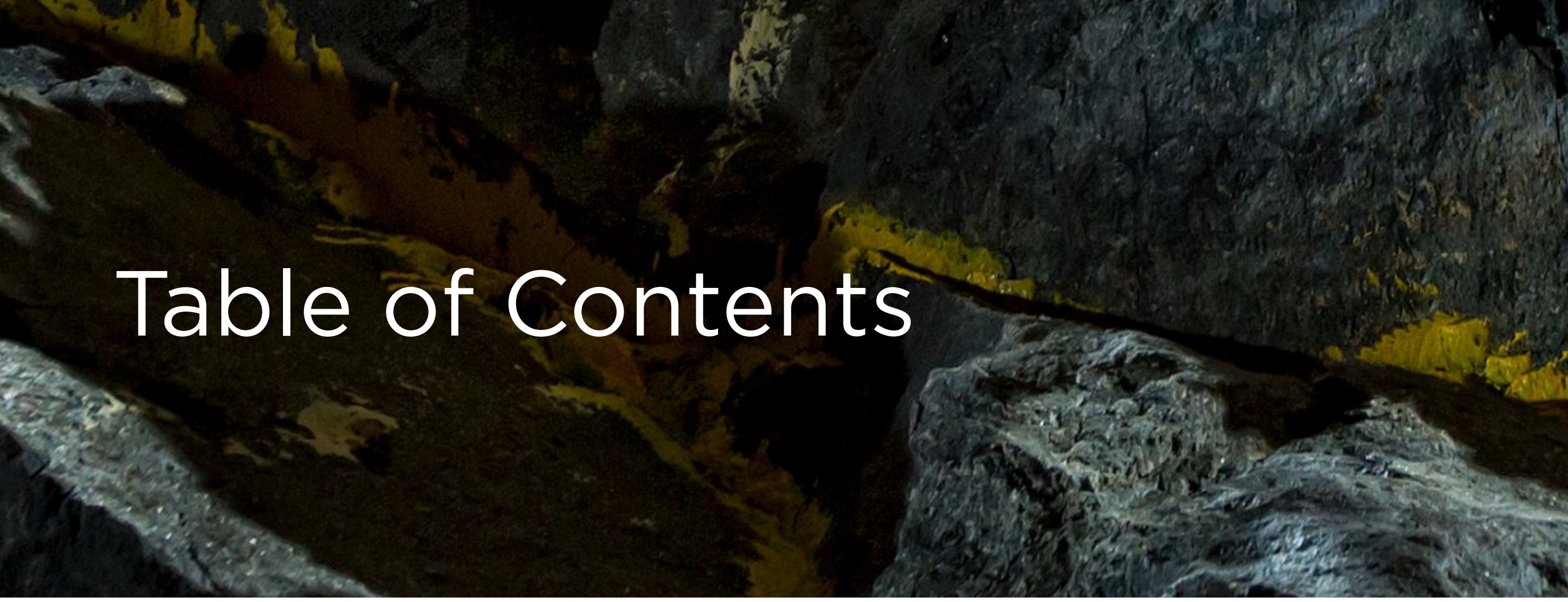
MINING INDUSTRY
OCCUPATIONAL
SAFETY & HEALTH

MINERALS COUNCIL
SOUTH AFRICA

# Guidelines for the Development, Implementation, and Verification of **Falls of Ground Control Measures**



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# List of Definitions

| TERM | DEFINITION |
| --- | --- |
| Assurance | Systematic activities to verify and ensure the effectiveness and implementation of controls, often through structured review boards and documented assurance processes at different managerial levels. |
| Assurance Review | A formal evaluation process conducted periodically to assess the adequacy and effectiveness of controls and leading indicators, often documented for compliance and continuous improvement |
| Bow Tie Analysis | An analytical method for identifying and reviewing controls intended to prevent or mitigate a specific unwanted event. |
| Cause | A brief statement of the reason for an unwanted event (other than the failure of a control). |
| Compliance Threshold | A defined target or minimum standard for acceptable compliance with controls or procedures (e.g., 90% support compliance), set to ensure robust risk management and justified for transparency in incident investigations. |
| Control | An act, object (engineered) or system (combination of act and object) intended to prevent or mitigate an unwanted event. |
| Control Owner | The designated individual or role accountable for ensuring that a specific control is implemented, monitored, and maintained effectively. |
| Critical Control | A control that is essential to preventing an unwanted event or mitigating its consequences. Its failure would significantly increase risk, regardless of the number of events it addresses. |
| Deviation | Detailed criteria that define what "effective" looks like for a control, including design standards, operational parameters, and measurable outcomes. |
| Digital Assurance | The use of technology (e.g., dashboards, sensors, tablets) to automate and streamline control verification, monitoring, and reporting processes for real-time decision-making. |
| Enabling Environment | The organisational, cultural, and systemic conditions that support the effective implementation and sustainability of technical and behavioural controls (e.g., leadership commitment, resource availability, and operational discipline). |

| | |
|---|---|
| **Entry Examination** | A systematic pre-entry check of workplace conditions to ensure safety, often incorporating TARP for hazard response. |
| **Escalation Protocol** | A predefined procedure for raising alerts and initiating corrective actions when deviations from compliance thresholds or control failures are detected. |
| **Exclusion Zone** | A designated area around a hazardous site (e.g., unstable ground or unsupported area) where entry is prohibited except for authorised, protected personnel. |
| **Falls of Ground (FoG)** | Incidents where rock or earth unexpectedly collapses or falls in an underground or surface mine, posing risk of injury, fatality, or operational disruption. |
| **Fatigue Management** | A set of policies and practices designed to limit shift duration, ensure adequate rest periods, and reduce risks associated with tiredness and loss of alertness in the workforce—tracked by compliance with roster and rest period requirements |
| **Hazard** | A source of potential harm to people, assets, or the environment. |
| **Human Factors** | Considerations involving workforce well-being, competency, fatigue management, absenteeism, training, and supervision—all tracked as leading indicators associated with safe behaviour and operational discipline. |
| **Key Performance Indicator (KPI)** | A quantifiable measure (leading or lagging) used to assess the effectiveness of controls, operational performance, or safety management objectives in mining contexts. |
| **Lagging Indicator** | These are retrospective measures that quantify outcomes after an event has occurred. They typically focus on past incidents, injuries, and failures within a safety system (ICMM, 2012). Common examples in mining include Lost Time Injury Frequency Rates (LTIFR), Total Recordable Injury Frequency Rates (TRIFR), fatalities, and reported incidents. While crucial for historical performance tracking and external benchmarking, lagging indicators provide limited foresight into potential future incidents or the effectiveness of preventative controls (Integrate Sustainability, 2019). They essentially measure the failure of control systems and indicate what has already gone wrong. |
| **Leading Indicator** | **These are** proactive, **forward-looking measures that assess the effectiveness of control measures and management systems** before an incident occurs (ICMM, 2012). They provide early warnings, enabling organisations to detect and mitigate risks or potential failures proactively (Integrate Sustainability, 2019). Examples include the number of safety audits conducted, inspection compliance rates[1], and verification of critical control effectiveness. These indicators reflect inputs and conditions, measuring what might go wrong and why, thereby influencing desired outcomes (Integrate Sustainability, 2019). |
| **Material Unwanted Event (MUE)** | An unwanted event where the potential or real consequence exceeds a threshold defined by the company as warranting the highest level of attention (e.g. a high-level health or safety impact). |
| **Mine to Design** | A leading indicator evaluating adherence to mine plans and design layouts, including the integrity of safety barriers like barricades and exclusion zones. Measurement includes deviation from plans and compliance rates for barricade positioning. |
| **Mitigating Control** | A measure activated after an unwanted event to reduce its consequences. (e.g., emergency response plans after a ground fall). |
| **Monitoring Technology** | Use of technological instruments (e.g., extensometers, tell-tales, seismic sensors, LiDAR) to detect ground movement, provide early warnings of instability, and track instrument uptime and warning lead times. |

