NSW GOVERNMENT

NSW Resources Regulator

PLANNED INSPECTION PROGRAM

GROUND OR STRATA FAILURE – UNDERGROUND METALLIFEROUS

CONSOLIDATED REPORT

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Executive summary

A crucial part of the NSW Resources Regulator's Incident Prevention Strategy involves targeted assessment and planned inspection programs for mines and petroleum sites. This is a focus on assessing an operation's control of critical risks through evaluating the effectiveness of control measures in the mine's safety management system.

We developed a bowtie hazard management framework and standardised assessment checklist for each program plan. Under each program plan, the effectiveness of the safety management system at each mine site is assessed against a standard set of control supports and critical controls.

This final report summarises assessment findings from 19 mines in relation to the assessments for the principal hazard of ground or strata failure in underground metalliferous mines conducted during the period from September 2019 to January 2020.

The threats and critical controls that were assessed in this program are shown in Table 1. Note that this is not a definitive list of controls for all ground and strata risks, rather a selection of critical controls that were appropriate to assess in an underground environment.

Table 1. Threats and Critical Controls for the Material Unwanted Event (Ground or Strata Failure)

THREAT/CONSEQENCE	CRITICAL CONTROL
Issues with driven roadways	PC1.1 – Drives developed and ground support installed as per approved design/plans
	PC1.3 – Ground or strata monitoring
Issues when caving ground or strata	PC2.2 – Goaf/cave monitoring and response to changes
Issues with pillars	PC3.1 – Stable pillars
Fatality or injury of people due to falling ground	MC1.1 – Workers to avoid positioning themselves within fall zone of unsupported ground or strata

Legislative requirements and published guidance relating to the management of ground or strata failure risks are at Appendix A. Figure 1 presents safety compliance findings of the threat/consequence and critical controls for each de-identified mine. Explanatory notes on the assessment system are in Appendix B.

Key Findings

The key findings uncovered during the planned inspection program are outlined below:

- Three of the nineteen mines inspected were under care and maintenance and one mine was not in operation at the time of inspection. Another two mines were only conducting development activities for future mining and had not started production activities.
- A variety of mining methods were in use at the mines conducting production activities including:
  - block caving
  - sub-level caving
  - open stoping using either paste or hydraulic filling
  - bench stoping with waste fill
  - conventional bottom-up longhole stoping backfilled with cement hydraulic fill or waste
  - small open or bench stopes, with a combination of cemented and dry rock backfill
  - panel open stopes mined bottom upwards towards small crown pillars separating the panels.
- All mines except one had prepared and implemented formal ground or strata failure principal hazard management plans (PHMPs), however there were several mines where the PHMP and associated trigger action response plan (TARP) documentation was not relevant, current, or readily available.
- Generally, compliance was found to be of a good standard, with ground and strata support systems installed to design requirements in development drives and associated stoping areas. On occasion, strata support installation information was inconsistent with the information being used at the time the support was being installed.
- Issues regarding ground or strata monitoring were identified at several mines (i.e. poor positioning of monitoring devices, devices not maintained or mines not routinely collecting, recording, and analysing monitoring information).
- The two block cave mines had well developed cave management and associated seismic monitoring systems in place, including on-site geotechnical expertise and associated technical personnel to manage and maintain real-time seismic monitoring systems.

- Workers were aware of the risk associated with unsupported ground, and the controls to prevent entry to these areas. Bunding and barricading of draw-points was conducted to a high standard. At one mine, inadequate standards for restricting access to areas of unsupported strata were identified.
- Support installation equipment and consumables were not always readily available or maintained in a fit for purpose condition. Checks of installation equipment and consumables were not always undertaken prior to use.

