# GEOTECHNICAL CONSIDERATIONS HIF AUDIT - 17/06/2003 02:57:37 PM

## 1. MSIA Reg 10.28(1)

| Point | Standard | Guideline |
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| 1.1 | The geotechnical aspects of the mine, particularly those issues that control rock stability, have been recognised as a major potential hazard to the health and safety of all people working underground. | Intent: To verify that management are fully aware of the hazards from rock failure at the mine.<br>Personnel: Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist.<br>Method: Sight minutes of senior management meetings. Has senior management commissioned geotechnical investigations which consider employee exposure to rock failure hazards and recent rock failure incidents? |
| 1.2 | Geotechnical hazard analysis is ongoing at the mine. | Intent: To verify that the geotechnical hazards are continuously assessed at the mine.<br>Personnel: Manager mining, underground manager, chief mining engineer, technical services manager, chief geologist.<br>Method: Sight records of geotechnical hazard assessment. This may include the identified geotechnical hazards being ranked according to severity. Does the mine have its own geotechnical engineer if not does the mine have regular visits from a representative of a consulting geotechnical organization? |
| 1.3 | A formal, multi-disciplinary, mine planning and design process exists and is used for mining work. | Intent: To verify that a mine planning and design process is in place. To verify that the system functions consistently regardless of who is "on site" and despite personnel turn-over.<br>Personnel: Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist, mine planning engineer.<br>Method: Sight documentation from mine planning and design meetings. Are the meetings minuted or recorded in some way? Sight examples of approved mine plans and accompanying notes or memoranda. Are they stored and accessible for future reference or review. Have mine design standards been set and are they documented? |
| 1.4 | A set of development planning and design criteria have been drawn up to provide general guidance in mine planning and design. | Intent: To verify that a consistent approach to development planning and design, particularly during absence from site of key personnel and high personnel turn-over.<br>Personnel: Underground manager, mining engineer, geologist, mine planning engineer, surveyor, geotechnical engineer.<br>Method: Interview personnel. Sight a copy of the development planning and design criteria eg Standard Layouts for excavations and rock reinforcement. |

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| 1.5 | The decisions relating to mine designs have been documented. | Intent: To verify that a record is kept of why mining decisions were made. To record the assumptions on which the design may have been based. To recommend where additional work or data may be required.<br>Personnel: Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist, mine planning engineer.<br>Method: Sight notes, memoranda or technical reports accompanying approved mine plans. Have the design decisions been documented. Have the design assumptions, if any, been clearly and unambiguously stated? |
| 1.6 | Mine design drawings are signed off by the underground manager and all relevant geology, surveying and engineering professionals. | Intent: To establish management accountability for the proposed mine plan.<br>Personnel: Registered manager, manager mining, underground manager, chief mining engineer, technical services manager, chief geologist, mine planning engineer.<br>Method: Sight approved mine design drawings and check that signatures and dates are present. Only film originals or paper prints are acceptable. Computer images are not acceptable (they can be changed easily). |
| 1.7 | Mine planning and design matters are regularly discussed with the underground workforce. | Intent: To verify that the underground workforce are made aware of the reasons why mining work is being carried out in various areas of the mine.<br>Personnel: Underground workforce.<br>Method: Ask the workforce about their understanding of the reasons why certain headings are being developed, why stoping blocks are being mined and what difficulties are expected in say the next 6 months. What do they know about the possible causes of the ground control problems, if any, that the mine has experienced recently (eg seismic events, rockbursts, rock falls, etc)? Sight minutes of meetings. |
| 1.8 | Mine planning and design meetings are held monthly or more frequently. | Intent: To verify that mine planning and design is an on-going process and not a series of ad hoc crisis meetings. The mine planning and design process should lead production, not the reverse.<br>Personnel: Manager mining, underground manager, chief mining engineer, technical services manager, chief geologist, mine planning engineer, mine geologist, mine surveyor, electrical engineer, mechanical engineer, maintenance engineer (as required).<br>Method: Sight minutes of mine planning and design meetings. When was the last meeting held? |

## 2. MSIA Reg 10.28(2)(a)

| Point | Standard | Guideline |
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| 2.1 | Geotechnical domains are used to divide the rock mass into volumes of similar expected ground behaviour in three dimensions. | Intent: To verify that the variation in ground conditions has been recognised and quantified.<br>Personnel: Geologist, mining engineer, geotechnical engineer.<br>Method: Sight plans, sections, longitudinal projections that show the expected range of ground conditions. Have these been contoured, shaded or otherwise identified? Have the different ground conditions been graded or classed in some way, eg A, B, C, … ; class 1, class 2, etc? |

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| 2.2 | Diamond drill core is logged geotechnically, before being split. | Intent: To verify that as much geotechnical information as possible is recovered from the core before it is spilt.<br>Personnel: Geologist, geotechnical engineer.<br>Method: Is the core geotechnically logged and colour photographed before being split? |
| 2.3 | Geotechnical mapping is being carried out on a regular basis, in stopes and development headings, consistent with the rate of mining advance, where limited or no geotechnical information is available. | Intent: To verify that geotechnical data is collected from the rock mass using scanline mapping or area mapping etc.<br>Personnel: Geologist, geotechnical engineer.<br>Method: Sight underground mapping sheets completed by geologist/geotechnical engineer. Is geotechnical data collected? |
| 2.4 | Geotechnical information from core logging, scanline and/or area mapping is regularly entered into an appropriate database. | Intent: To verify that geotechnical data collected is stored in a database and is available for further processing.<br>Personnel: Geologist, geotechnical engineer<br>Method: Is geotechnical data stored in a database? The database used could be part of the geological drill hole database. View a sample of the geotechnical database by selecting typical holes chosen at random. |
| 2.5 | Structural data plotting, analysis and presentation of geotechnical data on planes of weakness is conducted. | Intent: To verify that geotechnical data has been used to quantify the ground conditions.<br>Personnel: Geologist, geotechnical engineer.<br>Method: Have geotechnical software packages(eg DIPS or SAFEX) or manual plotting methods been used to process the data? Have the geotechnical properties of the planes of weakness been determined (eg number and orientation (dip and dip direction) of joint sets; persistence (length), spacing and joint surface properties (eg roughness, planarity), etc)? Have these properties been plotted and summarised? |
| 2.6 | The geotechnical information is used to determine the geotechnical domains, which are revised from time to time, as new information becomes available. | Intent: To verify that the geotechnical data are being used.<br>Personnel: Geologist, geotechnical engineer.<br>Method: Have the Q, RMR, MRMR or similar ratings been used to quantify the ground conditions? Sight plans, cross-sections of bore hole paths showing Q, RMR MRMR values etc plotted along the path of the holes at say 1 to 2 m intervals. Are the geotechnical domains based on an interpretation of these data? Note: A summary in table form for each domain, listing the identified characteristics of the joint sets and rock properties, is very useful for future geotechnical analysis work eg support and excavation design. |
| 2.7 | The ground behavior characteristics in all areas of the mine have been generally categorized as soft rock conditions, hard rock conditions or seismic rock conditions. | Intent: To verify that the ground behavior has been broadly classified within the mine.<br>Personnel: Geologist, geotechnical engineer, mine planning engineer, underground manager.<br>Method: View documentation classifying the rock mass of each area of the mine broadly into the three general categories of ground behavior? (See pages 10 - 11 Guidelines Geotechnical Considerations in Underground Mines) |

