Inrushes and Subsidence
Major Hazard Standard

MHS-09
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PURPOSE AND SCOPE

The purpose of this standard is to eliminate fatalities and serious injuries resulting from inrushes or subsidence caused by the uncontrolled mass movement of materials into, in and around open pit and underground mining operations. This standard applies to all WMC operations throughout their life cycles.

It applies to the prevention and control of the mass movement of:

- Water – surface or natural eg karstic,
- Rock,
- Mud,
- Fill – wet or dry,
- Tailings,
- Raise drill cuttings

The Standard also applies to the air-blast effects which may occur as a result of mass material movements which occur in confined spaces.

This standard does not cover:

- Gas outbursts, rock-bursts, open pit or tailings storage facility slope stability or management.
- Risks associated with exploration and other activities on remote areas exposed to landslides, mudrushes, flash floods etc (see MHS Remote Areas and Natural Disasters).

Related WMC Major Hazard Standards are:

- SAF-MHS-01 Underground Ground Control
- SAF-MHS-16 Slope Stability.

DETAILS

1. Responsibility

The General Manager or equivalent is responsible for ensuring that each site has the necessary processes, procedures and/or controls in place to either prevent, or to isolate people from, the potentially hazardous consequences of uncontrolled mass material movements. The General Manager or equivalent shall also ensure:

- Compliance with all applicable statutory and regulatory requirements.
- That the level of personal safety risk associated with each potential mass material movement hazard is assessed and is acceptable to WMC.
- That adequate controls are identified, designed and implemented in accordance with a risk based process, to ensure that all persons (including the public after closure) are not exposed to inrush and subsidence hazards which may pose a safety risk.
- That the design process and design detail for controls required to mitigate the risk associated with inrush and subsidence hazards are commensurate with the complexity of the hazard and the controls.
- That the training and competence of all personnel associated with inrush, subsidence and air-blast issues are appropriate to the complexity of the issues being considered or the tasks being carried out.
- That regular due diligence is carried out to confirm that the process and implemented controls are adequate to manage the safety risk associated with inrush and subsidence hazards.
2. Hazard Management Process

2.1 Overview

The risks associated with inrush and subsidence and associated air-blast hazards can be minimised by the rigorous consideration of potential hazards, and the systematic design and implementation of appropriate mitigating controls.

It is difficult to completely design-out some potential inrush and subsidence hazards as some incidents may occur as a result of an unforeseen combination of events, or when conventional design limits are exceeded. For example, an inrush may occur when the peak flow from a short duration cyclonic storm event exceeds the peak runoff during a 1 in 100 year 24 hour flood event.

An iterative risk based process needs to be used at each stage of the Project Lifecycle to identify and manage the risks associated with mass material movement hazards and the potential consequences should an incident occur.

In some cases, where control of the movement may not be predictable or possible, the best approach to risk management may be isolation of personnel from a potential hazard, rather than trying to design-out the hazard.

2.2 Design / Risk Management Process

Each Operation or Project shall identify all potential inrush & subsidence hazards in and around each mining operation.

Risk assessments shall be conducted by competent mining personnel.

A concise Water Control Plan shall be prepared for each mining operation. The plan explains the management of water in response to potential Inrush and Subsidence hazards. Information contained in the Plan shall be relevant to the management of inrush and subsidence risks. Related hydrological, hydrogeological studies etc shall be referenced and stored separately. The plan should include:

1. A summary of likely hydrological phenomena

2. An Inrush and Subsidence Hazard Map(s) for each mining area which shall indicate clearly:
   i. All significant inrush and subsidence sources, including:
      a. External sources eg backfill, water or tailings storage facilities, and natural features eg. ground water aquifers, karstic features, landslides etc. These may suddenly release a large quantity of water or mud if intersected by or passing near to mine workings.
      b. Internal sources eg excessive fines in cave muckpiles.
      c. Potential flowpaths
   ii. Safe exit routes

3. Contingency and Emergency Preparation and Response Plans including:
   i. Severe weather plans
   ii. Alarm response – reaction sequence and allowable actions in response to lead indicator trigger alarm.
   iii. Emergency response plans – reaction sequence and allowable actions to mitigate consequences of inrush, subsidence and/or air-blast incidents.

The potential flowpaths and flow extents of flowable material sources shall be defined in accordance with current geotechnical best practice.

A risk assessment shall be conducted on each mining related inrush and subsidence hazard to ensure that:

1. Material movement from external sources will always be controlled to move towards a clearly defined destination along a known and adequately sized pathway.

