responsibility?
Geotechnical Engineer	• Assist and support the Geotechnical Section in the application of rock mechanics to ensure the safest and most cost effective extraction of the orebody while maintaining the integrity of the mine. • Maintain health, safety and environmental standards in compliance with the systems adopted on the mine namely ISRS and ISO140001. • To provide rock mechanics support for the Production teams by addressing all ground control issues. • To monitor the implementation, quality assurance and adherence to design of all support installations. • Act as liaison with suppliers and consultants specialising in, or related to, all geotechnical matters. • To contribute to the formulating of procedures and standards for the installation of all ground control measures at the Lisheen Mine. • Initiate and oversee quality assurance testwork with a view to ensuring ground control procedures are both suitable and cost effective. • Provide timely verbal and written geotechnical advice on all new mine designs. • To advise on the implementation of geotechnical monitoring programs as required. • To provide training in ground awareness and support installation as required. • To ensure that the geotechnical database is continuously updated with core logging, scan lines, core photos, mapping and all test work. • To provide risk assessments in areas of potential instability ie. remnant pillars or tertiary stoping. • To carry out any necessary modelling of high risk geotechnical zones to ensure safe and efficient extraction. • To ensure that best practice geotechnical advice is provided at all planning sessions. • To do whatever his/her common sense and experience dictates as good rock mechanics practice for the furtherance of the company. • To promote ground awareness and good rock mechanics practice among all Lisheen employees. • Other duties as may be required by the Senior Geotechnical Engineer.

Who?	Role and responsibility?
Strata Control Officer	• Assist and support the Geotechnical section in the application of rock mechanics to ensure the safest and most cost effective extraction of the orebody while maintaining the integrity of the mine. • Maintain health, safety and environmental standards in compliance with the systems adopted on the mine namely ISRS and ISO140001. • To provide rock mechanics support for the Production teams under the guidance and mentoring of the Geotechnical Engineer, addressing all ground control issues immediately. • To monitor the implementation, quality assurance and adherence to design of all support installations. • To ensure all faces and working areas are risked assessed for ground stability. • To carry out full geotechnical risk assessments on all planned working areas within the 3MRF. • Assist in formulating procedures for the installation of all ground control measures at the Lisheen Mine. • Provide timely verbal and written geotechnical advice on all new mine designs. • Assist in the implementation of geotechnical monitoring programs as required. • To ensure that the geotechnical database is continuously updated with core logging, scan lines, core photos, mapping and all test work. • Other duties as may be required by the Geotechnical Engineer.

Who?	Role and responsibility?
Chief Technical Services Engineer	• Maintain health, safety and environmental standards in compliance with the systems adopted on the mine namely ISRS and ISO14001 as per the attached. • Ensure compliance with Mines & Quarries Act, 1965, Safety, Health and Welfare at Work Act, 1989, Environmental Protection Act, 1992, Fisheries Act, 1959-90 and all other relevant codes of practice, regulatory requirements and legislation of the Republic of Ireland. • Ensure the quality supply of technical services to the mine production department. • Oversee all geotechnical facets of the mine and ensure these are accounted for in all mining plans. • Oversee the backfilling strategy for Lisheen. • Oversee the ventilation of the mine. • Oversee the preparation of short, medium and long-term production schedules and plans for the mine. • Oversee the compilation and issuing of drill and blast plans to the mine production department. • Oversee the survey department and surveying of all underground voids. • Oversee the annual Ore Reserves process for the mine and sign off on the annual Resource and Reserve statement. • Prepare and present yearly and life of mine capital and operating budgets for the Mining Department. • Oversee monthly survey reports, KPI's, and mine production reports. • Advise and initiate improvements to the mine as required. • Maintain all relevant technical services procedures and ensure all personnel in the technical services department are adequately trained for their position and informed of the standards and procedures.

Who?	Role and responsibility?
Mine Planning Engineer	• Maintain health, safety and environmental standards in compliance with the systems adopted on the mine namely ISRS and ISO 14001 as per the attached. • Identify appropriate mining methods & designs for the extraction of ore. • Prepare conceptual and final stope designs using Vulcan Software and other software as appropriate. • Design all underground development. • Design all underground services required to support the mining. This includes: Ventilation, electrical power supply & dewatering systems. • Communicate all aspects of designs through written reports to all stakeholders. • Back analysis of designs & stopes upon completion of mining. • Specify, in conjunction with the Geotechnical Engineer, stope fill requirements. • Specify short term mining sequences and issue short and medium term schedules. • Assist in the annual Ore Reserves process. • Analyse mine performance and prepare reports of same as required by Lisheen management. • Design the underground ventilation network. Ensure compliance with all relevant statutory requirements under Irish Mining Legislation. Recommend changes to the ventilation network as required so as to improve the efficiency of same. • Compile and present a three month rolling forecast to the production department on a monthly basis. • Undertake and supervise other miscellaneous activities as required by the Chief Technical Services