[1] Refers to monitoring the crew compliance to mandatory inspections, such as entry examinations

| | |
|---|---|
| Occupational Health and Safety (OHS) Performance | A measure of an organisation's effectiveness in managing workplace health and safety risks, typically tracked by both leading and lagging indicators, including injury rates, compliance audit results and proactive safety initiatives. |
| Performance Specification | Detailed criteria that define what "effective" looks like for a control, including design standards, operational parameters, and measurable outcomes. |
| Predictive Analytics | Data-driven techniques used to forecast potential failures or hazards based on trends in leading indicators and control performance. |
| Preventive Control | A barrier or measure implemented before an unwanted event to stop it from occurring (e.g., quality ground support installation to prevent falls of ground). |
| Repeat Incident | Any recurrence of the same type of adverse event (such as an injury, hazardous occurrence, equipment failure, or fall of ground) at the same location, or involving the same causative factors, after a previous initial incident where corrective actions should have been implemented to prevent a recurrence. |
| Risk | The likelihood and consequence of an unwanted event impacting objectives, commonly expressed as a combination of probability and severity. |
| Risk Control System | A risk control system is a structured collection of policies, procedures, technological solutions, and actions designed to prevent, detect, or mitigate hazards that could result in adverse safety, health, or operational events in mining operations. It is an essential part of managing workplace risk, ensuring that barriers—such as ground support, entry examinations, crew training, and monitoring technologies—operate as intended to prevent incidents like falls of ground.<br><br>Risk control systems are typically mapped and evaluated using tools such as bowtie analysis, which visually links threats to unwanted events and the preventive and mitigative controls in place to address them. The effectiveness of a risk control system is measured using leading indicators (proactive) to check the health of controls before incidents occur, and lagging indicators (reactive) to track incidents or system failures after they happen. |
| Support Compliance | A leading indicator measuring whether ground support installations (e.g., bolts, mesh, props) meet specified engineering standards. Compliance is tracked via inspections, audits, and material quality checks, with compliance rates and defect closure rates used for measurement. |
| Top Event | Within Bow Tie analysis, the central undesired incident, such as a fall of ground, from which consequences propagate if preventive controls fail; visualised as the "knot" in the Bow Tie diagram. |
| Trigger Action Response Plan (TARP) | A structured procedure prescribing actions when predefined triggers are detected, supporting timely hazard management. |
| Unwanted event | A description of a situation where the hazard has or could possibly be released in an unplanned way, including a description of the consequences. |
| Verification Activity | A structured process or task undertaken to confirm that a control is in place and functioning as intended. Verification activities may include inspections, audits, and performance tests. |
| Zero Harm Commitment | An industry-wide pledge to eliminate fatalities and serious injuries through proactive risk management, continuous improvement, and leadership accountability. |

# Executive Overview

This guideline consolidates insights from industry workshops, technical reviews, and collaborative safety initiatives to strengthen proactive risk management for Falls of Ground (FoG) in the South African mining sector. It provides a structured approach for developing, implementing, and verifying control measures, with a strong emphasis on leading indicators that enable early detection of risk and continuous improvement.

The guideline integrates key frameworks such as the Industry Ground Control Framework (IGCF), Khumbul'ekhaya 2.0, and FOGAP Pillar 5 into a unified system addressing both technical and behavioural elements of ground control. It outlines practical steps for mapping controls, defining Key Performance Indicators (KPIs), setting compliance thresholds, and digitising monitoring processes through tools such as the digitising monitoring processes through tools such as real-time dashboards or other digital platforms, including the optional use of the Beehive App. and real-time dashboards.

By shifting focus from reactive lagging indicators to predictive, data-driven leading indicators, this guideline supports the industry's commitment to Zero Harm. It enables mines to:

- Identify and monitor controls for FoG risk (e.g., support compliance, mine-to-design, entry examination).
- Align leading indicators with technical standards and behavioural enablers.
- Standardise verification and assurance processes across operations.
- Foster cross-functional collaboration and continuous improvement through quarterly reviews and workshops.

This document serves as a practical reference for operational teams, safety managers, and leadership, ensuring that FoG risk management evolves from compliance-based practices to proactive, integrated systems that safeguard lives and enhance operational resilience.

1

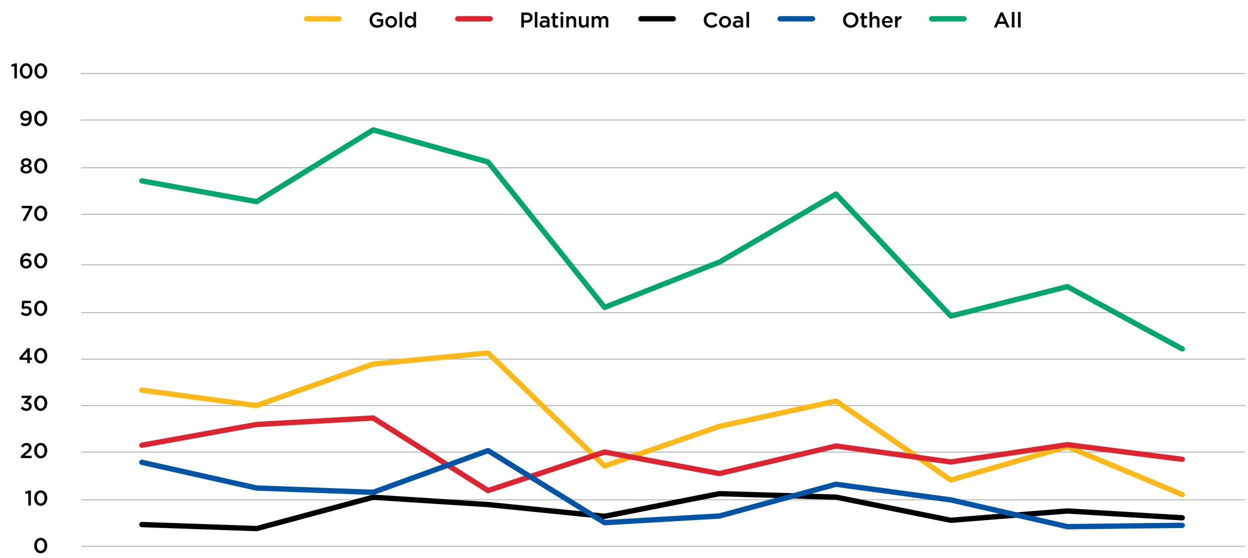
# Background

Over the past ten (10) years, the South African mining industry has demonstrated a marked improvement in safety performance, primarily due to collaborative interventions from employers, organised labour, government, and business partners. From 2015 to 2024, overall fatalities in the sector were reduced to record lows, with 42 fatalities reported in 2024 the lowest ever in the history of South African mining (see Figure 1). Major milestones include the tripartite Mine Health and Safety Council's adoption of rigorous safety milestones, Zero Harm commitments, the launch of industry-wide initiatives such as Khumbul'ekhaya, and the implementation of the CEO Zero Harm Forum. Employers have invested in new technologies, comprehensive training, and improved medical surveillance, while employee representatives drove adoption of safety codes, worker empowerment for hazard identification, and reporting. The Department of Minerals and Petroleum Resources (DMPR) intensified mine inspections and regulatory enforcement, while business leadership in Minerals Council South Africa initiated targeted research, behaviour-based programs, and performance monitoring to bolster compliance and collective learning.

Falls of Ground (FoG), historically as been the leading cause of fatalities and injuries in underground mining, however, the industry has seen significant reductions due to a range of focused interventions.

In the past ten (10) years the industry has seen FoG-related fatalities decline to 13 in 2024, and the lowest figure of 6 fatalities recorded in 2022 (see Figure 2). Key interventions, depicted in figure 3, included the introduction of entry examinations, real-time monitoring systems for ground stability, remote installation of support, permanent workface areal mesh, and improved seismic management. The Minerals Council's Fall of Ground Action Plan (FOGAP) has also played a transformative role, encouraging the adoption of leading practices, collaborative safety culture, and ongoing research into new technologies and risk management approaches. While challenges remain, particularly with complex geotechnical risks, these combined efforts have established FoG as a priority, delivering measurable improvements for the industry and its workforce.

**Number of Fatalities by Commodity**




| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gold | 33 | 30 | 39 | 40 | 18 | 26 | 30 | 15 | 20 | 11 |
| Platinum | 21 | 27 | 28 | 12 | 20 | 16 | 21 | 18 | 21 | 19 |
| Coal | 5 | 4 | 10 | 9 | 7 | 11 | 10 | 6 | 8 | 6 |
| Other | 18 | 12 | 11 | 20 | 6 | 7 | 13 | 10 | 6 | 6 |
| All | 77 | 73 | 88 | 81 | 51 | 60 | 74 | 49 | 55 | 42 |