2. For internal material sources eg excessive fines in cave muckpiles, the risks associated with potential mudrushes (which in this case cannot be controlled), are mitigated using the “distance, drain, draw” principle.

3. The risk of exposure of personnel to uncontrolled mass material movement is low as a result of:
4. Exit or escape routes are adequate and accessible.

5. Access to escape routes and emergency response plans are communicated clearly to all persons who may be affected by mass material flows.

Emergency response and rescue personnel shall be adequately informed and trained to ensure that response and rescue operations do not increase the risk to themselves or others.

2.3 Site Geotechnical Processes and Documentation

The geotechnical requirements for each mining area applicable to potential inrushes and subsidence incidents shall be fully documented in the Ground Control Management Plan for that area.

The GCMP shall describe the responsibilities, competencies, design processes, approval and operating processes etc. (see SAF-MHS-01 Underground Ground Control and SAF-MHS-16 Slope Stability).

Documentation and plans for each mining area, including actions arising from Risk Assessments, shall be Appended to the Ground Control Management Plan. The documentation shall demonstrate compliance with this Standard.

3. Lifecycle Requirements

A project lifecycle consists of identifiable stages
- Planning and Design
- Operation
- Decommissioning and closure

Throughout this cycle all inrush and subsidence hazards shall be managed in accordance with this Standard.

4. Mine Planning and Design

4.1 Surface Drilling and Data Collection

A drilling plan shall be developed to ensure that:

- All relevant geotechnical and hydrogeological data is collected during the exploration program for later use (see SAF-MHS09-R01).
- The position and alignment of all drill holes is checked to consider the potential impacts of intersecting mine voids
- All drill holes are marked and their spatial position (collar and hole alignment/deviation) recorded for location relative to existing and future underground workings.
- All drill holes are capped to prevent surface water entering the hole.
- Drill holes are grouted to avoid any undesirable connection between a water source and underground workings.

4.2 Disused Adits and Old Workings

Prior to accessing disused underground or surface workings:
- An inspection and risk assessment shall be carried out by a competent mining/geotechnical engineer to assess all potential hazards associated with entering and working in disused workings.
- All entrances to disused workings shall be secured against unauthorised access. Only competent persons or people accompanied by competent persons are authorised to access workings.
- Workings shall be de-watered to a safe level before entry by a competent person is authorised.

4.3 Mining Areas - Minimum Standards

The design and operation of mining areas shall comply with the requirements of State mining regulations.

The requirements of the Western Australia Mines Safety and Inspection Regulations 1995 (WA) Section 10.8 (Underground) and 13.8 (Open Pits) (see MHS 09 (Underground Ground Control) and 16 (Slope Stability) respectively) represent the minimum WMC requirements. The various Department of Minerals and Petroleum Resources (DMPR) guidelines applicable to these regulations include:

1 For more information on access to disused workings see guideline in Safe Mining – Practical Guidance for Managing Safety and Health in the Mining and Extractive Industries, ANZMEC, Sections 56-100.
** Major Hazard Standard **

** Inrushes and Subsidence **

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- Geotechnical Considerations in Open Pit Mines August 1999.

These regulations and guidelines are the minimum standards to be applied in the consideration of Inrush and Subsidence hazards.

### 4.4 Mine Planning and Design

The consideration of Inrush & Subsidence hazards shall be incorporated in each stage of mine planning and design.

A formal approval process shall be developed for current and future work, which ensures that the current designs, work plans and hazard maps are signed-off by the Registered Mine Manager.

Documentary evidence shall be maintained to show that the GM is at all times aware of, and approves, the level of risk associated with Inrush & Subsidence hazards.

The consideration of Inrush and Subsidence hazards shall be incorporated in the Ground Control Management Plan (see MHS 09 and MHS 16) and dealt with as a separate topic considering:

a. The level of complexity of the potential hazards and geotechnical conditions at the time. The assessed level of complexity may change as the mine develops.

b. The responsibilities and required competencies of WMC operations personnel.

c. The required competency and experience of the geotechnical design team.

d. The most appropriate design process for each control measure.

e. The geotechnical investigation programme required to provide adequate design information.

f. Identification and consideration of external influencing factors (seismicity, groundwater, tailings storage facilities etc), assessment of their influence, and design of appropriate controls.

g. The performance monitoring strategy.

h. Emergency procedures for isolating hazardous areas; installation of barriers, evacuation of personnel, etc.

i. The formal approval process to be followed prior to starting work or implementing a change to the design.