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| 2.8 | The underground workforce in general, and mining crews in particular, have been trained to understand the importance of geological structure and its influence on rock stability. | Intent: To verify that the underground workforce has been trained in the factors that control the rock mass response to mining activities.<br>Personnel: Underground workforce generally; in particular air-leg miners, drillers (development and stoping), charge-up, scaling, rockbolters, loader drivers, rise miners and service crews.<br>Method: Interview the workforce have they been trained in ground control issues? When, where and how relevant was the training? Who provided the training? |

## 3. MSIA Reg 10.28(2)(b)

| Point | Standard | Guideline |
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| 3.1 | There are drilling and blasting designs for each geotechnical domain. | Intent: To verify the use of rational drill and blast design procedures, rather than relying entirely on experience.<br>Personnel: Underground manager, mining engineer, supervision.<br>Method: Ask how were the drill and blast patterns determined. Were any proprietary drill and blast design packages used? If so, which one? Sight a copy of the drill and blast patterns. Must address both drilling (eg number of holes, spacing, length, orientation, etc) and charging matters (eg explosive types used in various holes, primers, detonators, initiation sequence, special precautions (eg dust explosions)). |
| 3.2 | The drilling and charging crew(s) understand the importance of correct drilling and charging work procedures. | Intent: To verify that the drilling and charging crews understand that correct work procedures are essential for a quality excavation.<br>Personnel: Lateral and vertical development mining crews, air-leg miners etc.<br>Method: Interview the drilling and charging personnel. What problems, if any, have the crew experienced? |
| 3.3 | Development jumbo operators drill holes parallel and to the correct alignment as per the specified layout. | Intent: To verify that the development rounds are drilled correctly.<br>Personnel: Supervision, lateral development crews, maintenance crews.<br>Method: Observe drill hole barrel parallelism back from the face and drilling practices at the face. |
| 3.4 | Explosive of a lower energy level is used in perimeter holes as per design. | Intent: To verify that the explosives used minimise blast damage to the rock mass in the walls and backs.<br>Personnel: Supervision, lateral development crews, air-leg miners.<br>Method: Observe charging of the face, note explosive used in the perimeter holes. Is this the explosive specified in the standard work procedure? (Note: it is preferable that decoupled cylindrical cartridges are used.) This may also be an issue for the penultimate row of holes. Note: In hard rock conditions, half hole barrels are indicative of “good” mining practice. |

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| 3.5 | Detonators and compatible primers are used to initiate the main explosive charge. | Intent: To verify that the main explosive charge is detonated efficiently.<br>Personnel: Mining engineer, supervision, lateral development crews, air-leg miners.<br>Method: Observe primers with detonators being inserted into drill holes in the face, prior to loading the main explosive charge, during the charging process.<br>Note: For ANFO to reach its optimum "velocity of detonation" it must be correctly initiated with a detonator/primer of appropriate explosive energy. This will generally maximise the face advance per round. |
| 3.6 | Overbreak at the excavation perimeters is monitored. | Intent: To verify that measuring of overbreak occurs to maintain quality of excavation.<br>Personnel: Underground manager, mining engineer, surveyor, development crews.<br>Method: Enquire as to whether the mine has a policy on the maximum percentage of overbreak that is acceptable? Is the percentage overbreak regularly determined? Sight a copy of fortnightly or monthly summary of the percentage overbreak, as calculated by the surveyor, for each heading. Is this information permanently recorded by the mine and contractor? Is the overbreak information regularly given to the development crews? |
| 3.7 | A system exists to correct mining techniques where excess overbreak is encountered. | Intent: To verify that overbreak is actively managed.<br>Personnel: Underground manager, mining engineer, supervision, development crews.<br>Method: Sight memoranda from underground manager or mining engineer requesting<br>a reduction in overbreak for stated headings. Sight copy of survey overbreak pickups for these headings that demonstrates that overbreak has been reduced and is less than the maximum permitted. |

## 4. MSIA Reg 10.28(2)(c)

| Point | Standard | Guideline |
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| 4.1 | Openings are designed having regard for the prevailing geological structure, rock stress field and rock mass strength. | Intent: To verify that the geotechnical factors controlling opening dimensions and geometry (present and future) are taken into account in the design process.<br>Personnel: Underground manager, mine planning engineer, geologist, geotechnical engineer.<br>Method: Interview personnel establish whether rock mass classification, block analysis and/or stress analysis methods been used to determine maximum opening spans that can be mined? |
| 4.2 | The size of the opening span, determined as a linear dimension, exposed area or shape factor (area/perimeter), has been based on the prevailing site ground conditions as determined by one of the rock mass classification methods or some other recognised method. | Intent: To verify that the two and three dimensional geometry of the opening (present and future) is matched to the prevailing ground conditions.<br>Personnel: Underground manager, mine planning engineer, geologist, geotechnical engineer.<br>Method: Interview personnel establish whether rock mass classification, block analysis, stress analysis or other recognised methods been used to determine maximum opening spans that can be mined? |

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| 4.3 | The interaction of adjacent openings has been taken into consideration to minimise the potential for adverse stability conditions. | Intent: To verify at the design stage that the potential for adverse stability conditions, caused by the proximity of adjacent openings, is addressed.<br>Personnel: Underground manager, mine planning engineer, geologist, geotechnical engineer.<br>Method: Interview personnel. Have two or three dimensional stress analysis techniques been used to account for interaction between adjacent openings? Has past experience with similar geometry been back-analysed to determine the rock stress state and stability conditions? Is the rock stress state likely to precipitate collapse? |
| 4.4 | Increases in stope span during the stoping phase are subject to geotechnical review. | Intent: To verify that changes in stope span due to ore body variations encountered in the stope development or production stage are geotechnically assessed to ensure that the support design is matched to the increased stope span and the prevailing ground conditions.<br><br>Personnel: Underground manager, mine planning engineer, geologist, geotechnical engineer.<br>Method: Interview personnel establish whether rock mass classification, block analysis, stress analysis or other recognised methods been used to determine maximum opening spans that can be mined? |

## 5. MSIA Reg 10.28(2)(e) & (3)(e)

| Point | Standard | Guideline |
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| 5.1 | The purpose and design life of the excavation has been determined. | Intent: To verify that a determination has been made of how long the excavation is expected to remain open and in a safe condition. Hence, it is known how long the rock support and reinforcement is expected to last.<br>Personnel: Underground manager, mine engineer, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight mining approvals for headings and stopes selected |
| 5.2 | The number, size, shape and orientation of the openings has been considered in relation to the potential formation of unstable blocks or wedges. | Intent: To verify that the potential size of the blocks that can form has been estimated.<br>Personnel: Geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Have block analysis programs (eg SAFEX and UNWEDGE) been used to estimate potential block sizes? |
| 5.3 | A recognised rock support and reinforcement design method has been used to design the required rock support and reinforcement system. | Intent: To verify that there is a reasoned explanation for the rock support and reinforcement being used in the mine.<br>Personnel: Underground manager, mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Which, if any, of the rock support and reinforcement design methods have been used (see page 18 of the Guidelines Geotechnical Considerations in Underground Mines)? Does the design method specifically refer to the type of support and reinforcement elements proposed (eg friction rock stabilisers)? Or has something else been substituted? |