**Figure 1:** Number of fatalities by  commodity as per DMPR report

## Fall of Ground Fatalities

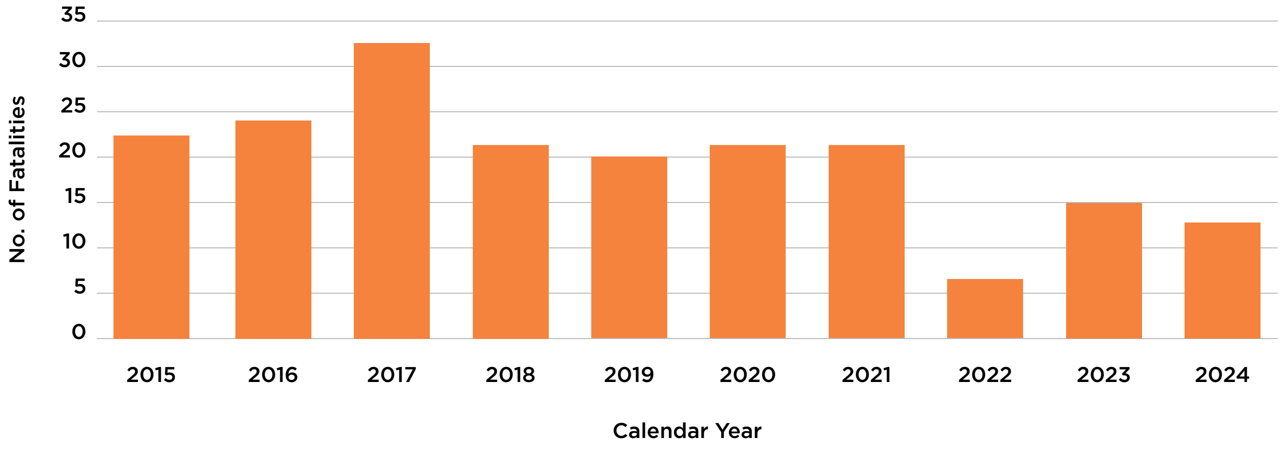



**Figure 2:** Number of Falls of Ground fatalities as per DMPR report

## Falls of Ground leading practices and initiatives

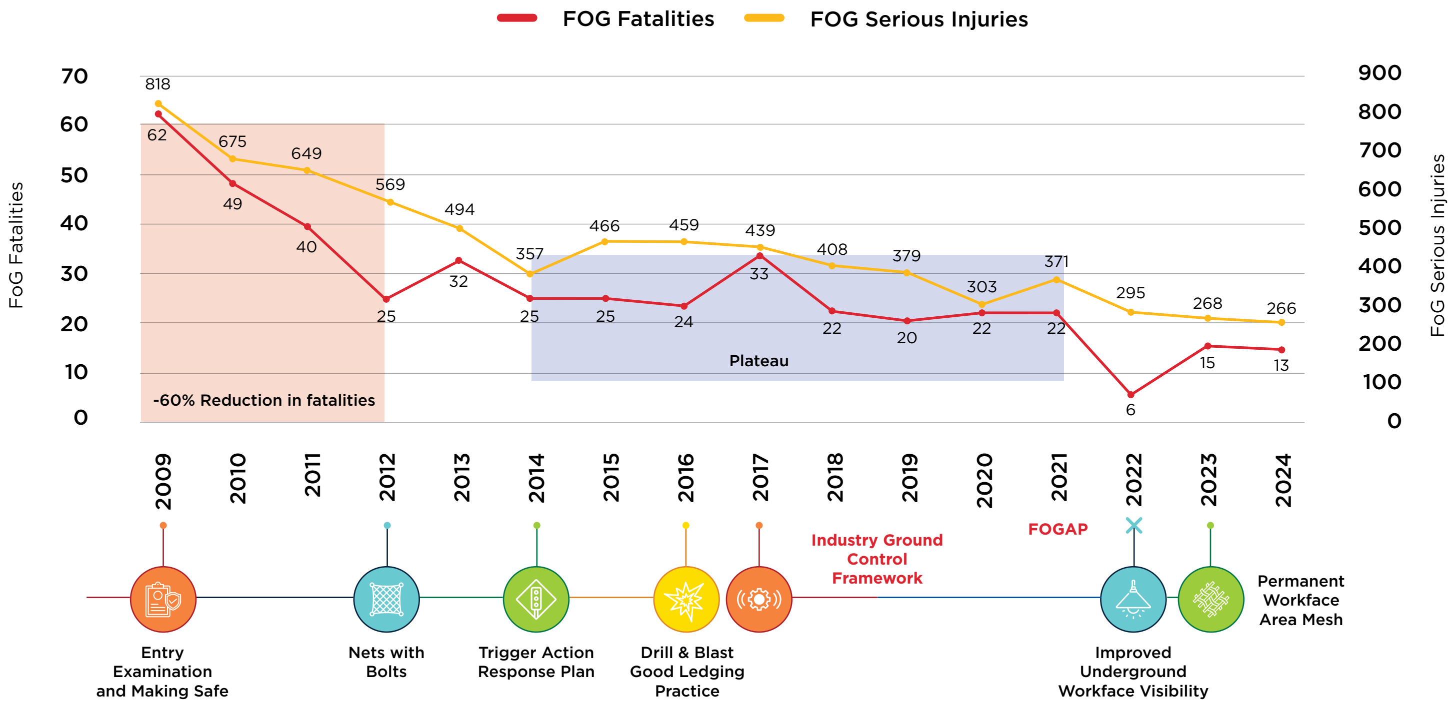



**Figure 3:** Industry interventions and their effect on Falls of Ground safety trends

To further build on the industry's progress and success, it is essential to understand how safety achievements have been measured, tracked, and guided using leading and lagging indicators. In mining safety, lagging indicators are retrospective metrics that track outcomes such as recorded fatalities, injuries, and serious incident rates, serving as benchmarks to assess the effectiveness of past interventions and identify areas needing further improvement. Leading indicators, in contrast, are proactive and predictive measures that signal the health and effectiveness of risk controls before an incident occurs.

By systematically using both types, the South African mining sector can be able to shift its focus from merely responding to incidents to anticipating and preventing them. This dual approach enables continuous learning, drives ongoing risk reduction, and supports sustainable progress towards Zero Harm, ensuring operational excellence and the safety of every mine worker.

## 1.1 Leading and lagging indicators in mining safety

The mining industry, inherently characterised by complex operational risks, has increasingly recognised the imperative to transition from reactive to proactive safety management paradigms (ICMM, 2012). This shift necessitates a comprehensive understanding and strategic application of both leading and lagging indicators in assessing and improving occupational health and safety (OHS) performance.

## 1.2 Value proposition for leading indicators

The strategic integration of leading indicators is pivotal for achieving sustained improvements in OHS performance (ICMM, 2012). While lagging indicators are essential for transparent reporting and benchmarking, they do not inherently drive preventative action (ICMM, 2012). Leading indicators, by monitoring the precursors to harm, offer several critical values:

- Proactive risk management: They enable early identification of weaknesses in control systems, allowing for timely intervention before incidents materialise (Integrate Sustainability, 2019).
- Enhanced decision-making: By providing real-time insights into the health of safety controls, leading indicators empower management to make informed decisions and allocate resources effectively (ICMM, 2012).
- Culture shift: Their focus on positive actions and preventative measures fosters a proactive safety culture where employees are actively engaged in identifying and managing risks, rather than merely reacting to incidents.
- Improved efficiency: Preventing incidents not only safeguards lives, but also reduces associated costs from investigations, production losses, and compensation claims.
- Enhanced decision-making: By providing real-time insights into the health of safety controls, leading indicators empower management to make informed decisions and allocate resources effectively. This requires transforming raw data into actionable intelligence.

## 1.3 Contrast between leading and lagging indicators

The fundamental difference between leading and lagging indicators lies in their temporal orientation and purpose. Lagging indicators are reactive, looking backward at past failures and measuring outcomes that have already occurred. They tell us "What happened." Conversely, leading indicators are proactive, looking forward to predicting future performance and measure activities undertaken to prevent incidents. They tell us "What is being done to prevent something from happening" (Integrate Sustainability, 2019). While lagging indicators report on the consequence of safety system failures, leading indicators provide insights into the health and effectiveness of the safety system itself, offering an opportunity for intervention and improvement before negative events occur.

## 1.4 Common barriers to adoption of leading indicators

Despite the recognised value, organisations often face challenges in effectively adopting and utilising leading indicators (ICMM, 2012):

- Lack of clear definitions and consistency: Inconsistent terminology and understanding can hinder effective implementation and comparison across different operational units or organisations.
- Data collection and management: Challenges in establishing robust systems for collecting, analysing, and reporting new types of data associated with leading indicators. Also, the time required to obtain the same metrics from the entire operation with the resources at hand. Data is required for the entire mine to enable on-mine benchmarking and identification of poor performing crews / sections.
- Resistance to change: Organisational inertia or a deeply ingrained reactive safety culture can impede the shift towards proactive measurement.
- Complexity and evolution: Leading indicators are not static; they need to evolve with the organisation's maturity and changing risk profiles, requiring continuous review and adaptation (ICMM, 2012).
- Perceived lack of direct link to outcomes: Some stakeholders may struggle to see the immediate correlation between proactive measures and the prevention of incidents, particularly when lagging indicators are the primary focus of performance evaluation.

## 1.5 The imperative for proactive monitoring

High risk industries have long debated the inevitability of accidents. One school of thought, Charles Perrow's "Normal Accident Theory," posits that catastrophic events are inherent to industries with high complexity and close coupling, and that society should consider rejecting such industries. However, a second school of thought argues that high-risk industries can achieve zero fatalities, as demonstrated by High-Reliability Organisations (HROs). The best-performing mining companies exhibit characteristics of HROs, such as technical excellence, operational discipline, chronic unease, and integrated risk management.

The 2013 Grasberg mining disaster[2], which resulted in 28 fatalities, served as a stark reminder of the limitations of reactive safety systems. The Freeport-McMoRan CEO's admission, "I did not see that coming," at an ICMM meeting highlighted a critical gap in risk perception at the highest levels. This event catalysed global best practice research and reinforced the need for systems that make risks visible before they materialise. Often, bad news about failing controls never reaches someone with the authority to act on it. The challenge is to bridge the gap between the perception of safety ("Work-as-Planned") and the reality of operations ("Work-as-Done"), where latent hazards can accumulate over time due to the "normalisation of deviance".