Recommendations

Most sites have good management systems in place to manage ground or strata failure hazards. However, there are several areas where systems should be reviewed to ensure that a strong focus is maintained on ground or strata failure hazards. The following recommendations are made:

- ground or strata PHMP and related TARP documentation should be reviewed on a regular basis to ensure that current controls remain effective and that any new controls are appropriately evaluated, assessed, documented, and implemented
- ground or strata monitoring equipment is installed as per the original equipment manufacturer (OEM) requirements in safe locations, by appropriately trained and competent personnel, regularly inspected and maintained, to ensure it functions correctly and effectively
- ground or strata monitoring results are collected and analysed by competent personnel in a timely manner, or after a defined trigger event has occurred
- ensure all personnel installing ground support are competent, have the correct design and installation documentation, along with fit for purpose equipment and consumables to ensure the support is installed to the mine's standards
- ensure standards and procedures for restricting access to areas of unsupported strata are effectively implemented
- regular task observations should be undertaken during ground support installation activities.

Introduction

Our planned assessment programs provide a planned, risk-based and proactive approach to assessing how effective an operation is when it comes to controlling critical risk. These programs apply the following principles:

- a focus on managing prescribed 'principal hazards' from the Work Health and Safety (Mine & Petroleum Sites) Regulation 2014
- evaluation of the effectiveness of control measures implemented through an organisation's safety management system
- consideration of the operation's risk profile.

The objective of risk profiling is to identify the inherent hazards and the hazard burden that exist at individual operations in each mining sector in NSW. The information is then used to develop the operational assessment and inspection plans that inform the program.

Scope

Planned inspection programs include two assessment types:

- targeted assessments, incorporating:
  - desktop assessment of:
    - compliance against legislation with respect to the management of health and safety risks associated with ground or strata failure – see Appendix A for details
    - the definition of the controls the mine utilises to prevent and mitigate the risks to health and safety associated with the prevention, detection and suppression of ground or strata failure.
  - a workplace assessment of the implementation of those controls through the inspection of plant and worker interviews.
- planned inspections, which involve a workplace assessment of the implementation of controls through the inspection of plant and worker interviews only.

The process

The process for undertaking an assessment under a planned inspection program generally requires:

- preliminary team meetings, preparation and review of documents
- execution of an on-site assessment involving:
  - a site desktop assessment of relevant plans and processes measuring legislative compliance of the relevant plans (targeted assessments only)
  - the inspection of relevant site operations (both targeted assessments and planned inspections).
- discussion and provision of feedback to the mine management team on the findings and actions that need to be taken by the mine operators in response.

Assessment findings

Controls assessed

Threat

- Issues with driven roadways.

Critical control: Drives are developed and ground support installed, as per approved design/plans.

Objective: Drives are developed and supported to provide safe workplaces.

Performance requirement:

- ground failure risks are identified, and suitable controls are proposed
- procedures describe how the identified ground failure controls are implemented
- support plans detail excavation limits and minimum support installation requirements
- trigger action response plans (TARPs) describe the conditions that warrant re-assessment of minimum support requirements
- fit for purpose support installation equipment and consumables are used to effectively install support to the required standard
- procedures describe safe and effective excavation and support installation methods
- mining and support installation tasks are competently performed.

Specific findings for this critical control included:

- All mine operators, except one that was not in operation, had well developed and effectively implemented ground or strata Principal Hazard Management Plans (PHMP) that included ground support installation procedures, support plans and associated TARPs.
- PHMP support installation information was, at times inconsistent, with the information available at the time support installations were taking place.
- Support installation equipment and consumables were not always readily available or maintained in a fit for purpose condition at some mine operations. Checks of installation equipment and consumables was not always undertaken prior to use.

- Documented procedures relating to ground support assessments by competent persons, such as underground mine supervisors and geotechnical engineers, were not all current or readily available.
- Inspectors identified that ground support in some development headings was not installed to the mine's standards.
- Most mine operators had good ground support Quality Assurance (QA) and Quality Control (QC) programs in place that included regular rockbolt pull testing, grout quality testing with cylinder tests and water/cement ratio tests, shotcrete testing and task observations of ground support activities during installation. However, some issues were identified with fibrecrete/shotcrete and cable bolt testing being inconsistent, not reviewed, or failed with no rectification taking place.

Threat

- Issues with driven roadways.

Critical control: Ground or strata monitoring.

Objective: A ground or strata failure event is avoided by identifying and reacting to change.