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| 5.4 | Where cement grouted dowels are installed as initial rock reinforcement sufficient curing time is allowed for them to become effective. | Intent: To verify that the initial rock reinforcement in use is capable of supporting its design load capacity before further excavation occurs.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight a copy of the rock support installation procedure. |
| 5.5 | A technical specification exists for all the rock support and reinforcement systems in use. | Intent: To verify that the mine has its own technical specifications for the various types of rock support and reinforcement in use.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight a copy of the rock support and reinforcement technical specifications prepared by the mine. |
| 5.6 | The rock support and reinforcement technical specifications are based on the reinforcement design. | Intent: To verify that the specified rock support and reinforcement matches that recommended by the geotechnical design process.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Does the rock support and reinforcement technical specification match the design recommendations? If not, what is the explanation for the difference? |
| 5.7 | The rock support and reinforcement technical specifications states the load capacities (support resistance) and the energy absorption capacities of the various elements in the system. | Intent: To verify that the strength and energy absorption capabilities of the rock support and reinforcement are stated and not just assumed.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight the rock support and reinforcement specifications. Are the load capacity and the energy absorption capacity stated for the various elements of the rock support and reinforcement system?<br>Note: The support system load capacity in the technical specifications should be down-rated by a factor of safety or an “installation quality factor”. The “installation quality factor” will recognise the variability inherent in the underground construction environment. Thus, the field load capacity of the support system will be less than the tensile strength of the bar as given by the design method (audit point 5.5). |
| 5.8 | Samples of the groundwater are routinely collected and chemically analysed to determine the potential for corrosion of the rock support and reinforcement system. | Intent: To verify that potential corrosion issues have been recognised and that mine water chemistry is monitored.<br>Personnel: Underground manager, mining engineer, geotechnical engineer.<br>Method: Interview personnel. Is the chemistry of the groundwater known? Sight results of chemical analyses |
| 5.9 | The installation procedures provided by the supplier(s) of the rock support and reinforcement elements are being followed. | Intent: To verify that the recommended installation procedures are used.<br>Personnel: Underground manager, supervision, mining engineer, geotechnical engineer and operators.<br>Method: Interview personnel. Observe installation procedures. Does the mine have a copy of the manufacturer’s recommended installation procedures? Sight copy of these procedures. Is the mine using the recommended installation procedures? |

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| 5.10 | Variations to the recommended installation procedures have been discussed and agreed with the supplier and documented prior to their implementation. | Intent: To verify that the modified installation procedures are acceptable to the supplier.<br>Personnel: Underground manager, supervision, mining engineer, geotechnical engineer.<br>Method: Interview personnel. Sight documentation. Ask about possible variations to the installation procedures. Have these been agreed with the supplier prior to implementation? |
| 5.11 | Purpose designed and built equipment is being used to install the rock support and reinforcement. | Intent: To verify that the equipment used is purpose designed and built for installing rock support and reinforcement.<br>Personnel: Underground manager, supervision, mining engineer.<br>Method: Interview personnel. Sight the manufacturer's description of the intended use of the equipment. Is this how the equipment is being used? If not, has the mine discussed with the manufacturer the use of the equipment in the manner proposed? |
| 5.12 | There is a written standard work procedures for all the various types of rock support and reinforcement installed at the mine. | Intent: To verify that written standard work procedures exist that describe how the rock support and reinforcement is to be installed and that they are enforced.<br>Personnel: Underground manager, supervision, mining engineer and operators.<br>Method: Interview personnel.Observe installation. Sight copy of standard work procedures. Compare observed work procedures with those in the standard. Are they in agreement? If not, what explanation can be provided? |
| 5.13 | The workforce installing rock support and reinforcement have been trained in the correct installation procedures. | Intent: To verify the workforce have been trained in the correct installation procedures and understand the reasons why they are installing the rock support and reinforcement in the manner stated.<br>Personnel: Underground manager, supervision, mining engineer and operators.<br>Method: Interview personnel. Have the workforce been trained in the correct installation procedures? Discuss with the underground workforce. Do they understand why they are doing what they are doing? When was training provided? By whom? |
| 5.14 | The storage and handling of rock support and reinforcement elements are such that deterioration with time is minimised. | Intent: To verify that deterioration of support and reinforcement components is minimised.<br>Personnel: Supervision, mining engineer, stores officer.<br>Method: Inspect the surface and underground locations where the rock support and reinforcement equipment is stored. Are the components, particularly threaded components, protected from rain, groundwater, contamination during storage and general damage during transport? Are resin cartridges protected from direct sunlight and high temperatures? Are pallets of bagged cement shrink wrapped? Note: Ground support and reinforcement should be stored "like with like" to avoid mis-match of components, eg putting friction rock stabiliser plates on expansion shell rock bolts (it does happen!). |
| 5.15 | The intact rock strength will permit the full tensile strength of the bar to be achieved in a load test where expansion shell rock bolts are used. | Intent: To verify that expansion shell rock bolts can develop their full load capacity.<br>Personnel: Underground manager, mining engineer, geotechnical engineer.<br>Method: Sight results of expansion shell load tests. Does the rock bolt bar fail before the expansion shell anchor? |

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| 5.16 | The correct bore hole diameter, as recommended by the procedure, is drilled. | Intent: To verify that the hole diameter achieved is in the correct range.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, supervision, drill bit re-sharpening contractor and operators.<br>Method: Interview personnel, Have the diameters of holes drilled in the rock for support been measured? Are the re-sharpened drill bits graded according to diameter range? Are the re-sharpened drill bits colour coded to indicate a range of bit diameters? Have support load tests been done using holes drilled with different bit sizes? Has the support load capacity been related to bit size ranges for each geotechnical domain ? Note: This audit point is particularly important with friction rock stabilisers (eg Split Sets) where the load capacity is very sensitive to the correct hole diameter range. |
| 5.17 | The correct hole length is drilled and flushed clean of drilling sludge | Intent: To verify that the rock bolt and anchorage method (eg expansion shell, resin cartridges, etc) can be inserted to the correct depth.<br>Personnel: Supervision, mining engineer, rock support and reinforcement crew.<br>Method: Observe holes being drilled. Are the correct hole lengths being drilled (this should not be an issue, however it is included for completeness)? For upholes, was the drilling water left on after the bit stopped drilling for say a few seconds? Was the return water clean? For down holes, it is much more important to blow the hole out with compressed air (if available) and water to remove all drilling sludge. This is very important for long down holes drilled for cablebolts. |
| 5.18 | The drill hole orientation is appropriate for the excavation geometry and expected block movement. | Intent: To verify that the full effective length of the support is used.<br>Personnel: Supervision, mining engineer, rock support and reinforcement crew.<br>Method: Observe hole being drilled in the backs and walls, particularly in development headings. Are the holes generally perpendicular to the excavation surface? Note angle of boom to backs and walls. Is it perpendicular to the rock surface? Does the boom length, relative to height or width of the excavation, make it difficult to drill perpendicularly to the rock surface?<br>Note: Very flat holes seriously reduce the “effective” length of the support (proportional to the cosine of the included angle). |
| 5.19 | Load capacity of the individual elements (anchorage, bar or tendon and surface restraint) are appropriately matched to prevent premature failure of any one component. | Intent: To verify that there is no weak link in the support system.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Has load testing been carried out on the support? Sight results of load tests. Does the bar or strand fail before the anchorage method (expansion shell, grout, frictional interference fit)? Does the bar fail before the nut or ring pulls through the plate? What support failures, if any, have been observed?. What failed – anchorage method; bar/tube/strand or threaded end/ring/plate/nut/ barrel and wedge anchor? |
| 5.20 | All components to be encapsulated in resin or cement grout are clean and free of deleterious materials eg loose rust, oil, grease, fill, etc. | Intent: To verify that the support element is able to development the full bond strength between itself and the grout.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Inspect installation procedure. Are the support elements (particularly bar, tube or strand) free of loose flaking rust, oil, grease, paint, fill? |