## 1.6 Elimination of Falls of Ground Action Plan (FOGAP) and the role of leading indicators

The Elimination of Falls of Ground Action Plan (see Figure 4) was formally approved by mining industry CEOs in 2021, signifying a significant corporate commitment to eliminate falls of ground-related harm. FOGAP was developed through industry partnerships, including the Minerals Council South Africa, technical committees, and professional associations, to enable mines to break through the plateau of falls of ground incidents, striving for the goal of zero harm. The program implements targeted strategies, shares leading practices, and supports ongoing innovation and learning to improve underground safety performance.

[2] On May 14, 2013, a tunnel collapse at Freeport-McMoRan's Grasberg mine in Papua, Indonesia, killed 28 workers and injured 10 others. The incident occurred during a safety training session in the Big Gossan underground facility and highlighted serious gaps in proactive risk monitoring and control assurance.

## FOGAP Pillars

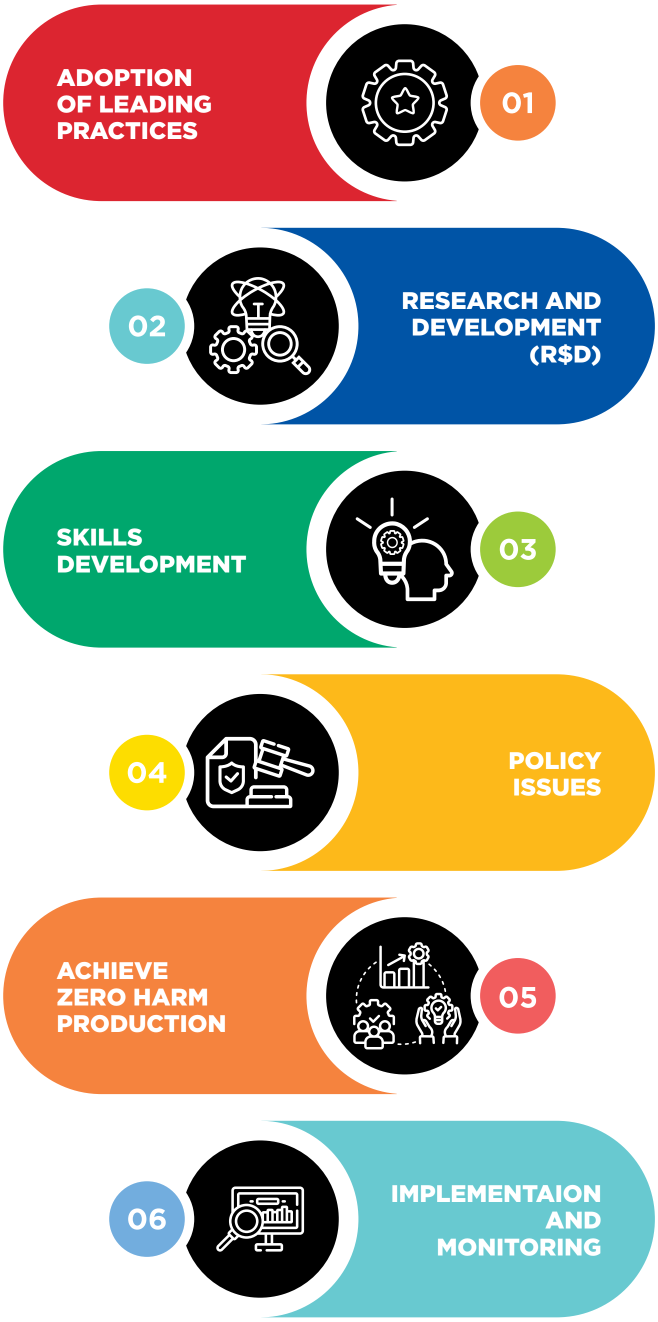



**Figure 4:** Six pillars of FOGAP

Pillar 6 of FOGAP focuses on implementation and monitoring to ensure sustainable, measurable impact in eliminating falls of ground incidents. This pillar explicitly emphasises the importance of establishing robust systems for monitoring and assuring the effectiveness of controls designed to prevent falls of ground incidents. Within this context, leading indicators play an indispensable role. They provide the necessary foresight and real-time feedback mechanisms to assess whether the preventative actions and control measures mandated by FOGAP are being effectively implemented and are indeed reducing the likelihood of FoG events. Successful adoption of leading indicators in FOGAP Pillar 6 will enable continuous improvement, ensuring that the control measures remain dynamic, responsive, and effective in safeguarding our workforce.

The 2024 CEO Heartfelt Conversation, further reinforced the industry's commitment to Zero Harm and highlighted the critical role of data-driven decision-making and proactive predictive learning in achieving sustained OHS improvements. The insights from this conversation emphasised expanding the use of AI-driven risk intelligence and standardising common controls, which directly supports the imperative for robust leading indicator frameworks within initiatives like FOGAP. This collective understanding and executive endorsement underscore the strategic importance of workshops like the FoG Leading Indicators Workshop in translating high-level commitments into tangible, measurable safety interventions (Minerals Council South Africa, 2025).

Building on this historical progress and the collective efforts of industry stakeholders, the next phase of improvement requires a deeper understanding of how safety performance is measured and proactively managed. This report introduces a focused exploration of leading indicators, tools that enable early detection of risk and support the effectiveness of controls. The following sections outline the rationale, development, and implementation of leading indicators for Falls of Ground (FoG), providing a practical framework for industry-wide adoption.

# 2

# Introduction

This guideline summarises key feedback and insights gathered through workshops, focused discussions, and review meetings conducted for the Falls of Ground (FoG) leading indicators initiative throughout 2025. These engagements are part of an ongoing commitment to improve safety management in mining by identifying and addressing hazards in line with the Elimination of Falls of Ground Action Plan (FOGAP) approved and adopted in 2021.

The timeline in Figure 5 depicts key milestones and collaborative initiatives in the South African mining industry's effort to eliminate Falls of Ground incidents between 2021 and late 2025, focusing on strategic planning, adoption of industry standards, and ongoing improvement of monitoring and control measures. This timeline illustrates a sustained, multi-year effort involving senior leadership, technical workshops, and continuous feedback—which are essential for driving meaningful and lasting reductions in falls of ground incidents.

The initial workshop held on May 6, 2025, brought together over 60 industry participants, led by the MOSH FoG team, and started with a review of the industry's FoG Bowtie. The industry FoG Bowtie was formally adopted in the year 2022 and it visually represents pathways from hazards to top events and ultimately to consequences, along with the barriers (controls) designed to prevent these events or mitigate their impact.

The review of this industry FoG Bowtie is crucial as it facilitates a common language for risk assessment, highlights controls, and provides a structured framework against which the efficacy of leading indicators can be rigorously assessed and continuously improved.

Subsequent discussions leveraged the Bowtie framework to support the identification of risk control measures that the industry considers essential for monitoring, verification, and the development of leading indicators.