Accurate survey of nearby old or disused workings shall be carried out to confirm their position relative to proposed new workings and existing relevant infrastructure eg tailings dams etc.

Information from ongoing drilling programs, development, stoping and monitoring is used in the safe design, development and operation of the mine.

Water and / or backfill retaining/draining structures are adequately designed and monitored to ensure ongoing integrity (includes water storage, linings in shafts and development openings, dams etc.).

Each aspect, stage and modification of the design shall be risk assessed to determine the management strategy and controls required at the time to minimise the risks associated with inrush, subsidence and airblasts.

### 4.5 Mining Methods

For mass mining methods:

- For open stoping methods the expected stope stability relative to the size, shape and orientation of stoping voids shall be assessed, together with the potential mechanisms of failure and the probability of collapse, subsidence and airblast.

- For caving methods the caveability of the rock mass and the subsequent potential for voids, subsidence and airblasts shall be assessed.

(Both these factors imply a knowledge of applicable structural and rock mass classification data.)

All escape ways shall be located or otherwise protected so that:

- They are not a pathway to any potential inrush.
• They are not in an area of possible subsidence.
• All connections to an escape way are designed to prevent an inrush blocking it.

Mining of the crown pillar or mining through to the base of an open pit shall be the last mining activity unless the mining method results in an acceptable level of risk, and provision has been made for flood control.

Where the mining method requires large voids to be created, the risk of subsidence, inrush and airblast shall be assessed.

Pillar stability shall be assessed using accepted geotechnical formulae incorporating time related effects.

The undercutting methodology for cave initiation shall be designed to mitigate the risk of airblast.

4.6 Pass Design

Ore and waste pass design shall ensure that:
• The risk of “hang-ups” and “rushes” are minimized.
• There is a safe method to clear “hang-ups”.
• Provisions for access and inspection of passes take into account the effects of ‘hang-ups’ and ‘rushes’ of material.

(For guidelines see SAF-MHS09-R01)

4.7 Backfill

Where backfill is to be used:
• The backfill system, the distribution system, the fill drainage system and the fill barricade design shall be designed by a competent engineer and shall undergo a formal technical review by an external backfill specialist(s).
• Internal and external competence shall be appropriate to the specific design task, eg the structural design of a barricade requires geotechnical and structural design input and review.
• The backfill material specification shall be based on thorough investigation that ensures the stability of the fill material and control of liquefaction.
• The design and management of backfill systems shall be incorporated in the Ground Control Management Plan (see MHS 09 and MHS 16) and dealt with as a separate topic considering:
  a. The level of complexity of the system, its components eg water and fill retaining structures, potential hazards, and geotechnical conditions. The assessed level of complexity may change as the mine develops.
  b. The required competency and experience of the backfill system design team.
  c. The responsibilities and required competencies of WMC operations personnel.
  d. The most appropriate design process for each system element and each risk control measure.
  e. The geotechnical, hydrogeological and hydrological investigation programmes required to provide adequate design information.
  f. Identification and consideration of external influencing factors (seismicity, groundwater, tailings storage facilities etc), assessment of their influence, and design of appropriate controls.
  g. The performance monitoring strategy.
  h. Emergency procedures for isolating hazardous areas; installation of temporary barriers, evacuation of personnel, etc.
  i. The formal approval process to be followed prior to starting work or implementing a change to the design.
4.8 Surface Water Runoff

Where there is a potential for surface water runoff to enter operating workings, controls or diversion structures shall be sized to ensure that there is an acceptably low level of risk to personnel working in potentially exposed areas in the event of a Probable Maximum Flood event. The peak flow during a Probable Maximum Flood event shall be determined by a competent hydrology professional.

All diversion structures shall be designed by a competent engineer.

Where surface water inrush and/or subsidence risks are managed by isolation, as opposed to controlling the mass movement, eg closure of an open pit or underground operation before a severe storm rather than relying on diversion structures, a response plan eg Severe Storm Response Plan shall be detailed in the Water Control Manual/Plan.

Where there are safety critical surface water diversion or control structures, risk management should involve evacuation of affected areas under extreme conditions. There shall be no attempt to continue working in areas exposed to potential inrush from surface water flows during extreme conditions.

Monitoring of surface water flows during severe storms eg monitoring the flow level in diversion channels, shall not be conducted during extreme conditions as this exposes personnel to safety risks.