Performance requirement:

- ground and strata monitoring requirements are identified as a control in a risk assessment
- procedures describe how the arrangements for ground or strata monitoring are to be implemented and reflect the level of hazard associated with specific excavations
- TARPs describe ground or strata conditions and behaviour that warrant predefined action
- ground or strata monitoring devices are appropriately placed
- the condition of roadways and installed support are inspected and monitored
- monitoring data is collected, recorded, analysed and reported
- identified secondary support requirements are prioritised by qualified people
- competent persons correctly install and accurately read strata monitoring devices
- competent persons inspect and monitor the condition of roadways and installed support.

Specific findings for this critical control included:

- ground or strata monitoring devices were either not positioned appropriately or not installed as per the mine's standards
- underground mine supervisors and geotechnical engineers were not routinely collecting, recording, and analysing information from strata monitoring devices
- measurement and analysis of information from strata monitoring devices were either not current or readily available
- reduction in geotechnical competency onsite limiting inspection and monitoring of installed support systems
- competency for the contract workers who conduct pull testing at one mine was not readily available onsite
- damaged and non-functioning strata monitoring equipment was found, with the inspection and maintenance program for the damaged strata monitoring equipment not established and no signage to indicate the location of the monitoring equipment.

Threat

- Issues when caving ground or strata.

Critical control: Goaf/cave monitoring and response to change.

Objective: Prevent unplanned failure of ground in production activities and infrastructure by monitoring and predicting potential ground loading.

Performance requirement:

- a risk assessment considers production induced failure of ground or strata
- procedures describe how cave monitoring and change controls relating to ground or strata failure are implemented, verified and validated
- void sizes, mining and backfill schedules are based on engineering principles
- mine plans are effectively communicated

Specific findings for this critical control included:

- The block and sub level caving mines had effectively implemented a risk based PHMP and associated cave management plans (CMP). The CMP included real time seismic monitoring systems and associated TARPs.

- Adequate on-site geotechnical capability was available, which included regular geotechnical inspections and analysis of monitoring data.
- Monitoring and inspection programs included, convergence monitoring, surface subsidence monitoring, extensometers monitoring, rock noise reporting, shotcrete crack mapping and regular check scaling programs.
- TARPs and associated procedures were in place to communicate mine plans and any changes in ground and strata conditions or seismic activity to the underground workforce.

Threat

- Issues with pillars.

Critical control: Stable pillars.

Objective: Pillars support the strata for the intended purpose and lifecycle.

Performance requirement:

- pillar failure risks are identified, and suitable controls are proposed
- procedures describe how the identified pillar failure controls are implemented
- required pillar strength is determined considering the purpose and lifecycle of the pillar
- required pillar dimensions are communicated
- pillars are mined to the specified dimensions and spacing.

Specific findings for this critical control included:

- No mine operators were using traditional pillar mining methods as a primary ground support system, (e.g. post pillar cut and fill mining). Most mines use bulk mining methods that limit the use of pillars, such as block and sub level caving, long hole open and bench stoping with a range of fill types. While some pillars are formed and used in these bulk mining methods, they are not generally used as the primary ground or strata support system.
- Most mine operators have effective systems in place to ensure that pillars are mined to design and are regularly monitored for signs of deterioration.

Consequence:

- Fatality/injury of people due to falling ground or strata.

Critical control: Workers to avoid positioning themselves within fall zone of unsupported ground or strata.

Objective: Systems prevent people being exposed to the risk of being struck by unsupported strata.

Performance requirement:

- the risk of people being struck by unsupported strata is identified and suitable controls are identified
- procedures are developed to implement the controls identified to prevent people from being exposed to unsupported strata
- the procedures, tools and equipment required to protect people from being exposed to unsupported strata are available and in good operating order
- the risks associated with exposure to unsupported strata and the required controls are explained to people who could be exposed to unsupported strata or who are required to implement the controls for protecting people from unsupported strata
- supervision is provided to ensure the controls required for protecting people from being exposed to unsupported strata are effectively implemented.