Who?	Role and responsibility?
Drill & Blast Engineer	• Maintain health, safety and environmental standards in compliance with the systems adopted on the mine namely ISRS and ISO 14001 as per the attached. • Prepare conceptual and final stope designs using Vulcan Software. • Prepare drill ring designs and blast plans for pillars and stopes. • Communicate all aspects of designs through written reports to all stakeholders. • Back analysis of designs & stopes upon completion of mining. • Analyse mine performance and prepare reports of same as required by Lisheen management. • Compile and present a monthly long hole forecast to the production department. • Undertake and supervise other miscellaneous activities as required by the Chief Technical Services Engineer

D. Sign-off Certificate example

LONG HOLE DESIGN SIGN OFF

THE LISHEEN MINE

STOPE: **DATE:**

CIRCULATION			
PLANNED COMPLETION DATE	Geology assessment		
	Geotechnical assessment		
	Development		
	Support		
	Ring design		
	Drilling start date		
	Firing start date		
	Monthly production rate		
GENERAL INFORMATION & PLANNING & D&B ENG	Tonnes and grade		
	Are the planview, all sections issued with mining sequence?	YES	NO
	Are neighbouring excavations and voids indicated on the plan?	YES	NO
	Is barricade position indicated on the plan?	YES	NO
	Do paste barricades need to be constructed prior to drilling or blasting the stope?	YES	NO
	Are there breakthroughs that need to be guarded near the stope? Are they on the plan?	YES	NO
	Are there areas that must be avoided or barricaded due to thin middlings?	YES	NO
	Is there potential for paste leaking into this stope?	YES	NO
	Are there any intersecting drill holes? (Indicate on plan)	YES	NO
	Exposed paste strength		
	Planned Dilution		
	Burden, spacing		
	Hole diameter		
	Ring dump angle		
	Raise dimension		
	Are any special drilling and blasting instructions required?		
	Comments:		
	Signed:	Position:	Date:
	Signed:	Position:	Date:

CIRCULATION			
ROCK MECHANICS	Is area supported adequately for purpose?	YES	NO
	Do any geotechnical risks exist to threaten safe mining?	YES	NO
	Is any instrumentation required & is it in place?	YES	NO
	Does FW drive/HH/HW drive require pre-support, special roof or sidewall	YES	NO
	Are cable bolts support required?	YES	NO
	Are any special geotechnical instructions required?	YES	NO
	Ground conditions		
	Signed: Position:	Date:	
GEOLOGY	All physical mapping, sampling and diamond drilling from this area		
	this area complete?	YES	NO
	Area up to date HW/FW surface provided?	YES	NO
	Are there contaminants or low grade zone to avoid?	YES	NO
	Is more than one lens being mined?	YES	NO
	Are known structures included on the plan?	YES	NO
	Signed: Position:	Date:	
SURVEY	Are required surveys complete?		
	Is asbuilt model completed & published for the area?		
	Name of asbuilt triangulation		
	Signed: Position:	Date:	

CIRCULATION			
SECTION MINE CAPTAIN	Are support installed, pillars checked and all equipment removed?		
	Have all water makes in drift/panel been picked up?		
	Is the area cleaned for Long Hole access?		
	Signed:	Position:	Date:
		Signature:	Date:
	TS Engineer		
	U/G Superintendent		
	Mine Manager		

CLOSING COMMENTS (PLANNING ENG)			
	Signed:	Position:	Date:

Figure 31: Long Hole Design Sign Off sheet

E. Site modified Bieniawski RMR system

ROCK MASS CLASSIFICATION - example RMR

PARAMETERS	RUN 1	RUN 2		
RQD	92.3	66.7	*Standard run/recovery(>100mm)*100 - both lengths indicate good ground*	These parameters used to obtain the 'Predict' values for planning. Initial development and primary stoping
JOINT NUMBER	92.3	66.7	*Single and single + random joint set no change to rating*	
JOINT FREQUENCY	92.3	63.4	*Length 1 - same, length 2 with 8 ff/m derate RQD value by 5%.*	
ALTERATION	92.3	50.7	*Length 1 - same, length 2 with value of 0 (soil) derate value by 20%.*	
VUGGYNESS	92.3	43.1	*Length 1 - same, length 2 with value of 0 (soil) derate value by 15%.*	Parameters used for more detailed examination of longterm excavations
ROUGHNESS	92.3	36.6	*Length 1 - same, length 2 with value of 0 (soil) derate value by 15%.*	
STRENGTH	92.3	33.0	*Length 1 - same, length 2 value of 2 (weak rock 5-50mpa) derate value by 10%.*	
ROCK MASS RATING	92.3	33.0	***Length 1 - all parameters indicate very good ground at RMR of 92.3. Length 2 - poorer ground but suspect that the alt/vug & rgh values have been recorded wrong, a 0 value indicates a crushed rock /soil and does not match the ff/m or str. values. I would check this length with photos or geological log, for primary development would give a RMR of 50.7***	
WEATHERING / WATER			*Crude values - dry 0%, damp 5%, wet 10%, multiple flows 15%, high flow with pressure 20%*	Parameters used in secondary or tertiary extraction stage.
ORIENTATION			*Crude values includes direction and dips -very favorable 0% to very unfavorable 20%*	
STRESSES (stress red. fact)			*Values take into account secondary mining,paste exposure, pillar removal 0% - 20%*	
BLASTING			*Primary devt. 0%, benching 5%, slash retreat 10%, predrilled pillars 15%, LH stoping 20%*	
DRMS				
CLASS 1				