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| 5.21 | Fully grouted elements show a grout return at the hole collar. | Intent: To verify that the element is fully encapsulated in grout.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Observe installation of grouted support. Where support is installed in the hole first and then grouted: is there a grout return at the hole collar? Alternatively, where grout is placed in the hole first and the support is then pushed through the grout: is some of the grout displaced from the hole collar? This is considered to be the same as a grout return. |
| 5.22 | Correct tensioning or loading procedures are used for tensioned elements. | Intent: To verify the rock support and reinforcement system is loaded correctly.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Observe tensioning of support underground. Are the support manufacturer's installation and tensioning procedures being followed? Is the recommended tensioning equipment being used? |
| 5.23 | Retensioning of point anchor rock reinforcement is carried out. | Intent: To verify that tension in point anchored reinforcement systems is maintained.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Does the recommended support installation procedure require that the tension be checked? Is retensioning or torque testing of point anchor reinforcement carried out on a random basis?. Are the reinforcement manufacturer's instructions being followed? |
| 5.24 | Rock support and reinforcement is protected against corrosion for the design life of the opening. | Intent: To verify that the design life rock support and reinforcement and the openings are matched. Corrosion issues should be addressed and remedied in permanent openings (see page 17 of the Guidelines Geotechnical Considerations in Underground Mines).<br>Personnel: Underground manager, mining engineer, geotechnical engineer.<br>Method: Interview personnel. Does the mine have areas where corrosion is likely to be a problem? Is the corrosion in these areas likely be adverse for the support load capacity? What corrosion protection has been incorporated into the support technical specification (see audit point 5.5)? Does the installed support meet the required specification for corrosion protection. |

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| 5.25 | Representative load testing is conducted for all types of rock reinforcement used in the mine. | Intent: To verify the installed rock reinforcement load capacity complies with the technical specification.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Sight results of load tests conducted during the previous 12 months on the various types of rock reinforcement used in the mine. Is the test equipment and the test procedures as per the International Society for Rock Mechanics (ISRM) suggested methods of testing or suitable adaptation thereof? Do the results of the load testing comply with the support technical specifications (see audit point 5.5)? Note: The load tests could be incorporated into the rock support and reinforcement supply contract. Rein forcement elements tested shall be installed in the mine by mine workforce using mine equipment and usual work procedures (ie not one off specials). The annual minimum number of load tests should be approximately 1% of the total number installed for each type of support or a minimum of 5, which ever is the larger, for each geotechnical domain. |
| 5.26 | Representative load versus displacement testing has been conducted on rock reinforcement used in the mine where seismic rock conditions exist. | Intent: To verify the installed rock reinforcement load-displacement performance complies with the technical specification for seismic rock conditions (see audit point 2.9).<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Sight results of load-displacement tests conducted during the previous 12 months on the various types of rock reinforcement used in the mine. The test equipment and procedure to be as per the ISRM suggested methods of testing or suitable adaptation thereof. Do the results of the load versus displacement testing comply with the support technical specifications (see audit point 5.5)? Note: The load-displacement tests could be incorporated into the rock support and reinforcement supply contract. Reinforcement elements tested shall be installed in the mine by mine workforce using mine equipment and usual work procedures (ie not one off specials). The annual minimum number of load-displacement tests should be approximately 1% of the total number installed for each type of support or a minimum of 5, which ever is the larger, for each geotechnical domain. |
| 5.27 | The mine has an action plan that is implemented when it is found that the load capacity of the installed rock reinforcement system does not meet the required standard. | Intent: To verify that any deficiencies identified in the load capacity of the installed support systems are rectified.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, supervision.<br>Method: Interview personnel. Does the mine have an action plan? Sight a copy of the proposed action plan. Has the plan ever been implemented? The “required standard” is the technical specification, see audit point 5.5. |

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| 5.28 | Resin grouts are stored at the temperature range recommended by the manufacturer. | Intent: To verify that management recognise that resin grouts can "go off" very quickly in hot weather.<br>Personnel: Mining engineer, geotechnical engineer, supervision, stores officer, rock support and reinforcement crew.<br>Method: Interview personnel. How and where the resin cartridges are being stored? Does this conform to the manufacturer's recommendations? Note: Resin that is partially off or set in the cartridge will not provide the required anchorage capacity for a standard length of support. |
| 5.29 | Resin grouts are consumed before their use by date. | Intent: To verify that management recognise that resin used after their "use by date" may have deteriorated and may not develop the same strength as new resin.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Does the support crew check the "use by date" on the resin cartridge boxes prior to use? |
| 5.30 | Mixing of resin grouts is in accordance with the manufacturers instructions. | Intent: To verify that management recognise that resin not mixed in accordance with the manufacturer's instructions may void any manufacturer's guarantee (if any).<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Is the resin mixed for the correct time? Is the correct time delay (set time) allowed for prior to tightening the nut? |
| 5.31 | Cement grouts are mixed at the recommended water:cement ratio. | Intent: To verify that the correct water:cement ratio is being used.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Does the support technical specification state the water:cement ratio? Is the correct amount of water added per bag of cement? This should be specified in the technical specification (see audit point 5.5). |
| 5.32 | Water used in cement grouts is of the required quality or such that the minimum specified grout compressive strength can be developed in the required time. | Intent: To verify that the required grout strength can be obtained.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Is potable (drinking quality) water used to mix the cement grout?<br>Note: Impurities in the water (eg chloride salts) may adversely effect the grout compressive strength and corrode the steel in contact with the grout. Water quality should be stated in the technical specifications (see audit point 5.5). |
| 5.33 | Cement additives are mixed at the specified amounts for correct time. | Intent: To verify that cement additives, eg fluidisers, are added at the recommended dosage rates and mixed for the correct time. Any additives should be stated in the technical specifications (see audit point 5.5).<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Are the additive manufacturer's instructions for dosage amount and mixing time being complied with? |