### Timeline of Key Milestones and Collaborative Initiatives

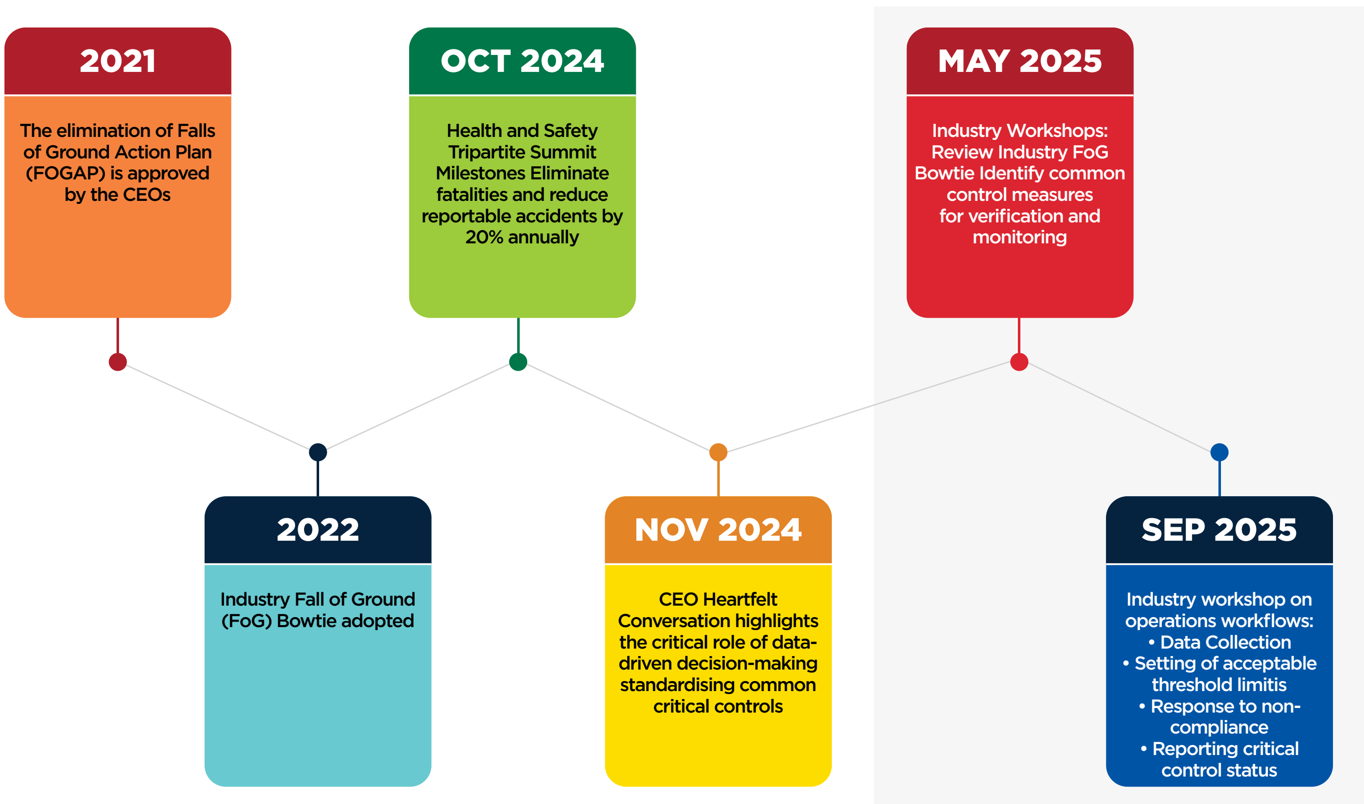



**Figure 5:** Timeline of key milestones and collaborative initiatives

3

# Key discussion themes and industry insights

Key feedback and insights revealed several critical themes regarding the practical implementation of leading indicators and control verification processes:

- **Broad alignment on critical controls:** Most mines share a strong alignment on the critical controls required to manage fall of ground risks, including mining to design, support compliance, barricading, and safe workplace declarations. This is evidenced by the critical control frameworks implemented at major operations such as Thungela Resources and Anglo American.
- **The compliance threshold dilemma:** A major point of contention is the justification for compliance thresholds. While controls are routinely measured, the rationale for accepting, for example, 90% compliance versus demanding 100% remains a challenge, particularly during incident investigations. This calls for transparent, defensible, and documented rationales for any established tolerance levels.
- **Challenges in standardisation:** Participants widely acknowledged the difficulty in defining and standardising KPIs for controls and leading indicators. Site-specific differences, unique risk profiles, and operational nuances make a "one-size-fits-all" approach difficult, often leaving metrics unclear and hard to measure robustly.
- **Data collection and reporting gaps:** Information collection often relies on a mix of routine and ad-hoc underground visits, with data being manually collated in systems like MS Excel before escalation. This creates a lag in reporting and can prevent real-time, risk-based decision-making.

## 3.1 Outcomes

Drawing from the insights gained during the workshops and guided by established industry best practices, five risk control measures have been collectively identified by industry for monitoring (see Table 1). A risk control measure is a specific action, barrier, procedure, or safety device implemented to prevent hazardous events from occurring or to reduce the severity of their consequences (Wang & Sifamen, 2024).

In the mining context, risk control measures are the practical components within a ground control system that directly address identified hazards. They can be categorised using the hierarchy of controls depicted in figure 5.

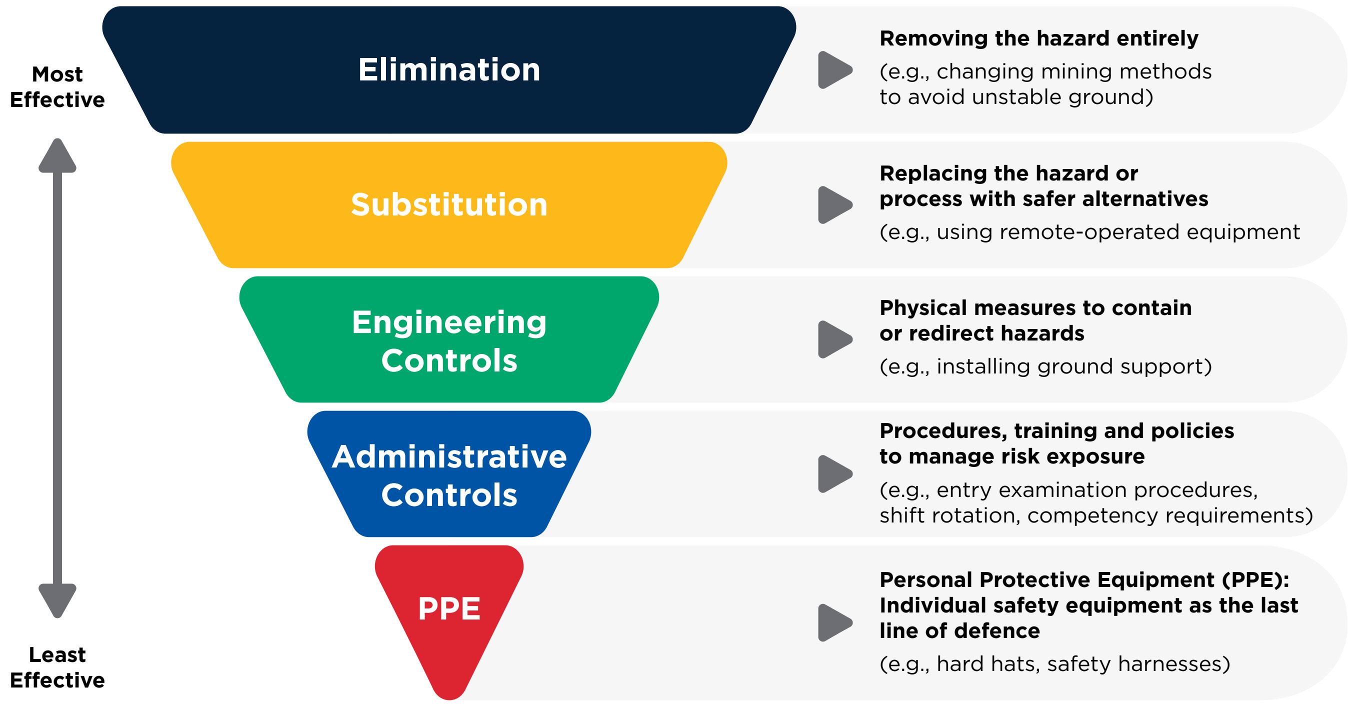



**Figure 6:** Hierarchy of controls

Table 1 outlines these risk control measures and provides recommended monitoring and measurement guidelines for each. These guidelines are designed to ensure accurate tracking of leading indicators, effective verification of control performance, and continuous improvement in falls of ground risk management.

These guidelines are intended as a reference point and acknowledge that individual mining operations may adopt alternative approaches to monitoring and measurement based on site-specific conditions, existing systems, and levels of operational maturity.

| | RISK CONTROL MEASURE | TYPE OF CONTROL | MONITORING GUIDELINES | MEASUREMENT GUIDELINES | FOCUS |
|---|---|---|---|---|---|
| 1 | **Support compliance** | **Engineering** | • Routine checks by qualified personnel to visually assess support quality and completeness.<br>• Independent audits by rock engineering departments or third parties to verify compliance.<br>• Monitor quality of support materials through supplier certification and on-site checks. | • Number of identified defects (e.g., non-tensioned bolts, missing mesh) per area or inspection.<br>• Percentage of identified deficiencies rectified within a stipulated timeframe. | This indicator ensures ground support installations meet specified standards. |
| 2 | **Mine to design** | **Engineering** | • Regular surveying to confirm excavations align with approved designs.<br>• Use of digital tools to visually identify deviations. | Deviation from plan:<br>• Measured in meters or percentage of area where excavation deviates from design. | This indicator measures compliance with the mine design. |
| 3 | **Entry examination, making Safe, and Trigger Action Response Plan (TARP)** | **Administrative** | • Random field observations and inspections to witness making-safe procedures.<br>• Ensure pre-entry checklists are accurately completed and signed off.<br>• Maintain clear records of TARP triggers, actions taken, and resolutions.<br>• Checks to ensure barricades are correctly positioned, visible, and intact. | • Checklist completion rate: Percentage of checklists completed accurately.<br>• TARP activation frequency: Number of TARP triggers for ground conditions per shift or area.<br>• TARP effectiveness rate: (Number of successful TARP activations / Total TARP activations) x 100.<br>• Number of documented instances of entry into exclusion zones. | This focuses on the effectiveness of entry workplace examinations, the use of Trigger Action Response Plan and the integrity of safety barriers like barricades and exclusion zones. |

| | | | | | |
|---|---|---|---|---|---|
| 4 | **Monitoring technology** | **Engineering** | • Regular review of data from extensometers, tell-tales, seismic sensors, and ground penetrating radar.<br>• Monitor response time and effectiveness when alarms are triggered.<br>• Use modern scanning technology to detect ground deformation. | • Percentage of time monitoring instruments are operational and provide reliable data. | This indicator tracks the use of technology to detect ground movement and provide early warning. |
| 5 | **Human factors** | **Administrative** | • Fatigue management: Monitor compliance with shift rosters, working hours, and rest periods.<br>• Absenteeism rates: Track and analyse trends in unscheduled absences.<br>• Training and competency: Monitor completion rates for mandatory training and conduct regular competency assessments.<br>• Supervisor Presence & Engagement: Track supervisor presence at the work face and documented safety interactions. | • Absenteeism rate: (Total absent days / Total scheduled working days) x 100.<br>• Training completion rate: Percentage of employees who have completed required training.<br>• Supervisor safety interactions: Number of documented safety discussions or hazard observations per supervisor per shift. | This addresses the impact of workforce well-being, competency, and supervision on safety. |

## 3.2 Typical control monitoring and verification process

The control verification process illustrated in figure 7 represents a typical example adopted by mining operations to support proactive safety management and early hazard identification. It begins with the systematic identification of controls through Bowtie analysis, defining those measures essential to maintaining ground stability, such as engineered support design, exclusion zones, and compliance to the mine plan. Once identified, these controls are subjected to a structured compliance monitoring regime involving scheduled inspections and condition assessments. Field verifications ensure that all controls are functioning as designed, and any deviations or high-potential hazards are flagged and corrected immediately to prevent escalation.