A section of a DD hole v.good and poor

DEPTH FROM	DEPTH TO	Run	Recovery	RQD	Joint frequency	Lith	JOINTS Num.	JOINTS Alt.	JOINTS Vug.	JOINTS Rgh.	Rock Material Str.	Rock Material Infill	REMARKS
152·89	153·80	·91	·84	92.3	2	5.00	1	1	1	1	3		
153·80	155·0	1·20	·80	66	8	S-Nm	2	0	0	0	2		

ROCK MASS CLASSIFICATION - Ratings

PARAMETERS	RATING 1	2	3	4	5	NUMBER / METER <10	10-15	15-20	>20
RQD	*Derate by following persentage*								
JOINT NUMBER	0	0	10	15	20				
JOINT FREQUENCY						0	5	10	20
ALTERATION	0	0	10	15	20				
VUGGYNESS	0	0	5	10	15				
ROUGHNESS	0	0	5	10	15				
STRENGTH	15	10	0	0	0				
ROCK MASS RATING									
WEATHERING / WATER									
ORIENTATION									
STRESSES									
BLASTING									
DRMR									
CLASS 1									

LEGEND – PARAMETER CODES

RUN =	Length of total amount of drilled core.
REC =	The total length of the core recovered as solid cylinders greater than 100mm
RQD =	The sum of all core pieces >10cm, measured along the center line of the core, drilling breaks excluded, expressed as a percentage of the drilled run length.
JF =	Joint frequency, the sum total of discontinuities (joints, fractures) counted in the drilled run length.
Num =	Estimated number of joint sets
1	Massive, no or few sets
	One set
2	One set plus random
	Two sets
3	Two sets plus random
	Three sets
4	Three sets plus random
	Four or more sets, random, heavily jointed
5	Crushed rock, earthlike

FF
Fracture frequency per metre of run.

Weathering (Alteration)

1	Fresh
2	Slightly weathered
3	Moderately weathered
4	Highly weathered
5	Completely weathered
6	Residual soil

Vuggyness

Non vuggy	0
To Highly vuggy	5

Rock Strength

5	Very strong (>200MPa)
4	Strong (100 – 200 MPa)
3	Medium (50 – 100MPa)
2	Weak (5 – 50MPa)
1	Very weak (1 – 5MPa)

Roughness

1	Discontinuous joints
	Rough and irregular, undulating
2	Smooth, undulating
	Slicken sided, undulating
3	Rough or irregular planar
4	Smooth, planar
5	Slicken sided, planar

Infill

Clay	(CLY)
Sand	(SND)
White dolomite	(W-DOL)
Pink dolomite	(P-DOL)
Calcite	(CAL)
Argillite	(ARG)

F. Area Assessment Checklist

AREA: DS00D04

DESK STUDY	COMMENTS	By /Date
Predict layer ground conditions	Very small section of class 1, mostly class 4.	DJ 4/7/13
Diamond Drilling surface & u/g	Show a relatively poor hanging wall contact with very poor areas near features (wrench fault and fault at DS11D01 - DS11D10 intersection). Neither of which should directly intersect this stope, however the massive overbreak area from the wrench fault is only 6 metres away from the northern corner of the designed stope. RQD for first 2 metres above hanging wall contact is 0. RQD then improves to 60 for the majority of the stope.	DJ 4/7/13
Local Structure	Wrench fault to the north of the stope has invariably caused us massive problems, however this should be a minimum of 6 metres away. There was also an E-W striking fault at the end of the DS11D11 which will cut the southern corner of the stope. There is a fault at the DS11D01 - DS11D10 intersection whith uncertain of strike (approx. NW-SE). This caused massive overbreak. Development of the DS00D04 crossed the very steeply dipping footwall which had extremely poor ground on it for approximately 3 metres. This area in the drive now has a shotcrete arch on the footwall side but this area of the FW may cause some issues, particularly to the drilling around DS00X04.	DJ 8/7/13
Core Photos	DSC-121, DSC-167, DSC-257, DSC-334, LK-0325, LK-0856, LK-0863, LK-0922 attached. Refer to plan 1, sections a-a1 through d-d1 and Diamond drilling section.	DJ 4/7/13
Face Sheets	Faulted around DS00X04 hammerhead. Very poor ground in the face sheets in H01 slightly to the south of where it goes over the top of the DS00D04. This is likely to be where the E-W fault and the low angle fault NE-SW in the H01 intersect.	DJ 4/7/13
Existing support	56% of the presupport required for DS00S04 is complete. "derryville Sandwich" on the H01; sets, mesh and shotcrete. Top level drives are all roof and sidewall bolted and shotcreted. Paste exposures are shotcreted, but not bolted (may need checking up). FOG material in DS08G02 is not supported at all. Shotcrete Arch on the footwall contact.	DJ 8/7/13
Recent mining.	Many of the stopes along the wrench fault were removed in recent months. All have overbroken to a large extent. This is a cause for concern for this stope. However there is approx 6 metres distance to the wrench fault and the hanging wall of the stope is slightly in this case which should mean improved conditions. The stoping of the very end of DS11S11 did not overbreak to any great extent. There should therefore be no problem with the E-W striking fault. This area in DS11S10 was not tight filled, it may be filled when we fill the 40S01 depending on the extent of the collapse in DS11S11, in fact we may get some of this overbreak coming in at this point.	DJ 8/7/13
Span to be created.	Span to be created depends on whether we need to consider the paste filled surrounding areas in the span or not. If we do then the span is approx 270 metres along the length of the drive and over 200 metres along the width of the drive reducing at the end to 17.2 metres where the pillars remain. However the DS panel 8 stopes are filled to a high enough level to be considered tight filled for this stope. The DS11S10 which is not currently tight filled should be filled from a higher point when DS40S01 is filled (this will need veryfying when the stope is filled). With tight paste fill around the stope, the maximum span is 42.8 x 20.8 (average as stope shape is not straight) this gives a hydraulic radius of 7. This is a figure which should be stable with presupport and since much of the hanging wall area is already developed and supported.	DJ 9/7/13
Paste exposure	Paste is exposed in DS09S02 - of good quality and shotcreted. Paste in DS08G02 is on top of collapse material which may cave and come into the stope. This should be shotcreted but is not yet done. Paste will be exposed in DS11S10, this was exposed in DS11S11 and was of good quality. It was not tight filled which means that the fill we will put in DS40S01 may come over the top. It therefore needs to be of good quality.	DJ 9/7/13