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| 5.34 | All grout mixing and pumping equipment is cleaned and maintained on a regular basis. | Intent: To verify that management recognise that dirty mixing and pumping equipment may contaminate the grout, possibly reducing its strength. Poorly maintained equipment will probably fail at the most critical time.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Is the grout mixing and pumping equipment cleaned each shift? Is the equipment free of set grout? Is the equipment maintained in accordance with its operating instructions? |
| 5.35 | Any equipment used to pressurise rock reinforcement is regularly maintained and operated at the recommended pressure. | Intent: To verify that management recognize that poorly maintained equipment may not correctly inflate Swellex type reinforcement. The anchorage capacity of such reinforcement with be less when not inflated in accordance with the manufacturers recommendations.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel.Is equipment maintained in accordance with the manufacturer's instructions? Is the equipment operated at the recommended pressure? . The anchorage capacity of such reinforcement with be less when not inflated in accordance with the specification. |
| 5.36 | Any equipment used to tension cable bolts is regularly maintained. | Intent: To verify that management recognize that poorly maintained equipment may not correctly tension cable bolts.<br>Personnel: Mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel.Is equipment maintained in accordance with the manufacturer's recommedations? |
| 5.37 | Shotcrete specification states the slump of the mix (for wet mix shotcrete), the uniaxial compressive strength and a measure of the toughness of the product. | Intent: To verify that shotcrete quality is adequate and consistent.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew, shotcrete contractor.<br>Method: Interview personnel. Shotcrete (wet mix or dry mix) quality control is the responsibility of the shotcrete contractor. This responsibility extends back to and includes the concrete batch plant.<br>Does the shotcrete contractor have a quality control system in place that complies with the relevant Australian Standards for concrete, cement, aggregate, sand, water, etc? Sight quality control documentation from shotcrete contractor. Sight results of slump test, uniaxial compressive strength tests and toughness testing conducted on samples of shotcrete delivered to the mine. |
| 5.38 | Samples of the mine shotcrete mix are collected at specified intervals, under normal mine operating conditions and tested in a NATA registered concrete testing laboratory for compliance with the shotcrete specification. | Intent: To verify that mine shotcrete quality meets the technical specification (see audit point 5.5).<br>Personnel: Underground manager, mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew, shotcrete contractor.<br>Method: Sight results of test work conducted by NATA laboratory on mine shotcrete samples. Do the results comply with the shotcrete specification (see audit point 5.38)? |

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| 5.39 | Shotcrete thickness is tested regularly during placement to verify that the specified thickness has been applied. | Intent: To verify that the shotcrete thickness complies with the technical specification (see audit point 5.38).<br>Personnel: Underground manager, mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew, shotcrete contractor.<br>Method: Interview personnel. What method is used to determine the shotcrete thickness? How often is testing carried out at each location where shotcrete is applied? Does the shotcrete thickness comply with the technical specification? Does the mine have an action plan to rectify this if the shotcrete thickness specification is not achieved? Note: Use of a remote thickness probe, on the shotcrete application boom, is one approach that may be used. The probe may consist of a steel rod with a shaped plate welded to the rod. The rod length protruding away from the plate = minimum shotcrete thickness. Plate shape should be imprinted in the surface of the shotcrete to show a successful thickness measurement. Where there is no plate imprint, the shotcrete is too thin. A range of plate shapes (eg round, triangle, square, etc) could be used, with other rod lengths, to indicate different shotcrete thicknesses. The shotcrete thickness may be determined prior to the shotcrete reaching final set. This method can provide a permanent marking of the shotcrete thickness on the surface of the shotcrete. Other shotcrete thickness testing methods may exist eg drilling holes in the shotcrete. If the shotcrete is too thin it may fail prematurely. |

## 6. MSIA Reg 10.28(2)(f)

| Point | Standard | Guideline |
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| 6.1 | Time dependent deterioration of the ground conditions has been recognised as potentially adverse for rock stability. | Intent: To verify that management recognise that ground conditions do not remain the same for ever.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Has time dependent deterioration of the ground conditions been experienced at this mine? If so, sight of records kept by the mine, eg photographic records, results of simple convergence monitors and regular observations/inspections of suspect areas, preferably noted in a record book. Has the mine carried out any three dimensional stress analyses of each mining stage? This may help to pin point areas of stress decrease/increase and hence possible deterioration of ground conditions. Note: Subtle changes in the rock stress field, particularly stress decreases and stress increases, (as a result of nearby mining) may trigger a deterioration in the ground conditions. |

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| 6.2 | The mining cycle has been adapted to the ground conditions to minimise the delay in installing the ground support. | Intent: To verify that the mining cycle is modified where adverse ground conditions occur.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Is the mining cycle changed depending on the ground conditions? Who assessed the ground conditions? How are the ground conditions assessed? Is the assessment based only on experience? Who determines when the change should be made? What is changed? Who makes the decision to revert to the standard mining cycle.<br>Note: Some changes to the mining cycle that may be appropriate include – reducing the length of the round, firing the most/all the face with low power explosives and spraying shotcrete directly on to the freshly exposed ground before the broken rock is mucked out. There may be other changes that are also possible. |
| 6.3 | Ground support elements other than cement grouted types are installed on a hole by hole basis. | Intent: To verify that each reinforcing element is installed as soon as the hole has been completed.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, supervision, rock support and reinforcement crew.<br>Method: Interview personnel. Does the complete installation of each rock bolt, etc occur on a hole by hole basis? Installation is said to be complete when plate is to fitted to a rock bolt, etc and pressed or tensioned against the rock around the hole collar.<br>The drilling of multiple holes before the installation of the first rock bolt should not be allowed. |

## 7. MSIA Reg 10.28(3)(a)

| Point | Standard | Guideline |
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| 7.1 | The pre-mining rock stress magnitude and orientation in the mine has been quantified. | Intent: To determine the stress (ie force per unit area) that is acting in the rock prior to mining.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Have rock stress measurements been conducted at the mine? What method was used to determine the rock stress magnitude and orientation? Sight a summary of rock stress measurement results for the three principal stresses (sigma 1, sigma 2 and sigma 3) magnitude relationship with increasing depth and orientation (dip and dip direction).<br>Note: The preferred method of rock stress measurement is the CSIRO Hollow Inclusion cell. |

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| 7.2 | The rock mass strength and deformation characteristics in the mine have been quantified. | Intent: To verify that the strength and deformation characteristics of the rock mass have been determined.<br>Personnel: Underground manager, mining engineer, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Have the rock strength and deformation properties been determined for the various geotechnical domains? Sight a summary of the estimated rock mass strength in terms of compressive strength, Young's modulus, Poisson's ratio etc for the various geotechnical domains. Note: This information may have been determined by laboratory testing of rock core samples or from biaxial tests carried out during rock stress measurement, ie using intact rock samples. These results may have to be adjusted (typically reduced) to take account of jointing in the rock mass. These data may also have been estimated by using stress analysis techniques to "back-analyse" a particular mining geometry. |
| 7.3 | The potential for mining induced seismicity or rockbursts to occur in the mine has been assessed. | Intent: To determine if the rock mass characteristics, virgin stress field or mining induced stress field have the potential for the development of seismicity or rockbursts.<br>Personnel: Registered manager, underground manager, mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight written reports and photographic record of rock falls and rock failure events in the mine over the past two years. The following points should be considered when assessing the seismic risk profile of the mine:<br>1. Rock mass characteristics, virgin stress field and mining induced stress field.<br>2. Have the mine excavations suffered damage as a result of a seismic event or rockburst?<br>3. Have the rock support and reinforcement suffered damage as a result of a seismic event or rockburst?<br>4. Has any one been seriously injured or killed as the result of a seismic event or rockburst?<br>5. Has the mine had to be cleared of all employees and/or inspected from the top down following a seismic event or rockburst?<br>6. How frequently has this occurred in the past two years?<br>What conclusions have the mine management come to regarding the level of seismicity and rockburst activity at the mine? Are they exercising their "duty of care" regarding the provision of a safe workplace? This is a critical audit point. Note: damage = failure of rock support and reinforcement; rock ejected from walls and backs; rocks shaken off walls or rock falls from the backs following a seismic event or a rockburst. |