Collected data are then captured through standardised rating tools, analysed for trends, and consolidated into site and management reports. Through ongoing reporting forums and benchmarking, operational trends are reviewed to identify leading indicators and performance improvements across operations. This continuous verification loop ensures that deviations are addressed promptly, lessons are captured, and reliability of controls is strengthened, ultimately allowing potential issues to be mitigated before an unwanted event occurs.

## Typical Control Verification Process Flow

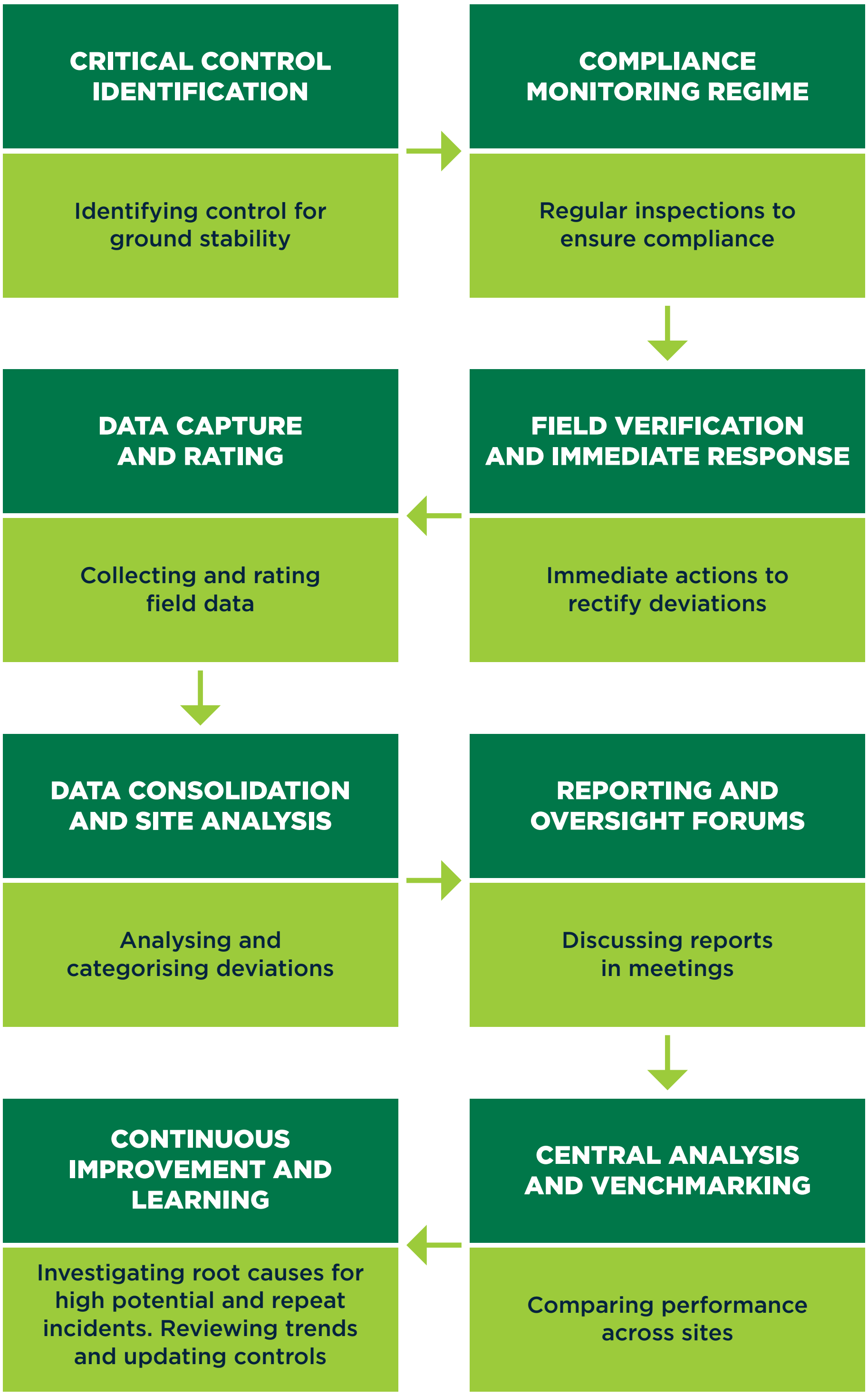



**Figure 7:** Typical control verification process flow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# 4

# Mining industry initiatives and strategies

The integration of the Industry Ground Control Framework (IGCF), Khumbul'ekhaya 2.0, and FOGAP Pillar 5 - Creating an enabling environment, presents a transformative opportunity to mature the falls of ground (FoG) risk management strategy across the South African mining industry. These initiatives converge on a shared objective: to eliminate FoG-related harm through proactive, data-driven, and behaviourally aligned safety systems.

## 4.1 Industry Ground Control Framework (IGCF)

The Industry Ground Control Framework (IGCF) depicted in figure 8 was initiated in October 2017 following concerns over regressing fall of ground fatality trends in the South African mining industry. The CEO Zero Harm Leadership Forum responded by commissioning a more holistic, industry-led approach to fall of ground management, moving beyond rockburst-specific guidelines to a comprehensive framework applicable across mining operations.

The IGCF provides a comprehensive framework for ground control, structured around technical elements (e.g., risk management, macro/micro design, implementation, monitoring, review, and innovation) and behavioural elements (e.g., leadership, just culture, operational discipline, and enabling environment). It formalises the lifecycle of ground control from hazard identification to control verification and continuous improvement.


**Figure 8:** Industry Ground Control Framwork (IGCF) initiated in 2027

The IGCF emphasises routine review cycles, risk thresholds, and management of change. It reinforces the need for dual assurance; linking leading indicators with lagging indicators to ensure both proactive and reactive safety measures are in place.

## 4.2 Khumbul'ekhaya 2.0

Khumbul'ekhaya 2.0 (see figure 8) is a transformational safety and health strategy developed to accelerate the South African mining industry's journey toward Zero Harm. Building on the foundations of the original Khumbul'ekhaya initiative, Version 2.0 introduces a more holistic and proactive approach by integrating leadership accountability, risk intelligence, and human-centric safety culture.

The strategy was launched in response to persistent workplace fatalities and high-risk incidents, despite previous improvements in safety performance. It shifts the focus from reactive interventions to learning from success, embedding behavioural, operational, and technological enablers to drive sustainable change.

Structured around five core pillars, Khumbul'ekhaya 2.0 promotes:

- CEO-led Visible Felt Leadership (VFL) engagements.
- Simplified Critical Control Management (CCM) across all organisational levels.
- AI-driven predictive analytics for real-time risk monitoring.
- Mental health and fatigue management integration.
- Adoption of MOSH leading practices and inclusive safety innovations.

Khumbul'ekhaya 2.0 complements IGCF's behavioural elements by promoting visible leadership, stakeholder engagement, and standardised safety protocols. This strategy supports the development of leading indicators that track human factors such as fatigue management, training completion, and supervisor engagement, critical precursors to FoG incidents.

## 4.3 FOGAP Pillar 5: Enabling Environment

Pillar 5 of the Falls of Ground Action Plan (FOGAP) focuses on creating an enabling environment that allows controls to function effectively and consistently across mining operations. This pillar recognises that even the most well-designed technical controls can fail if the surrounding organisational, behavioural, and systemic conditions are not conducive to their success.

An enabling environment is the foundation upon which all technical and behavioural controls rest. Without it, controls may be inconsistently applied, misunderstood, or undermined by operational pressures. An enabling environment ensures that:

- Controls are resourced, understood, and supported.
- Deviations are identified early and addressed proactively.
- Safety becomes a shared responsibility, embedded in daily operations.

Pillar 5 of FOGAP transforms safety from a reactive compliance exercise into a proactive, integrated system, critical for achieving Zero Harm in underground mining.

A web-based platform (the Beehive App) is available at.