Extraction sequence	This is the first in a series of stope extractions which are all reliant on one another. As this is the first, it is also the simplest. However it is necessary to ensure that presupport cable bolting is completed for future stopes in any area that will be inaccessible once paste filled. Also the paste fill needs to be of good quality as it will be exposed within stopes and in paste barricades which will be removed. For the future stability of these stopes it is also necessary that this stope is tight filled.	DJ 9/7/13
U/G INVESTIGATIONS	**OBSERVATIONS**	**by /Date**
Stability Assessment	Current stability is relatively good. The main concern at the moment is the narrow skin of ore on the paste on the LHS to the north east of DS00X04 and the overbreak at the footwall.	DJ 9/7/13
Support Assessment	Skin of ore is cabled to paste. Currently stable but will require monitoring during cabling as anchoring in paste is not ideal. The shotcrete arch needs another coat of shotcrete to complete it. Presupport is 56 % completed for this stope in DS00H01. FOG material in DS08G02 is not supported and should be before stoping.	DJ 9/7/13
Pillar Assessment	N/A	DJ 9/7/13
Risk Assessment	1. Collapse of skin of ore on paste during drilling. 2. FOG material in DS08G02 comes in. 3. Cave in of area between wrench fault and stope during stopeing. 4. Paste comes in from DS09S02 or any of the other surrounding stopes. 5. Brow failure, particularly at FW. 6. Paste o0r waste cave in from DS11S10.	DJ 9/7/13
Further Geotechnical Invesigations	Not required until usual monitoring of stoping.	DJ 9/7/13
RECOMMENDATIONS	**ACTIONS TAKEN**	**by / Date**
Additional Support required	Remaining presupport, Shotcrete DS08G02 FOG material. One more coat on shotcrete arch.	DJ 9/7/13
Instrumentation required.	Extensometer already installed above DS00H01.	DJ 9/7/13
Communication Noddy plans, board, briefings	Roll out to Shift Bosses and Mine Captains. No communication boards planned.	DJ 9/7/13
Closure void, waste or paste	Paste of high quality required since it will be exposed several times in the future. Tight fill required for stability of adjacent stopes. No waste packing possible as mining either side.	DJ 9/7/13
SUMMARY ON COMPLETION OF STOPE		

G. Geotechnical Risk Assessment

Geotechnical Risk Assessment/Facilitation Team Data

Department: Mining **Section:** MW 05S07 **Date:**17-04-2014

Subject: Pillar Retreat Activities of MW05S07 Area

Risk Assessment Team Names: J Pilkington, D Wixted-McPherson, P Condon, P Barrett, E Nilis and J Schoeman