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| 7.4 | There are regular geotechnical inspections, made on foot, of the active mine openings and their surroundings to document the mining history and any changes in the observed ground conditions and rock support and reinforcement behaviour. | Intent: To verify that changes in the ground conditions are recognised.<br>Personnel: Underground manager, supervision, geologist, mining engineer, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight record or summary of the ground behaviour in various areas of the mine. Have these been noted in a record book or on plans, longitudinal projection, etc? Are inspections of active mining areas occurring on a regular basis? Do these inspections specifically look at the ground conditions? How do these observations compare with other monitoring instruments (eg seismic monitoring system) or with predictions from numerical stress analysis methods? Note: Comments from the workforce should also be included. The record book entries should be regularly reviewed, initialled, dated and actioned by the Underground Manager. Regular feedback, on matters of concern to the workforce, should be given. |
| 7.5 | An on-going photographic record of significant geotechnical events, with written notes of observations, is maintained and regularly updated. | Intent: To verify that there is a record of important geotechnical events in the mine.<br>Personnel: Underground manager, mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight photographs with notes summarising events. Have these events been interpreted? What are their implications for future mining? Note: Later review of these history data may provide improved insights into what was occurring at the time. This may not be readily apparent, during mining, due to production demands and/or a lack of appreciation of the full magnitude of the event. |
| 7.6 | Displacement monitoring instrumentation is used where appropriate. | Intent: To verify that movement that is occurring in stope walls, on faults, floor settlement, etc is monitored.<br>Personnel: Underground manager, mining engineer, geologist, surveyor, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight graphical summary of results from extensometers, monitoring pins, convergence monitoring, precise levelling, etc. Sight plans showing monitoring instrument locations, development and stope voids. How often are the monitoring instrument read? How are they read (ie manually or automatically)? Who is responsible for ensuring that they are read? How are these data used? |
| 7.7 | Absolute and/or incremental rock stress measurement techniques are used where appropriate. | Intent: To determine if there has been any change (increase or decrease) in the rock stress field magnitude and orientation as a result of mining.<br>Personnel: Mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight results and interpretation of the rock stress measurements (absolute or incremental change). Note: Large changes in the mine geometry, eg mass blasting, can cause significant changes in the rock stress field. Generally more applicable in non-entry mining methods, eg longhole open stoping, sub-level caving, block caving and vertical retreat mining. |

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| 7.8 | Remote, three dimensional, laser based surveying techniques are used to monitor fall off, etc in large non-entry stopes. | Intent: To determine the extent of overbreak, underbreak or non-break in non-entry stopes.<br>Personnel: Underground manager, surveyor, mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Does the mine use longole open stope mining methods? Does the mine have unfilled open stope voids? Has there been large scale wall collapse in open stopes? Sight results from laser surveying techniques and determination of actual stope profile (plans and cross-sections may be useful) and overlying or nearby development. Is active caving occurring within the stope? Is nearby development likely to be effected by the caving front? How is the situation being managed? Note: The survey data can be useful in calculating wall rock or fill dilution. Used to monitor stopes that are caving or self mining upwards towards the surface, overlying development or other filled stopes. |
| 7.9 | Stoping history is regularly recorded on longitudinal projections for steeply dipping ore bodies or on plans for shallow dipping ore bodies. | Intent: To verify that mining history is recorded<br>Personnel: Mining engineer, geologist, surveyor, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight stope longitudinal projections. Have stope firings been marked off, showing tonnage and date for each firing? Have dilution estimates and ground behaviour comments been recorded? . This information is essential in the back-analysis of stope geometry to calibrate numerical stress analysis models. |
| 7.10 | A seismic monitoring system is installed in a mine where seismic and rockburst activity causes damage to the openings and/or the rock support and reinforcement systems in the mine. | Intent: To verify that a seismic monitoring system is installed in seismically active mines.<br>Personnel: Registered manager, underground manager, mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. See audit point 7.3. Has damage occurred regularly to mine excavations and the installed ground support? If yes to any one of points 2 to 5 in Audit Point 7.3, then a seismic monitoring system should have been installed. |
| 7.11 | A seismic monitoring system where installed is capable of detecting, processing and displaying a representative sample of the range of seismic events occurring in real time. | Intent: To verify that the installed seismic monitoring system is capable of monitoring a representative sample of the seismic events and rockbursts at the mine.<br>Personnel: Registered manager, underground manager, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Has the seismic system been supplied by a reputable supplier with experience in the mining industry? Has the supplier conducted test work underground to determine the P and S wave velocities? Has the supplier prepared a report recommending a particular seismic monitoring system, sensor type (ie geophone or accelerometer) and locations of sensors underground? Has this recommendation been accepted in its entirety by the mine? Can the seismic monitoring system carry out the required quantitative seismological processing in real time? Can the system discriminate between blasts and seismic events occurring very soon (ie preferably within seconds to minutes) after blasting? |

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| 7.12 | The monitoring results are regularly communicated to the workforce. | Intent: To verify that management have informed the workforce of monitoring results etc.<br>Personnel: Underground manager, supervision, mining engineer, geologist, surveyor, geotechnical engineer, mine planning engineer, all underground workforce.<br>Method: Interview personnel. Are regular meetings are held with all members of the workforce who work underground? Is ground behaviour information shared with the workforce at these meetings? Are the results of seismic monitoring displayed on plans or longitudinal projections that are readily accessible to the workforce? Management should verify that the workforce are informed of potentially adverse ground behaviour that is occurring or may occur in the mine. Essential to reduce the element of surprise for the workforce. |

## 8. MSIA Reg 10.28(3)(b)

| Point | Standard | Guideline |
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| 8.1 | The mine has conducted back-analyses of stope and/or pillar behaviour. | Intent: To verify that the observed performance of stope voids and pillars is used to calibrate numerical stress analysis models.<br>Personnel: Mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. How do the results of numerical stress analysis compare with observed ground behaviour and results from monitoring instruments (displacement and stress change)? Is there a reasonable level of agreement between the numerical modelling, observed ground conditions and monitoring results? . |
| 8.2 | Interpretation of results from the back-analyses takes account of the range of ground conditions and the installed rock support and reinforcement. | Intent: To verify that interpretation of results from the back-analyses of stope and/or pillar performance has been conducted for all ground conditions occurring at the mine.<br><br>Personnel: Mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Have the results been interpreted on the basis of similar ground conditions and/or similar levels of the installed rock support and reinforcement? |
| 8.3 | The results of the back-analyses are plotted in graphical form. | Intent: To verify that results are produced in graphical form.<br>Personnel: Mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Sight graphical summary of back-analyses. Note: Each stope back-analysed may be represented by one point on the graph. The ground response for sill pillars, abutments and stope walls may be amenable to this type of simple x-y plot. Hence, a summary of ground response may be built up over a number of years in the form of a ' design graph' or ' experience graph' . |