5. Operation

5.1 Management

Mine management shall ensure that:

- A risk register is maintained for potential uncontrolled mass movement of material in existing and proposed mining areas.
- A risk review and/or risk assessment is carried out and all relevant plans updated if there is an identified change of scope in operations
- Scheduled actions arising from risk reviews / assessments are audited quarterly to confirm implementation, and reported to the GM.
- A set of leading indicators are identified and the monitoring of lead indicators e.g. ground movement, cracking, pumping, water flows, rainfall, structure movement etc is used to define alarm trigger levels.
- A response plan is triggered by a defined alarm level (or incremental change in a leading indicator) e.g. cyclone warning triggers Severe Weather Response Plan
- Only competent and skilled personnel are selected for positions that involve assessment and control of mass movement of material.
- Line management have nominated accountabilities, authorities and lines of communication for the control of mass movement of material and the management of associated risks.
- There is a contingency plan for situations involving an uncontrolled mass movement of material.
- Standard Work Procedures are developed through Job Safety Analyses and implemented for any activity that is not covered by an existing Standard Work Procedure including:
  a. Raise drilling and bogging of cuttings.
  b. Mining under crown pillars.
  c. The storage, controlled handling and disposal of mud, sump slimes, raise bore cuttings, shaft spillage etc.
  d. The drawing of material from a shrink stope or cut and fill stope when persons are working in the stope. This procedure shall include communications methods.
  e. The drawing of material from a caving method including:
     1. monitoring of any possible voids
     2. regular monitoring of the progress of the cave front
3. draw control from the cave
   (to minimise the possible
   generation of voids).

f. The storage, handling and disposal
   of rock, road-base, sand and
   gravels. This procedure shall
   include guidelines for the design of
dumps for different material types.

g. The regular inspection and
   maintenance of escape ways that
   ensures availability.

h. The operation of ore and waste
   passes including:
   1. control of water and mud
      entering the passes
   2. the clearing of blockages
   3. monitoring the material levels
      in passes
   4. periodic inspections or
      monitoring of pass conditions
   5. desired material size control
   6. operation of pass control
      mechanism
   7. start-up and shutdown
      requirements

5.2 Identifying Specific Hazards

The geotechnical review required by
SAF-MHS-01 Underground Ground Control
shall include consideration of hazards involving
uncontrolled mass movement of material.

A geotechnical investigation shall be conducted
prior to drilling any permanent raise and a risk
assessment conducted using the results of the
investigation.

The exact location of inaccessible workings or
suspected voids in the vicinity of an open pit or
underground mine shall be confirmed by drilling
or other appropriate means before developing
towards them.4

Where there is an identified risk of uncontrolled
mass movement of material, the accumulated
void volume shall be determined regularly.
Controls shall be implemented to ensure such
mass movement into the void cannot lead to
damaging airblasts.

In caving operations there shall be documented
mining processes detailing the rate of draw,
 bogging at drawpoints, and reporting of voids.
The process ensure that voids do not exceed
manageable volumes.

All documented processes and procedures
shall be reviewed annually or following an
incident or change of scope.

The safe distance normal mining operations
and infrastructure development may approach a
suspected inrush, subsidence or airblast hazard
shall be rigorously analysed and reviewed by a
competent external expert. A Safe Work Plan
shall clearly describe actions to be followed
when working within this distance.

All development and accessible stope
excavations shall be surveyed and recorded on
mine plans before access is lost.

No open pit or underground excavation work
may commence without an approved work plan
(for guidance see SAF-MHS-01 Underground
Ground Control).

5.3 Inspection and Monitoring

Frequent inspection and monitoring is required
for the early detection of potential failures, and
to facilitate timely intervention to minimise the
potential impact of failures on safety and
production.

An inspection and monitoring strategy shall be
developed by the mine planning and design
team to inspect critical elements associated
with potential inrush and subsidence hazards,
and to monitor lead indicators.

Control structures, barriers and water or mud
storage structures etc shall be monitored
frequently using visual inspection procedures
and/or monitoring instruments.

The functionality of any monitoring system shall
be verified to ensure that it can be easily
operated by mine personnel, it is independent
of any failure it is monitoring, and it provides
meaningful results which will allow the
prediction of incipient failure.

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4 For more information see ‘Guidelines on Open Pit Mining Through
Underground Workings’ published by the Western Australian
Department of Mines and Energy.
Changes in conditions shall be routinely monitored to ensure issues and hazards are identified and their potential assessed.