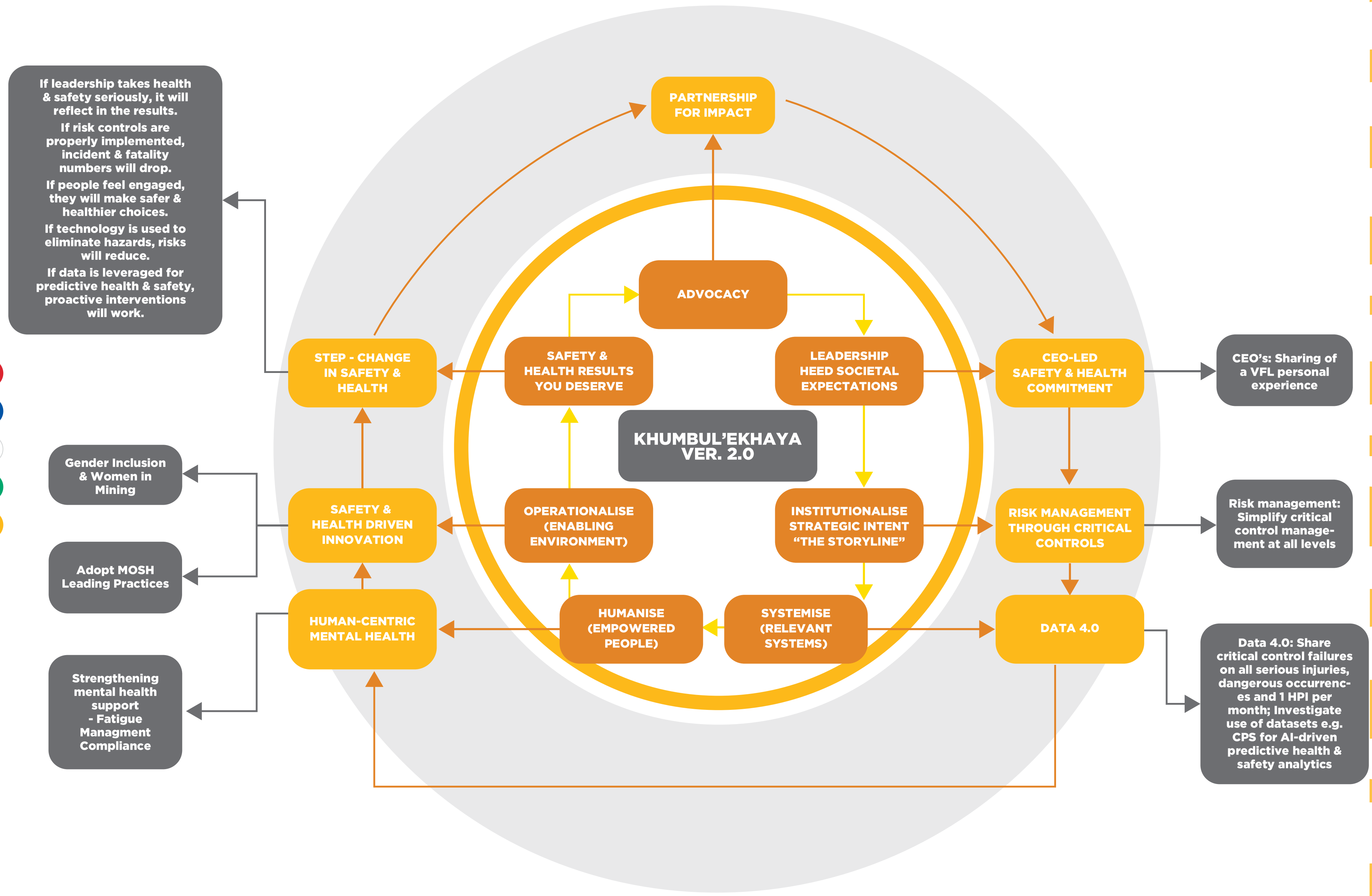
https://enablingenvironment.mineralscouncil.org.za

to support operations that choose to use it to operationalise the actions, behavioural components, and enabling conditions outlined in FOGAP Pillar 5 and the Industry Ground Control Framework (IGCF). Operations may alternatively use equivalent internal systems. It provides a structured digital platform for gap analysis, resource allocation to support the effective implementation and monitoring of controls. It enables mines to assess their readiness to implement IGCF and FOGAP Pillar 5 elements and track progress in real time.

## 4.4 Integration of initiatives

The integration of IGCF, Khumbul'ekhaya 2.0, and FOGAP enables the mining industry to holistically manage risk. IGCF provides the structural and technical foundation for ground control, while Khumbul'ekhaya 2.0 drives leadership accountability, behavioural transformation, and data-driven safety culture. FOGAP Pillar 5, operationalised through the Beehive App, ensures that enabling conditions such as planned work, resource readiness, and method statement execution are in place to support control effectiveness.

Together, these initiatives create a proactive environment where controls are not only implemented but continuously monitored, refined, and supported by leadership and workforce engagement. This integrated approach shifts the industry from reactive compliance to predictive, systemic risk management, advancing the journey toward Zero Harm.


KHUMBUL'EKHAYA VER. 2.0
PARTNERSHIP FOR IMPACT
ADVOCACY
SAFETY & HEALTH RESULTS YOU DESERVE
LEADERSHIP HEED SOCIETAL EXPECTATIONS
OPERATIONALISE (ENABLING ENVIRONMENT)
INSTITUTIONALISE STRATEGIC INTENT "THE STORYLINE"
HUMANISE (EMPOWERED PEOPLE)
SYSTEMISE (RELEVANT SYSTEMS)
STEP - CHANGE IN SAFETY & HEALTH
SAFETY & HEALTH DRIVEN INNOVATION
HUMAN-CENTRIC MENTAL HEALTH
CEO-LED SAFETY & HEALTH COMMITMENT
RISK MANAGEMENT THROUGH CRITICAL CONTROLS
DATA 4.0
If leadership takes health & safety seriously, it will reflect in the results.
If risk controls are properly implemented, incident & fatality numbers will drop.
If people feel engaged, they will make safer & healthier choices.
If technology is used to eliminate hazards, risks will reduce.
If data is leveraged for predictive health & safety, proactive interventions will work.
Gender Inclusion & Women in Mining
Adopt MOSH Leading Practices
Strengthening mental health support - Fatigue Managment Compliance
CEO's: Sharing of a VFL personal experience
Risk management: Simplify critical control manage-ment at all levels
Data 4.0: Share critical control failures on all serious injuries, dangerous occurrenc-es and 1 HPI per month; Investigate use of datasets e.g. CPS for AI-driven predictive health & safety analytics

5

# Required actions and strategic implementation

The insights from workshops and industry engagements provide a clear path forward for maturing the Falls of Ground (FoG) risk management strategy. The following actions are recommended to guide consistent, effective implementation across operations. These actions are supported by the checklist in Annexure 1, which serves as a practical roadmap for operational teams, ensuring that each is systematically planned, executed, and reviewed. It enables alignment with industry frameworks (IGCF, Khumbul'ekhaya 2.0, FOGAP Pillar 5) and supports continuous improvement across all phases of falls of ground risk management.

## 5.1 Utilise the Beehive App or equivalent platform for operational assessment

Utilise the Beehive App or any equivalent organisational platform to:

- Conduct structured gap analyses against IGCF technical and behavioural elements.
- Monitor the maturity and effectiveness of enabling conditions that support controls.
- Track and report leading indicator performance using standardised dashboards and templates.
- Ensure consistent data input formats, verification frequencies, and reporting flows across sites.
- Integrate outputs into operational risk reviews and assurance processes.

This will enable real-time visibility of control health and support proactive decision-making.

## 5.2 Incorporate Khumbul'ekhaya 2.0 metrics

Expand the scope of the human factor indicators to include behavioural metrics aligned with Khumbul'ekhaya 2.0, such as:

- Leadership visibility: Frequency of VFL (Visible Felt Leadership) engagements and safety interactions.
- Cultural assessments: Surveys or feedback mechanisms that measure safety culture maturity.
- Mental health and fatigue management: Inclusion of fatigue risk assessments and mental wellness program participation.

These indicators will strengthen the human-centric approach to FoG risk management and support broader occupational health and safety goals.

## 5.3 Refine and justify compliance thresholds

Establish a transparent and defensible process for setting and reviewing compliance thresholds for controls:

- Engage technical and operational teams to define site-specific thresholds (e.g., support compliance ≥ 95%).
- Document the rationale for each threshold, including risk tolerance, operational constraints, and historical performance.
- Ensure thresholds are approved by functional risk managers/authorities and reviewed periodically.
- Link threshold deviations to automatic escalation protocols, investigations, and corrective actions.

This will improve consistency in incident investigations and strengthen assurance.

## 5.4 Define key performance indicators (KPIs) for controls

Develop and implement KPIs or performance specification for each control to enable measurable, proactive monitoring:

- Define what "effective" looks like for each control (e.g., support installed to standard, instrument uptime).
- Align KPIs with IGCF technical and behavioural elements.
- Leverage the ICMM Health and Safety Critical Control Management Good Practice Guide[3] to define:
- Control objectives

International Council on Mining and Metals (ICMM). (2015). Health and safety critical control management: Good practice guide. ICMM. https://www.icmm.com

- Performance requirements
- Verification activities
- Reporting triggers
- Assign clear ownership and accountability for monitoring and reporting.