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| 8.4 | The as mined stope and pillar geometry is known. | Intent: To verify that the actual stope and pillar dimensions are known.<br>Personnel: Mining engineer, surveyor, geologist, geotechnical engineer, mine planning engineer.<br>Method: Sight plans, longitudinal projections, cross-sections or three dimensional representation of stope(s), preferably produced using remote laser based surveying techniques. Is realistic stope and pillar geometry available? |
| 8.5 | The as mined stope and pillar geometry is used in the analysis. | Intent: To verify that analysis of stope or pillar performance is done using actual stope and pillar dimensions.<br>Personnel: Mining engineer, surveyor, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Has there been any major overbreak, underbreak or nonbreak in the stope being back analysed? Do the survey pick-ups adequately represent these features? Have any major pillars or voids been left out? Is the stope shape used in the back-analysis a reasonable approximation of the actual stope geometry? |
| 8.6 | A suitable method has been used to predict the expected stability conditions based on the geometry of the opening and the ground conditions in that area. | Intent: To verify the use of geotechnical methods to estimate the stability conditions in the area.<br>Personnel: Mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. What has been method been used? Is it one that is recognised in the underground mining geotechnical literature? Has the mine developed it from their own experience or as an extension of the Stability Graph Method? Note: There must be a sound geotechnical basis for the method. It must be described in the current geotechnical engineering literature (preferably published in English). |
| 8.7 | The mine is using a justifiable method for pillar design. | Intent: To verify that a reasonable method of pillar design is being used.<br>Personnel: Mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. What method is being used? Are the limitations of the method understood? What are these limitations? Note: Limitations of the tributary area method include – abutments are ignored, stresses in the plane of the orebody are ignored, stress distribution in pillars is assumed to be uniform. |
| 8.8 | Two dimensional stress analysis techniques are used where there is a regular geometry in the area being analysed. | Intent: To verify the use of an applicable stress analysis technique.<br>Personnel: Mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Sight cross-section or longitudinal projection used in two dimensional stress analysis plus results of analyses. How have the results been interpreted? How do they compare with observed ground response? Is there a reasonable correlation between the two? Note: These methods can be used where the stope geometry is suitable, eg long tabular stopes with a regular cross-section or room and pillar stopes. |

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| 8.9 | Three dimensional stress analysis techniques are used to model complex mine geometry. | Intent: To verify the use of an applicable stress analysis technique.<br>Personnel: Mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Sight the three dimensional model that was used. Is it realistic? What results have been obtained from the analyses? How have they been interpreted? How do they compare with observed ground response? Is there a reasonable correlation between the two? |
| 8.10 | Results from numerical modelling are incorporated in stope and pillar design. | Intent: To verify that the numerical modelling results are used in stope and pillar design.<br>Personnel: Underground manager, supervisor, mining engineer, geologist, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. View stope and pillar design documentation. Where applicable have the results of Audit Points 8.7 to 8.9 been incorporated into the stope and pillar design? |

## 9. MSIA Reg 10.28(3)(c)

| Point | Standard | Guideline |
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| 9.1 | Mine production schedules take account of numerical stress analyses of stope extraction sequences. | Intent: To verify the selection of an extraction schedule that produces the least adverse ground conditions in future ore reserves.<br>Personnel: Underground manager, mining engineer, geologist, geotechnical engineer, mining planning engineer.<br>Method: Interview personnel. What, if any, alternative stope extraction sequences have been considered? Why were these rejected? Are there any adverse implications for future mining (eg highly stressed sill pillars)? How will these be managed? Note: aim to have the remaining ore reserves in the most mineable condition having regard for access requirements, drill & blast issues, ventilation, stope filling, major faults, past experience, etc. Does the mine have short term (1 to 2 years) development and production schedules? Does the mine have long term (up to 10 years or life of mine) development and production schedules? |
| 9.2 | For recoverable pillars, an appropriate pillar recovery plan exists and is implemented when pillars approach predetermined minimum dimensions. | Intent: To verify that recoverable pillars are mined in planned and systematic manner with suitable geotechnical design input.<br>Personnel: Underground manager, mining engineer, geologist, geotechnical engineer, mine planning engineer, supervision, pillar recovery team.<br>Method: Interview personnel. Does a pillar recovery plan exist? Is the pillar recovery plan based on geotechnical engineering and stress analysis techniques? |
| 9.3 | A geotechnical engineering justification can be provided if no fill is used in any stope. | Intent: To verify that mine management has justified leaving large open stopes.<br>Personnel: Registered manager, manager mining, underground manager, chief mining engineer.<br>Method: Interview personnel. Sight a geotechnical report that justifies that no fill is required in this stope. The mine must be able to demonstrate that the stope walls will be stable for the expected life of this part of the mine. |

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| 9.4 | There is a strategy for the supply and placement of fill. | Intent: To verify provision of fill for use in the stopes.<br>Personnel: Registered manager, manager mining, underground manager, chief mining engineer.<br>Method: Interview personnel. What is the availability and source of the fill? Inspect fill reticulation/handling system etc. Note: MSIR 9.26 regulates the use of cyanide tailings. |
| 9.5 | The mine has a specification for minimum fill quality. | Intent: To verify that the fill meets the minimum strength properties.<br>Personnel: Registered manager, manager mining, underground manager, chief mining engineer, mine planning engineer.<br>Method: Interview personnel. Sight a statement of the specifications for the minimum fill physical qualities (eg strength parameters, grading curve, etc). How was the specification for fill quality determined? How does it compare with other fill materials used nationally and internationally? The chemical and physical properties of the fill material do need to be considered. For example the chemical properties of the clay fraction of paste fills can have adverse effects. |
| 9.6 | Where consolidated fill is used in the mine it is designed in accordance with a recognised method. | Intent: To verify that consolidated fill placed in stopes meets certain minimum physical criteria.<br>Personnel: Underground manager, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Sight a summary of the fill design methodology. What is the basis for the fill design methodology? Is it a recognised fill design method? Note: consolidated fill means strength enhanced fill eg cement addition. |
| 9.7 | Quality control measures are in place to verify that fill placed in the mine meets the required specifications. | Intent: To verify that the fill placed in the stopes is subject to quality control.<br>Personnel: Underground manager, geotechnical engineer, mine planning engineer.<br>Method: Sight a summary of the fill quality control measures. How often is the fill placed in the stopes tested to meet the required specifications? Sight results of fill test work. What action is taken when the fill does not meet the minimum specifications? |
| 9.8 | All stopes requiring fill are filled as soon as practicable after the extraction of ore is complete. | Intent: To verify that the time that the stope walls have to stand unsupported is minimised.<br>Personnel: Underground manager, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. What is the average delay between completing stope mucking and commencing stope filling? Have there been any excessively long delays (ie several weeks to months) before filling commenced during the past year? How long does it take, on average, to complete filling a stope? Have there been any major stope wall collapses during the past year? |