Specific findings for this critical control included:

- All mine operators had identified the risks associated with unsupported strata and had identified suitable controls to prevent people entering unsupported areas and being struck by unsupported strata.
- Most mine operators use development jumbos for the installation of first pass ground support and have well established procedures in place to prevent jumbo operators and nippers being exposed to unsupported ground and strata hazards.
- Most workers, including supervisors, indicated that they have received information, instructions and training in strata management procedures and could readily identify unsupported strata and the controls required to manage the associated risk. This information was provided by various means, including underground inductions, geotechnical hazard awareness training, daily toolbox talks that included regular geotechnical presentations, job specific training modules and regular task observation including associated feedback.
- At a few mines, fit for purpose equipment, tools, and consumables were not always readily available or maintained for use in the installation of ground support systems.

- Effective supervision was generally provided when ground and strata installation was occurring.
- All mine operators, except one, had an effective standard for restricting access to areas of unsupported strata that included rock bunds, barricades, and associated signage.

Assessment findings by mine

Figure 1 presents aggregate assessment findings by threat/consequence and critical control, providing a summary view of the status of each mine's hazard management system. The assessment system recognises the value of fully implemented and documented controls by awarding an additional point if both elements were assessed as present. More details explaining the assessment system are found in Appendix B.

Figure 1. Assessment findings for the planned inspection program for ground or strata failure

	Threat				Consequence
	Issues with driven roadways		Issues when caving ground or strata	Issues with pillars	Fatality/Injury of people due to falling ground
	PC1.1	PC1.3	PC2.2	PC3.1	MC1.1
	Drives developed and ground support installed as per approved design/plans	Ground or strata monitoring	Goaf/Cave monitoring and response to change	Stable pillars	Workers to avoid positioning themselves within fall zone of unsupported ground or strata
Mine A	Red	Red	Orange	Orange	Red
Mine B	Green	Red	Green	Green	Green
Mine C	Not applicable	Green	Not applicable	Not applicable	Yellow
Mine D	Orange	Green	Green	Green	Green
Mine E	Yellow	Yellow	Green	Green	Yellow
Mine F	Yellow	Green	Green	Orange	Green
Mine G	Yellow	Green	Green	Green	Green
Mine H	Green	Orange	Green	Not applicable	Green
Mine I	Yellow	Green	Green	Green	Green
Mine J	Green	Yellow	Green	Green	Green
Mine K	Green	Green	Green	Green	Green
Mine L	Green	Green	Not applicable	Not applicable	Green
Mine M	Green	Green	Not applicable	Not applicable	Green
Mine N	Green	Green	Green	Not applicable	Green
Mine O	Green	Green	Green	Green	Green
Mine P	Green	Green	Green	Green	Green
Mine Q	Green	Green	Green	Green	Green
Mine R	Green	Green	Green	Not applicable	Green
Mine S	Green	Green	Green	Green	Green

Green (=100%)
Yellow (>= 80% and <100%)
Orange (>= 65% and <80%)
Red (<65%)
Not applicable

Notices issued

Of the 19 sites inspected under the program plan, 13 separate mines received notices relating to the principal hazard of ground or strata failure, while some mines received notices in relation to other matters. However, for the purposes of this report, contraventions related to other matters have been removed from the analysis. The notices issued for ground or strata failure were examined in detail and Table 2 below lists the notices issued by type and details.

Table 2. Notices issued for the planned inspection program for ground or strata failure

NOTICE TYPE	TOTAL ISSUED	NUMBER OF MINES
s.195 prohibition notice	0	0
s.191 improvement notice	9	7
s.23 notice of concerns	12	12
Total	21	13

Of the 21 notices issued, there were several common themes identified across the mines assessed under the program plan. Table 3 summarises the type of contraventions and outlines the total occurrences encountered. These themes can be related back to the critical controls outlined previously and identify some trends which are of concern.