The monitoring results shall be reported to the Responsible Manager, who shall immediately implement isolation measures in the event that any result triggers a response requirement.

5.4 Fill Operations

A Mine Backfill Control Plan shall be developed prior to backfilling operations which shall consider:

a. Method of filling underground voids.

b. The construction and quality control of fill barricades or bulkheads (rearings).

c. The specification and quality control of backfill quality e.g. hydraulic fill.

d. Operational aspects of water and fill retaining facilities – hang-ups, arching etc.

e. Drainage of fill – piping, overloading, liquefaction etc.

f. Monitoring performance relative to design – structural, seismic, blast damage, materials etc.

g. Inspection of barricades and other structures – drainage rates, signs of failure (cracking etc), water balance (quantity of bleed etc).

h. Skills and training requirements.

i. Risk assessments of backfill operations and associated activities.

Unconsolidated fill shall not be used behind lagging or barriers in or adjacent to shafts or raises.

Fill barricades will be designed and constructed to contain unconsolidated stope fill.

5.5 Underground Mine Water Control Plan

The Mine Water Control Plan for an underground operation shall also include consideration of:

a. Cover drilling for water.

b. Drilling through stand pipes and stop cocks.

c. Drilling through an aquifer from or into underground workings.

d. Grouting of drill holes.

e. Capping of surface drill holes.

f. Flow measurement.

g. Drainage and service network design and operation.

h. Start-up and shut-down requirements of water and tailings transfer systems.

i. Maintenance and monitoring requirements of water and tailings dams, underground stored water, pumps etc.

j. Contingency plans for dealing with high inflows, flooding and pump failure.

k. Ventilation effects from stagnant or inflowing water.

l. Monitoring requirements, frequencies and reporting.

m. Safe work procedures for any backfill related activity for which a standard safe work procedure does not exist.

5.6 Training

All relevant mining personnel shall be made aware of the possible circumstances and consequences of uncontrolled mass movement of material. Factual examples may elicit the best response.

5.7 Modifications

Modifications that alter the current approved mining method or process shall be subject to a formal approval process that ensures identification and control of hazards involving uncontrolled mass movement of material. Significant modifications shall be submitted as information to the relevant corporate technical manager.

When the site sends or receives communication regarding experiences in uncontrolled mass movement of material this information shall be used to review existing processes and procedures.

6. Emergency Response Plan

Each site shall have an Emergency Response Plan that includes provisions for rescue and recovery of survivors following an uncontrolled mass movement of material.
Because of the nature of uncontrolled mass movement of material, fatalities may occur either in the initial event or as a consequence of having means of egress denied, or during rescue operations.

The primary strategy for the elimination of fatalities therefore needs to be based on the prevention of uncontrolled mass movement of material.

7. De-commissioning and Rehabilitation

Potential hazards involving mass movement of material shall be considered in the Mine Closure Plan.

All plans of decommissioned mining areas shall be appropriately stored for future use.

The geotechnical stability of all crown pillars, other major pillars, existing stope voids, dams, dumps, embankments etc shall be investigated and established prior to final de-commissioning and rehabilitation.

8. Audits and Reviews

8.1 MHS Implementation Audit

An implementation audit will be carried out by a suitably qualified mining geotechnical specialist.

The object of the audit is to check if there is an appropriate process, accepted risk level and confirmation of performance.

The implementation audit will be carried out using the Audit Protocol developed for this Standard.

Once the Standard has been satisfactorily implemented, the Site Manager is responsible for the continued implementation of the Standard and may arrange follow up internal or external audits as required.

8.2 Planning, Design, Operational and Closure Audits / Reviews

Sufficient internal and external reviews and audits shall be undertaken to ensure ongoing compliance with this Standard.

The frequency of reviews and the competence of the reviewer(s) shall be determined by the complexity of the issue under review.

Each review or audit shall close with a list of agreed scheduled actions, and each review or audit shall audit actions scheduled in the current Inrush and Subsidence Risk Register.
APPENDICES

A Definitions

None

B Related Documents

SAF-MHS-01 Underground Ground Control
SAF-MHS-16 Slope Stability
SAF-MHS-18 Underground Ventilation
SAF-MHS09-R01 Guidelines to the Inrushes and Subsidence Standard
SAF-MHS09-R02 Water Control Plan Proforma

C Revision Information

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