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| 9.9 | Fill bulkheads/barricades are designed using recognised engineering methods. | Intent: To verify that fill bulkheads/barricades are correctly designed.<br>Personnel: Underground manager, geotechnical engineer, mine planning engineer.<br>Method: Interview personnel. Does the mine have a bulkhead/barricade design method? What is the source of the design method? Is the design method one that is recognised nationally and internationally? What water drainage provisions have been incorporated into the bulkhead design? Is the hydraulic pressure, behind the bulkhead, monitored during filling? What results have been obtained from pressure monitoring? Are the results within the bulkhead design specifications?<br>Note: bulkheads are designed to withstand high hydraulic pressures. Barricades are typically not designed to withstand any significant hydraulic pressure. |
| 9.10 | Fill bulkheads/barricades are installed to the design standard. | Intent: To verify that the installed bulkheads/barricades are constructed as designed.<br>Personnel: Underground manager, supervision, mining engineer, underground workforce.<br>Method: Interview personnel. Does the mine have a standard work procedure for bulkhead/barricade construction? Sight standard work procedure for bulkhead construction. What method is used to construct the bulkheads or barricades (concrete blocks, shotcrete over wire mesh, timber, cast concrete, etc)? Have the underground workforce been trained in the construction of bulkheads/barricades? What method is used to key the bulkheads/barricades into the floor, walls and backs? What problems, if any, have been experienced with bulkheads/barricades? |
| 9.11 | The mine has a graph or other means of displaying cumulative stope void, showing volumes of stope void created and fill placed, which is updated on a monthly basis. | Intent: To verify tracking of fill placement and cumulative stope void at the mine.<br>Personnel: Registered manager, underground manager, supervision.<br>Method: View the graph, or other means, demonstrate that the rate of stope filling is generally keeping pace with ore production? Are stope voids being progressively and systematically filled? Is the cumulative volume of stope void increasing at a faster rate than the cumulative volume of fill placed? If so, why? |

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| 9.12 | Water is not permitted to accumulate in any stope containing sand fill. | Intent: To verify that excessive hydraulic pressures do not build up behind bulkheads or in sand filled stopes generally.<br>Personnel: Registered manager, underground manager, supervision, underground workforce.<br>Method: Interview personnel. How is the water level in sand filled stopes checked? How often is the water level in sand filled stopes checked? Note: high hydraulic pressures may cause the bulkhead to burst allowing fill and water surge out of the stope and flow rapidly through the mine, creating a “mud rush” which would inundate areas of the mine. Such an event, if it occurred, would pose a very significant risk to the workforce. Is water being diverted into a sand filled stope that has been sealed with bulkheads? How is it proposed to drain the water from the stope? Where could water, from the mine dewatering system or naturally occurring groundwater, be entering sand filled stopes? Could this occur as a result of blocked drain holes, broken pipelines, overflowing sumps, etc? How often is the mine drainage system (drain holes, pipelines, sumps, pumps and settlers, etc) checked? Note: the occurrence of water in aquifers, cavities or other voids should be verified, monitored and drained if necessary where mining occurs adjacent to or below these features. |
| 9.13 | Before any pillar recovery is attempted below a filled stope measures are taken to check for free water in the stope and any water encountered is drained. | Intent: To verify that procedures exist to prevent sections of the mine being suddenly inundated by large volumes of water, fill and/or other materials.<br>Personnel: Registered manager, manager mining, underground manager, supervision, surveyor, mine planning engineer.<br>Method: Interview personnel. What records are kept of old stopes and workings? What records of the dewatering volumes extracted from the old workings have been kept? How is it demonstrated that these old workings have been effectively drained? |
| 9.14 | Blasting in the immediate vicinity of stopes that contain wet fill is not permitted. | Intent: To verify procedures to prevent liquifraction of the saturated sand fill by dynamic loading from blasting.<br>Personnel: Registered manager, manager mining, underground manager mine planning engineer.<br>Method: Interview personnel. Sight records of stope blasts and stope filling (eg on a longitudinal section) Estimate the minimum time period between the completion of the filling process and firing of adjacent stopes. What basis is there for the minimum time. Has fill liquefraction occred at the site. How is the potential for fill liquifraction managed. |

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| 9.15 | Major surface infrastructure and natural water courses are outside of the zone of influence of subsidence. | Intent: To verify the minimisation of the adverse impacts of subsidence on major surface installations (eg roads, pipelines, powerlines, shafts, offices, workshops, treatment plant, ventilation fans, tailings storage facilities, sub-stations, fuel storage areas, etc) natural structures and near surface features such as aquifers.<br>Personnel: Registered manager, manager mining, all department managers, underground manager, surveyor, mine planning engineer.<br>Method: Interview personnel. Sight a geotechnical assessment of the potential for caving or subsidence of materials above and/or beside large unfilled stope voids, sub-level caving or block caving mining methods. Has the angle of break been determined? Are major surface installations "outside" the zone subtended by the angle of break? Are large voids regularly surveyed with remote laser surveying device (eg Cavity Monitoring System) to detect change in void shape and volume? Is this information regularly communicated to senior management? How is the situation being managed? Note: The interaction of initially separate open pit and underground mine workings can create a situation where there is potential for open pit wall instability. The undermining of open pit walls by underground stoping operations can have serious implications for both mines (ie large scale collapse). A cascade effect can potentially be created that may have serious consequences for major surface installations, eg a hoisting shaft near an open pit that is subsequently extended by a caving mining method. |

## 10. MSIA Reg 10.28(3)(d)

| Point | Standard | Guideline |
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| 10.1 | Appropriate blast design procedures are used to design blasting patterns in long hole rising. | Intent: To verify the achievement of maximum advance and minimum overbreak per round with the minimum blast damage to the remaining perimeter rock.<br>Personnel: Underground manager, mining engineer, supervision.<br>Method: Interview personnel. Does the mine have a blast design procedure? Is it largely based on practical experience? Sight examples of use of blast design procedures in use. Have the blast designs been prepared by consultants or in-house expertise? How often are the blast designs reviewed? How do they incorporate changes in the ground conditions? Is the mine using inverse raising and other methods of long hole rising? |
| 10.2 | Appropriate blast design procedures are used to design blasting patterns in stopes. | Intent: To verify the achievement of optimum fragmentation and minimum overbreak per stope blast with the minimum blast damage to the remaining perimeter rock.<br>Personnel: Underground manager, mining engineer, supervision.<br>Method: Interview personnel. Does the mine have a blast design procedure? Is it largely based on practical experience? Sight examples of use of blast design procedures in use. Have the blast designs been prepared by consultants or in-house expertise? How often are the blast designs reviewed? How do they incorporate changes in the ground conditions? How is stope wall damage minimised? |

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| 10.3 | There is a standard work procedure for production blasts | Intent: To verify that the stope blasts are implemented in the manner intended in the blast design.<br>Personnel: Underground manager, mining engineer, supervision, charge-up crew.<br>Method: Interview personnel. Sight standard work procedure for production blasting. Sight stope charging sheet. Were they produced using the blast design procedure? |
| 10.4 | The workforce has been trained in the procedures and techniques used in production blasts. | Intent: To verify that the workforce has been trained in the procedures and techniques used in production blasts.<br>Personnel: Underground manager, mining engineer, supervision, charge-up crew.<br>Method: Interview personnel. Have the workforce been trained in production (stope) charging and explosives handling generally? |
| 10.5 | The mine uses recognised blast monitoring techniques in stope blasts to verify blasting performance. | Intent: To verify the stope blast design parameters are monitored.<br>Personnel: Underground manager, mining engineer.<br>Method: Interview personnel. Sight a stope blast monitoring report. Have stope blasts been performing according to design? |