Table 3. Notices issued – prevalence of categories of concern

IDENTIFIED CONCERN CATEGORY	TOTAL OCCURRENCES IN NOTICES
Documentation relating to controls for ground or strata failure (i.e. PHMP, TARPs) not relevant, current, or readily available	7
Equipment that is used to implement strata support is not readily available or maintained appropriately	5
Fibrecrete/shotcrete testing inconsistent, not reviewed, or failed with no rectification	3
PHMP support installation information inconsistent with information used at time of support installation	2
Strata monitoring devices either not positioned appropriately or installed as per site standards	2
Documentation relating to assessment by competent person (geotechnical engineer) not relevant, current or readily available	2

IDENTIFIED CONCERN CATEGORY	TOTAL OCCURRENCES IN NOTICES
Cable bolts testing inconsistent, not reviewed, or failed with no rectification	2
Supervisors not routinely collecting, recording, and analysing information from strata monitoring devices	1
Measurement information for strata monitoring devices either not current or not available	1
Workers not verifying or accurately reporting strata conditions in compliance to strata support designs and standards	1
Reduction in geotechnical competency onsite	1
Inadequate site standard for restricting access to areas of unsupported strata	1

Further information

For more information on safety assessment programs, the findings outlined in this report, or other mine safety information, please contact the NSW Resources Regulator:

CONTACT TYPE	CONTACT DETAILS
Email	cau@planning.nsw.gov.au
Incident reporting	To report an incident or injury call 1300 814 609 or log in to the Regulator Portal
Website	resourcesregulator.nsw.gov.au
Address	NSW Resources Regulator 516 High Street Maitland NSW 2320

Appendix A. Legislative requirements and published guidance relating to the management of ground or strata failure risks

The following is a list of certain legislative requirements for the management of ground or strata failure risks referred to in this report as provided by the Work Health and Safety (Mines and Petroleum Sites) Regulation 2014. In addition, several guidance documents are also noted which have been published and are available for industry distribution.

Work Health and Safety (Mines and Petroleum Sites) Regulation 2014:

- Clause 44B – Mining induced seismic activity
- Clause 52 – Ground and strata support
- Schedule 1, Part 1 Mines, 1 Ground or strata failure.

NSW Resources Regulator publications:

- Investigation report: Report into the death of Lee Peters at the Ridgeway Mine, Cadia, NSW on 6 September 2015
- IIR17-02: Strainburst: E26 sublevel cave (SLC) ore drive 8
- IIR15-02: Fatality when crushed in pinch point
- SA10-07: Shotfirer hit by falling shotcrete
- Case Study: Northparkes Air Blast

Appendix B. Assessment system explained

We use a bowtie framework to proactively assess how mine sites manage their principal hazards. Bowties are a widely used risk management tool that integrates preventative and mitigating controls onto threat lines that relate to a material unwanted event.

As part of program planning, controls were categorised in accordance with the ICMM handbook. Only controls deemed critical[1] are assessed under a planned inspection program. For a control to be assessed as effective, each of its control supports must be in place and operational.

Assessment findings

During each mine's onsite assessment, inspectors rate each control support and record the findings. Points are awarded depending on whether there was evidence that the control support had been documented and/or implemented.

For finding outcomes, points were awarded for each control support identified within a critical control. An overall assessment result for the critical control is then calculated as a proportion of the maximum possible points for that critical control. For example, if a critical control comprises ten control supports and five were assessed as fully implemented ('documented and implemented') and five were found to be 'not documented and not implemented' then the overall assessment result for that critical control would be 50%.

Table 4. Finding outcome and points

FINDING OUTCOME	POINTS
Documented and implemented	4
Implemented but not documented	2
Documented but not implemented	1
Not documented and not implemented	0

Critical control calculations also account for instances where control supports were not applicable to the mine being assessed or when control supports were not able to be assessed during a site visit.

[1] Critical Control Management Implementation Guide, International Council on Mining and Metals (ICMM), 2015.

The overall assessment result for each critical control has been assigned a colour based on the assessment bands presented in the table below. The colour band results are then used to identify industry focus areas requiring improvement.

Table 5. Assessment results and colour code

CRITERIA	COLOUR
An assessment result of 100% of possible points	Green
An assessment result of ≥80% but <100% of possible points	Yellow
An assessment result of ≥65% but <80% of possible points	Orange
An assessment result of <65% of possible points	Red