No.	Hazard	Potential Incident (Unwanted Event)	Current Controls	Consequence	Likelihood	Risk Rank	Additional Controls	Consequence	Likelihood	Risk Rank
1	Fall of ground from roof and sidewalls due to increased mining induced stress	Serious injury or fatality Equipment damage or loss Production disruption or loss	Pre-installed ground support Pre-drilling of entire area to be extracted Geotechnical assessment and monitoring Limited access to area Remote mucking operation Communication and Awareness	4	4	21	Inspections at re-entry Regular inspection of pillar sides and roof to detect any deterioration. Remote mucking stand location to be assessed in compliance with remote mucking procedure prior to mucking out Expediate Mucking of each firing	2	4	12
2	Spalling (pop-outs)/Sidewall deterioration	Injury to personnel Equipment damage	Installed support & shotcrete Limited access to area Remote mucking operation Communication and Awareness	3	3	13	Inspections at re-entry Regular inspections of MW05D02 & MW05R27 drives Take 5 Scale after each blast Expediate Mucking of each firing	2	3	8
3	Sudden collapse of brow/drawpoint	Serious injury or fatality Equipment damage or loss Production disruption or loss	Pre-installed support Limited access to area Remote mucking operation Communication and Awareness	4	3	18	Inspections at re-entry Regular inspections of MW05D02 & MW05R27 drives Take 5 Scale after each blast	3	3	13
4	No or inadequate ventilation	Health exposure Build up of fumes gases and dust Oxygen deficiency Production disruption or loss	Forced ventilation system Planning and sequencing of pillar extraction Supervision Communication and awareness Gas detection	2	3	8	Remote stand to be positioned at predetermined locations as indicated on associated plan throughout the mucking operations in this area Limit access to area	2	2	5
5	Congestion during mucking operations along access route and at entry to mucking area	Physical harm by collision or machine contact. Equipment damage or loss. Production deisruption or loss.	Planning and sequencing of mucking operations Barricades and signage Supervision Standard procedures and rules Communication and awareness	4	2	14	Ensure proper chain barricade/s installed and kept closed at all times when no activity in stope. Responsible supervisor to be contacted for permission to enter area. Limit access to area	3	2	9
6	Unauthorised access into work area by personnel	Exposure to potential loose, stressed pillars or unstable ground. Moving machinery and equipment. Build up of fumes or gases. Oxygen deficiency.	Barricades and signage Supervision Standard procedures and rules Communication Training Ventilation and gas testing	4	2	14	Ensure proper chain barricade/s installed and kept closed at all times when no activity in stope. Responsible supervisor to be contacted for permission to enter area Limit access to area	3	2	9

H. Non-Standard Support Request

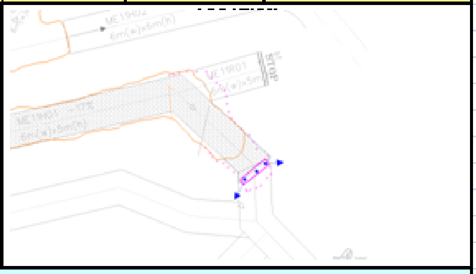
Non Standard Support Request						ME 12-13
Location: ME11H01			Issued by: J Talbot			Date: 27/06/2013
HEADING ON HOLD FOR NON STANDARD SUPPORT			(1) Section S/Boss:			Date:
PRE-CHECK : Area is safe to work in, risk assessment carried out and any deficiencies corrected prior to work commencing (e.g. pumps and services moved, mucked, scaled, bolted, vent, power and water in place).						
HEADING READY FOR NON STANDARD SUPPORT			(2) Service S/Boss:			Date:
Date and Shift						COMMENTS
CHAIN & SIGN INSTALLED						
UNIT TYPE INSTALLED						
# HOLES DRILLED						
# CABLES INSTALLED						
# GROUTED						
# TENSIONED						
# STRAPS						
# MESH						
OTHER						
S-35 SHOTCRETE (m^3)						
S-20 SHOTCRETE (m^3)						
Shift check by Service S/Boss						

JOB INSTRUCTIONS:

1. Install one row of 3 X 6m cables at face of 11H01
2. Strap and tension cables

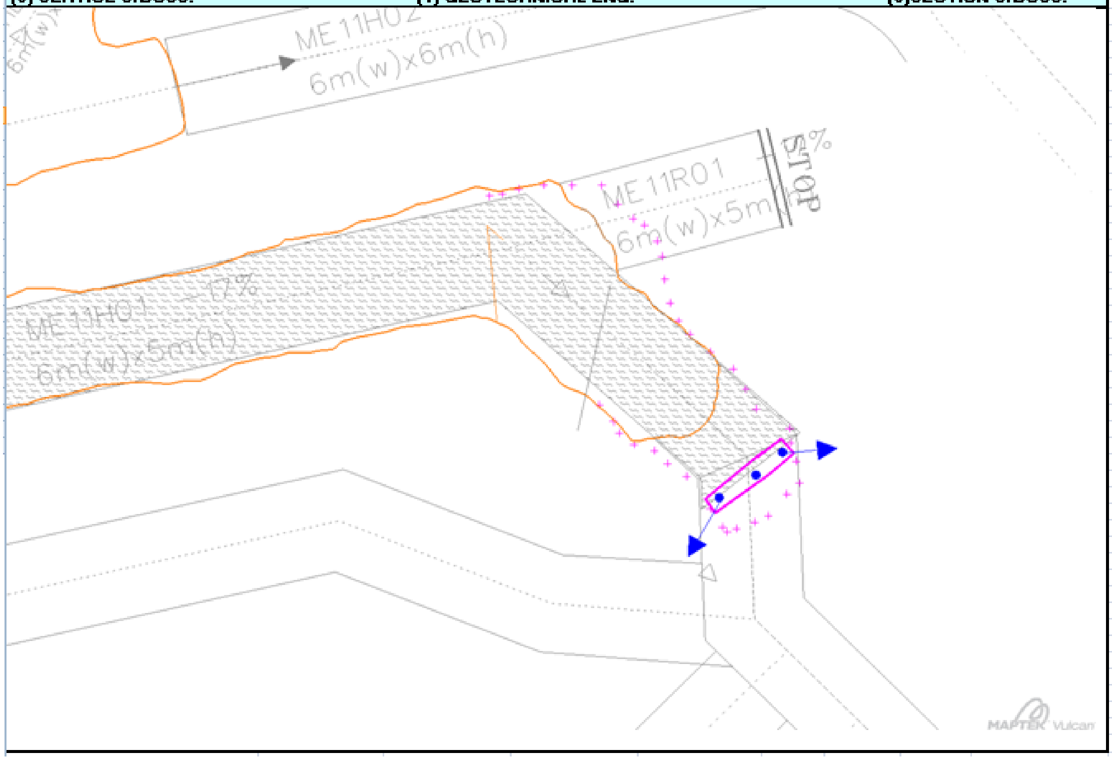
REASON: poor bolting

(Detailed plan overleaf)



WORK COMPLETED TO STANDARD, ALL EQUIPMENT REMOVED, HEADING CLEANED AND HANDED BACK TO SECTION

(3) SERVICE S/BOSS: (4) GEOTECHNICAL ENG: (5)SECTION S/BOSS:



I. Mining Departmental Procedure for Mechanised Roofbolting

<u>THE LISHEEN MINE PARTNERSHIP</u>

<u>MINING DEPARTMENTAL PROCEDURE</u>

<u>DRAFTED BY:</u>	Senior Geotechnical Engineer	<u>PROCEDURE NO.:</u>	M-DPR-04.9
<u>DISTRIBUTION:</u>	Supervisory Personnel	<u>REVISION NO.:</u>	2
<u>EFFECTIVE DATE:</u>	20.4.01.	<u>DATE OF ISSUE:</u>	19/02/2013
		<u>RELATED POLICY:</u>	Nil

Key words: ground support, support, roofbolt, rebar, resin, safety, stability,

<u>MECHANISED ROOFBOLTING</u>

1. PREAMBLE

The Lisheen trackless equipment complement includes three classes of Atlas Copco Boltec roof-bolting machines. These units can, when efficiently operated eliminate the exposure of people to the risks involved in manually drilling and installing support.

2. SCOPE

This procedure applies to all personnel engaged in underground mining operations and specifically to ground support. As such, the procedure applies to Section Heads, Mine Captains, Shiftbosses and miners.

3. OBJECTIVE

The objective of this procedure is to set out a methodology for the safe installation of rockbolts using the automatic roofbolters.
This procedure is **NOT** intended to replace the operating instructions for the roofbolter machine.

4. EQUIPMENT REQUIRED

- **Atlas Copco 335S/SH/M7C Boltec** ~~(Rig selection based on length of rebar to be installed)~~
- **Rebar** - Y25 x 2.4m long, c/w 100mm square domed washer and M24domed hex nut with spot weld 40mm from the 125mm threaded end and a 20degree chamfer at the top end.

		stock no. 5892
~~Length as required~~	~~1.8m~~	~~stock no. 46706~~
	~~2.4m~~	~~stock no. 5892~~
	~~3.0m~~	~~stock no. 29785~~
Resin - 25mm x 450mm	Fast set (Red)	stock no. 14696
	Slow set (Green)	stock no. 14704
Nozzle - 31mm OD / 27mm ID		stock no. 49163
Drill bit - 33mm 7 button		stock no. 42432

5. PROCEDURE FOR THE USE, HANDLING & CARE OF TRAILING CABLES

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1. Anchor cable end to an anchor point at the gate end box, or if using a rat trap anchored at the rat trap holder. This is done to prevent tension on the plug end and socket sets. Report immediately to your supervisor any rat trap that is not secured to the sidewall.
2. Drive the rig to the work area connecting water along the way. Park correctly when dismounting the machine.
3. Place the trailing cable along the sidewall to prevent damage to the cable. Place warning signs in at prominent positions to warn other vehicles of the cable.
4. When plugging in at a gate end box ensure the stop button is pushed in for the socket you are about to use and the light for that socket, (A or B) is off. When plugging into a rat trap isolate the supply cable at the GEB first, by using the red sock bag and padlock, and then connect to the rat trap.
5. Do not insert anything other than the plug into a GEB socket. If you can see dirt in the socket call an electrician to clean out, there is a risk potential for the pins to be live even if the pilot light is out. The electricians can isolate the circuit further by moving the isolation lever to the off position which will isolate both outlets on that bank.
6. Always carry out an Earth Leakage Test at the GEB when powering up as per Procedure M-DPR-13.9. In the event of test failure, switch off and inform shiftboss immediately.