KPIs are essential for transforming control monitoring into a structured, data-driven system that supports leading indicators.

An example of KPIs for controls is provided in Annexure 2 of this guideline.

## 5.5 Advance real-time monitoring and digital integration

Accelerate the shift from manual to digital systems for control monitoring and reporting:

- Implement real-time dashboards for leading indicators and control health.
- Develop live hazard maps linked to geotechnical monitoring data.
- Integrate electronic data collection tools (e.g., tablets, sensors) into underground workflows.
- Ensure data is accessible to supervisors and decision-makers for timely interventions.

Digital integration will enhance responsiveness and enable predictive risk management.

## 5.6 Clarify roles, responsibilities, and assurance

Standardise the reporting structure and accountability for control verification and leading indicator performance:

- Define clear roles for:
    - Underground crews (data collection)
    - Supervisors (verification and escalation)
    - Management (review and action)
- Streamline assurance processes by:
    - Consolidating multiple assurance review processes into a single, streamlined activity to improve efficiency and reduce duplication where appropriate.
    - Use digital platforms such as the Beehive App, internal dashboards, or equivalent systems to inform assurance activities.

This will improve efficiency and ensure that control performance is consistently monitored and acted upon.

## 5.7 Foster cross-functional collaboration

Strengthen collaboration between Safety, Rock Engineering, Technical Services and Operations to ensure integrated implementation:

- Align processes for control verification, leading indicator tracking, and incident response.
- Conduct joint reviews of control performance and leading indicator trends.
- Share learnings and best practices across disciplines and sites.
- Establish cross-functional working groups to close identified gaps and drive continuous improvement.

Collaboration is key to embedding leading indicators into daily operations and achieving Zero Harm.


GroundProbe

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# References

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9 **ICMM. (2024).**
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**Available at:** https://www.icmm.com

ANNEXURE 1

# FoG Leading Indicators Implementation Checklist

The purpose of the checklist is to provide a structured, step-by-step guide for mines to implement falls of ground leading indicators effectively and consistently across operations. It serves as:

- A practical tool for operational teams to ensure all critical actions are completed.
- A roadmap for compliance and readiness, helping mines align with industry frameworks like IGCF, Khumbul'ekhaya 2.0, and FOGAP Pillar 5.
- A mechanism for accountability, clarifying roles and responsibilities at each stage of implementation.
- A reference for assurance and audits, demonstrating that proactive risk management processes are in place.
- A driver for continuous improvement, enabling mines to track progress, identify gaps, and refine leading indicators over time.

## FALLS OF GROUND LEADING INDICATORS IMPLEMENTATION CHECKLIST

### PHASE 1: PLANNING AND PREPARATION

- [ ] Review the FoG Bowtie analysis and identify site-specific Material Unwanted Events (MUEs).
- [ ] Map existing controls to IGCF technical and behavioural elements.
- [ ] Conduct a gap analysis to assess enabling environment maturity.
- [ ] Define roles and responsibilities for control verification, monitoring, and reporting.

### PHASE 2: INDICATOR DEVELOPMENT

- [ ] Identify controls for FoG risk (e.g., support compliance, mine-to-design, entry examination).
- [ ] Define Key Performance Indicators (KPIs) for each control using ICMM Step 5 guidance.
- [ ] Establish compliance thresholds and document justification for each.
- [ ] Align leading indicators with both technical and behavioural elements.

### PHASE 3: SYSTEM INTEGRATION

- [ ] Digitise control verification processes using tablets, sensors, and real-time dashboards.
- [ ] Integrate leading indicator tracking into existing safety management systems.

### PHASE 4: MONITORING AND ASSURANCE

- [ ] Schedule routine inspections and verification activities for each control.
- [ ] Monitor leading indicator performance and escalate deviations as per defined protocols.
- [ ] Consolidate assurance reviews into streamlined reporting structures.
- [ ] Use dashboard outputs to inform management decisions and interventions.

### PHASE 5: CONTINUOUS IMPROVEMENT

- [ ] Conduct quarterly reviews of leading indicator trends and control effectiveness.
- [ ] Facilitate cross-functional workshops to share learnings and refine indicators.
- [ ] Update KPIs and thresholds based on operational changes or incident learnings.
- [ ] Report progress to senior leadership and align with Zero Harm commitments.

ANNEXURE 2

# Example of Key Performance Indicators (KPI) or Performance Specification for Controls

| | | | | | |
|---|---|---|---|---|---|
| **CRITICAL CONTROL NAME:** | Ground Supported to Standard | | | | |
| **CONTROL OBJECTIVE:** | To eliminate unplanned and uncontrolled falls of ground | | | | |
| **RELEVANT RISK EVENT(S):** | Uncontrolled Fall of Ground: Slope Failure and Falling Rocks | | | | |
| **ASSOCIATED TECHNICAL STANDARD(S):** | Geotechnical Standard for Mining | | | | |
| **FUNCTIONAL RISK AUTHORITY** | | | | | |
| **DOC. NUMBER:** | | Revision: | | Date of issue: | |
| **ISOMETRIX CONTROL ID** | | | | | |

**DESCRIBE THE MAIN ELEMENTS OF THE CONTROL THAT MUST BE IN PLACE FOR IT TO WORK PROPERLY AND DELIVER REQUIRED FUNCTIONALITY:**

| Element (equipment/task) | Functionality | Description | Design basis |
|---|---|---|---|
| Support unit/s installed according to the mine standard | Potentially unstable rock mass prevented from falling under the forces of gravity or seismic loading | Various types of support units such as rock bolts, packs, mesh and shotcrete are installed into, on or under the rock surface to support a potentially unstable portion of the excavation that can be dislodged under the forces of gravity or seismic loading | Geotechnical Standard for Mining |

| DESCRIBE AVAILABILITY, RELIABILITY AND SURVIVABILITY REQUIREMENTS FOR THE OVERALL CONTROL (OR SPECIFIC ELEMENTS IF GREATER DETAIL IS REQUIRED) | | | |
|---|---|---|---|
| Overall Control or Element | Availability | Reliability | Survivability |
| Support unit/s installed according to the mine standard | **Appropriate services:**<br>• Water<br>• Electricity<br>• Compressed air<br><br>**Sufficient support materials available when required:**<br>• Adequate budget<br>• Adequate supply chain management<br>• Correct stock rotation<br>• Correct storage conditions<br>• Support items meet design specifications<br>• Temporary support where support is installed conventionally<br><br>**Sufficient, Fit for Purpose equipment available when required:**<br>• Drill rigs<br>• Drill steel<br>• Drill bits<br>• Grouting equipment<br>• Tensioning equipment<br>• Spray support rigs<br><br>**Sufficient competent personnel to conduct support installation Effective shift time:**<br>• Sufficient, effective face time to perform all the activities in the mining cycle | **Support materials at working place meet design specifications:**<br>• Support components not damaged<br>• Support not expired where applicable e.g. resin<br><br>**Support installed according to the mine standard:**<br>• Spacing, tensioning, encapsulation, angles, sizes, distance to excavation boundaries correct. | **Design input parameters remain valid for actual mining conditions:**<br>Cement/grout deterioration<br>Unexpected rockmass/ loading/ weathering response<br>Corrosion of support |

| OUTCOMES: DOES THE CONTROL WORK PROPERLY AND DELIVER REQUIRED FUNCTIONALITY? | |
|---|---|
| **Sources of information and data**<br>**Existing activities by site teams that check controls are working properly** | **Verify Control Performance**<br>**Assessment of results by Control Owner recorded in Isometrix** |
| **Control Specific:**<br>• Start of shift inspection by miner and crew<br>• Over inspection by management e.g. shift supervisor, mine overseer<br>• Routine inspections by geotechnical department<br>• Routine inspections by safety department<br>• TARPs to identify changes in support requirements<br>• High risk follow-up inspections<br>• Store yard inspections<br>• Independent quality assurance of support items<br>• Incident and accident investigations<br><br>**Work Management:**<br>• Confirmation of Authorised Person appointments.<br>• PTOs (Planned Task Observations).<br>• Support standard procedure(s).<br>• Work executions documents (WED) with JRA's. | **MONTHLY**<br>• Is the % support compliance to standard/plan >= BU/Site threshold %? (Based on data collected throughout the month, not single inspection)<br>• Is the threshold value for the site justified and approved if < 100%?<br>• Is the rationale communicated and reviewed with relevant Functional Risk Authority/Subject Matter Experts to confirm acceptable tolerances are met such that the risk remains adequately managed?<br><br>**QUARTERLY**<br>• Are any failures identified, and actions implemented to restore control condition?<br>• Is the inspection program working and are we following up to address failures/weaknesses in a timely manner?<br>• Are monthly reports reviewed, and any needed interventions made to address identified control weaknesses or adverse trends?<br>• Are reports distributed to senior mine management showing compliance per month and trends over time?<br><br>**ANNUALLY** |

**APPROVAL**

| Authorisation | Job Title | Name | Signature |
|---|---|---|---|
| Functional Risk Authority | Head of Geotechnical Engineering | | |

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