REMEMBER- NEVER PLUG, UNPLUG OR HANDLE LIVE CABLES – POWER OFF AND ISOLATE FIRST.

If it is essential to move a live trailing cable, use the "Hot Stick". This is a non electric conductive stick with a hook at the end. Observe correct manual handling techniques when using the "Hot Stick" and get assistance when required. Do an earth leakage test. The earth leakage protection sensitivity is set and tested at a trip level which ensures that no person can suffer a significant electric shock should the rig or its electrical supply become faulty.

6. PROCEDURE

1. Position the bolter under supported and barred down roof.
2. Ensure that the face, hanging wall and sidewalls are properly barred and safe.
3. Set up the rig in such a way that the maximum number of bolts can be installed.
4. Ensure that the carousel is loaded with completed fitted rebar before entering the work place.
5. Ensure that sufficient resin of both Fast and Slow are available in the box.
6. Ensure that the correct drill steel and rebar length are available on the machine.
7. Check the support plan or pattern and decide where to collar the holes if necessary angle bolts to cross weak structures. **READ THE GROUND** and complete your Take 5 form.
8. Park brake engagement and gear in neutral.
9. Outriggers positioned on level ground.
10. Test the carousel for free movement.
11. Persons or objects not involved removed from area, ensure that no one is forward of the Cab.
12. ~~Trailing cable hung on side walls and warning sign in place.~~
13. Position the bolting head and push the stringer against the rock face.
14. Drill a 33mm diameter hole to the required length and flush with water.
15. Clear hose and nozzle with compressed air and change to injection position.
16. Insert the injection nozzle into the hole ensuring that some vent slots are exposed by injection of a small amount of air into hole.
17. Fill the charging device with 3 FAST resin capsules (25mm) and inject into hole.
18. Repeat the operation ~~as required~~ using 3 SLOW resin capsules. ~~each time.~~
19. Withdraw the injection nozzle and change to the bolting position.
20. Push the rebar 1/3 way up the hole and start the rotation anti – clockwise.
21. While continuing rotation push the rebar to the end of the hole – max time 30 sec.
22. Hold the rebar in place for a further 45 seconds to allow the resin set.
23. Tension the rebar by rotating clockwise with the bolt rotator.
24. If the resin fails to stay in the hole or insufficient resin (6 capsules) is installed the hole must be redrilled. A fully grouted hole is achieved when some resin extrudes from the collar.

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25. At the end of shift ensure that the boom, rail and resin nozzle is washed down and cleaned.
~~26. A 0.5m service (J bolt) hole must be drilled on the left hand sidewall 3m off the floor.~~
26 The carousel and resin cassette are to be reloaded under supported ground.
27. Following completion of bolting the face is to be barricaded off and the results recorded.
28. When drilling paste sidewalls DO NOT use bearing plates and install by pushing and rotating bolt into the paste leaving 100mm protruding.
29. If when drilling the roof it is found that less than 1.5m of ore remains inform the shiftboss.
30. If a resin cartridge becomes stuck in the nozzle, either move the machine back to supported ground to remove or manipulate the drill steel to hold the resin against the sidewall and retract the nozzle freeing the resin. DO NOT carry out repairs under unsupported ground.
31. In badly fractured/jointed ground it may be necessary to apply a sealing layer of shotcrete to provide surface restraint to allow collaring of holes.
32. All ABL sidewalls that have a dip greater than 15^0 must be bolted on either a 1.5 or 1m square pattern depending on how wet, steep or laminated the ABL is.
33. Any poor ground or unusual ground conditions must be reported to the shiftboss and noted in the daily bolting report sheet.

7. RESPONSIBILITIES

a) The Mine Captain is responsible for ensuring that all affected personnel are aware of and understands this procedure.
b) Shiftbosses are responsible for ensuring compliance with the procedure.
c) The operator must complete the daily report sheet in full and ensure that any discrepancies are brought to the attention of the shiftboss.

This Procedure Review Impacts on the Following:		YES	NO
1.	Critical Task Analysis / Additional Related Procedures need Review		X
2.	Orientation / Induction and Training is Required		X
3.	General & Specialised Work Rules to be Implemented		X
4.	Emergency Procedures to be Amended		X
5.	Hazard Identification and Related Risk Assessments to be Reviewed		X

Approved by:-

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Brian Keady
Mine Manager

____
Joe Burke
Senior Geotechnical Engineer

____
Brendan Morris
Production Superintendant

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J. Backfill/Stope Closure Certificate

LISHEEN MINE

NOTICE TO BACKFILL / STOPE CLOSURE CERTIFICATE

STOPE:____________________ MINE CAPTAIN: _________________ DATE:_____________

CIRCULATION			
1. PLANNING ENGINEER	Is plan of area issued showing barricade positions, high points, pour points and fill hole positions		
	Required paste level and volume of waste placement?		
	Geometry of waste acceptable & other relevant info marked?		
	Is the paste to be re exposed and how? (indicate on plan)		
	Are there any intersecting drill holes or potential leaks?		
	Signed:	Position:	Date:
2. ROCK MECHANICS	Is area supported adequately for purpose?		
	Do any geotechnical risks exist to threaten safe filling?		
	Is any instrumentation required & if so, is it in place?		
	Special instructions:		
	Signed:	Position:	Date:
3. GEOLOGY	Do minable reserves remain in Stope (attach plan if necessary)?		
	All physical mapping & sampling from this area complete?		
	Signed:	Position:	Date:

CIRCULATION			
4. SURVEY	Required survey complete ?		
	Asbuilt model completed & published?		
	Name of triangulation file?		
	Calculated volume.		
	Signed:	Position:	Date:
5. Tech. Service Engineer			
	Signed:	Position:	Date:
6. Production Superintendent			
	Signed:	Position:	Date:
7. SECTION MINE CAPTAIN	Stope examined for misfires?		
	Support installed, pillars checked and all equipment removed?		
	All waste placement completed & volumes recorded?		
	All services retrieved ?		
	Have all water makes in stope /panel being picked up? (if not give details)		
	Location of barricades and fill points checked and secure?		
	Signed:	Position:	Date:
STOPE HANDOVER	Mine / Backfill Captains after Walk Through completed		
8. Mine/Fill Captains	Walk through completed?		
	Take 5 risk card attached for handover to backfill captain?		
	Additional work required?		
	Signed:	Position:	Date:
	Signed:	Position:	Date:
9. BACKFILL MINE CAPTAIN	Backfill Plan (See completed stope sheet) :comments		
	For details of paste quality and pouring volumes see completed stope sheet		
	Is paste placed adequate for the above mining requirements (if no provide details)		
	Comments		
	Signed:	Position:	Date:
10. GEOTECHNICAL ENGINEER.	Paste fit for purpose		
	Unfilled areas identified		
	Plotted on Vulcan:	Filed:	
	Signed:	Position:	Date:

K. Ground Conditions / Hazard Report Card

GROUND CONDITIONS / HAZARD REPORT CARD					
DATE / TIME:				GCH Card #	
Person Reporting:					
Work Performed:					
Department / Supervisor					
Location of Incident:					
Nature of Incident	FOG	Stope Failure	Poor Ground	Ground Move.	Water make
	Cracking	Scats in roof	Blast damage	Paste	Noise
	ABL	Support	Feature	Pyrite in roof	Slabbing
Diagram showing location and type of Hazard			DESCRIPTION OF HAZARD		
PERSON REPORTING HAZARD – PLEASE COMPLETE SECOND PAGE					
SUPERVISOR TO COMPLETE:	Name:			Date:	
Action Taken:					
IS A GEOTECHNICAL INSPECTION REQUIRED	YES	NO	Other:		
GEOTECHNICAL ENGINEER USE:	Name:		Date Received:		
Action Taken:					
FEEDBACK (to originator and line supervisor on significance of event and corrective actions taken)					
Line Supervisor:	Date:	Signature:			
Initiator:	Date:	Signature:			
ACTIONS:	NSS:	Installed:	Checked:		
Geotechnical Engineers Signature:			Date:		

GROUND CONDITIONS HAZARD REPORT CARD CHECKLIST

TYPE OF HAZARD / REPORT *(tick all that apply)*

	Fall of ground		Bagged mesh		Installing ground support
	Poor ground conditions		Cracked shotcrete		Roof scats
	Failure of ground support		Faults / joints		Blast damage
	Ground movement		Brows		Groundwater
	Rock noise		Paste		Sidewall slabbing

Other *(describe)*

WHERE IS THE HAZARD LOCATED *(tick all that apply)*

	Roof		Shoulder		Drive
	Face		Draw Point		Intersection
	Floor		Raise		In stope
	Wall		Stope brow		Paste sidewall

Other *(describe)*

WHAT TASK WERE YOU PERFORMING WHEN YOU NOTICED THE HAZARD *(tick all that apply)*

	Located after hazard formed		Drilling		Trucking
	Inspecting site *(survey, mapping)*		Installing ground support		Loading
	Hand scaling		Charging		Install / maintain services
	Mechanical scaling		Mucking		Backfill pipes/barricades

Other *(describe)*

SIZE OF HAZARD / FALL OF GROUND

	Tennis Ball		4WD Vehicle		Large blocks
	Football		Scoop		Shaley slabs
	4WD Tyre		Sands / clay		Weathered ground

Other *(describe)*

EXISTING GROUND CONTROL MEASURES IN AREA OF HAZARD *(tick all that apply)*

	None		Cable bolts - untensioned		Perimeter blasting
	Rebar Bolts		Mesh / straps		Spiles
	Split Set Bolts		Shotcrete S20 or S35		Shotcrete arches
	Cable bolts - tensioned		Pressure grouting		Steel arches

Other *(describe)*

Feed back:

_Post on Geotechnical Notice Board - copy of original form with comments in feedback section.
-Line supervisor to be notified by email of support or follow up measures being taken and when completed.
-Originator to be informed on action being taken by Line Supervisor and for significant incident by the Geotechnical Engineer.
-Incident to be recorded in FOG database by Geotechnical Engineer.