DRAFT

Code of Practice

INUNDATION AND INRUSH HAZARD MANAGEMENT

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CODE OF PRACTICE

INUNDATION AND INRUSH HAZARD MANAGEMENT

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FOREWORD

This Code of Practice on inundation and inrush hazard management is an approved code of practice under section 274 of the *Work Health and Safety Act* (the WHS Act).

An approved code of practice is a practical guide to achieving the standards of health, safety and welfare required under the WHS Act and the Work Health and Safety Regulations (the WHS Regulations).

A code of practice applies to anyone who has a duty of care in the circumstances described in the code. In most cases, following an approved code of practice would achieve compliance with the health and safety duties in the WHS Act, in relation to the subject matter of the code. Like regulations, codes of practice deal with particular issues and do not cover all hazards or risks which may arise. The health and safety duties require duty holders to consider all risks associated with work, not only those for which regulations and codes of practice exist.

Codes of practice are admissible in court proceedings under the WHS Act and Regulations. Courts may regard a code of practice as evidence of what is known about a hazard, risk or control and may rely on the code in determining what is reasonably practicable in the circumstances to which the code relates.

Compliance with the WHS Act and Regulations may be achieved by following another method, such as a technical or an industry standard, if it provides an equivalent or higher standard of work health and safety than the code.

An inspector may refer to an approved code of practice when issuing an improvement or prohibition notice.

This Code has been developed by Safe Work Australia in conjunction with the National Mine Safety Framework Steering Group as a model code of practice under the Council of Australian Governments' *Inter-Governmental Agreement for Regulatory and Operational Reform in Occupational Health and Safety* for adoption by the Commonwealth, state and territory governments.

A draft of this Code of Practice was released for public consultation on [*to be completed*] and was endorsed by the Select Council on Workplace Relations on [*to be completed*].

SCOPE AND APPLICATION

This Code provides practical guidance to assist the mine operator to develop and implement a principal mining hazard management plan for inundation and inrush including those related to undersea workings. Outburst hazards are not included in the definition of inrush hazards and are the subject of a separate principal mining hazard management plan.

Who should use this code?

You should use this Code if you are a person conducting a business or undertaking and manage the risks associated with inundation and inrush. This Code can be used by workers and health and safety representatives who need to understand the risks associated with inundation and inrush.

How to use this code of practice

This Code includes references to both mandatory and non-mandatory actions. The references to legal requirements contained in the WHS Act and Regulations (highlighted in text boxes in this Code) are not exhaustive and are included for context only.

The words 'must', 'requires' or 'mandatory' indicate that legal requirements exist, which must be complied with. The word 'should' indicates a recommended course of action, while 'may' indicates an optional course of action.

1. INTRODUCTION

1.1 What is inundation and inrush?

Inundation or inrush is an ingress of liquid, gas or other substance with the potential to create an emergency situation and create a risk to health and safety of mine workers.

An inundation or inrush hazard involves the existence of the following:

- significant quantities of water or other fluid material
- any material that flows when wet
- flammable or toxic gases held under pressure in strata (as determined by application of the GHS or dangerous goods classification)
- backfilling, ore passes or hydraulic filled stopes
- unstable ground or strata that has the potential for an airblast or windblast
- water storage dams, tailings dams or waste dumps, and
- open pit slopes or hills.

These hazards can be pressurised and swiftly flow or release into or within a mine.

1.2 Who has duties relating to inundation and inrush?

Under the WHS Act, all persons who conduct a business or undertaking have a duty of care to ensure, so far as is reasonably practicable, that workers and other persons are not put at risk from work carried out as part of the business or undertaking.

The WHS Regulations identifies inundation and inrush as a principal mining hazard. To effectively control the risks, the mine operator must follow a *risk management process* and prepare and implement a hazard management plan which is included in the work health and safety management system (WHSMS).

The hazard management plan must always implement the best available knowledge, for example, the use of a Trigger Action Response Plan (TARP). ***Appendix A*** provides an example of a TARP for potential water inrush, mud rush or airblast.

It should also define a review and audit framework that considers the following:

- have an independent expert review the plan
- carry out a full audit of the system to check compliance and take required action
- investigate any event either causing inundation or inrush or having the potential to cause inundation or inrush
- regularly review the plan to ensure it is correct and relevant to the hazard, and
- review the system if drilling or other information indicates any of the significant assumptions about the inrush hazards are incorrect.

The hazard management plan should be reviewed and revised before the mine is extended into any new area ensuring that an inrush control zone identified in the hazard management plan:

- is of sufficient thickness to safely separate the mine workings from the relevant potential source of inrush, or
- is sufficient to provide a separation of 50 metres of solid rock between the mine workings and the assessed worst case position of the potential source of inrush if a potential source of inrush that is not an accessible place in the same mine

This Code provides guidance to help the mine operator meet these duties. General guidance on the risk management process is available in the *Code of Practice: How to*

Manage Work Health and Safety Risks. Further guidance to develop a WHSMS is available in the *Code of Practice: Work Health and Safety Management System*.

Consultation

When managing risks, the mine operator must consult with workers and other persons at the mine including other persons conducting a business or undertaking. Further guidance on consultation, cooperation and coordination can be found in the *Code of Practice: Work Health and Safety Consultation, Co-operation and Co-ordination.*

2. IDENTIFYING HAZARDS

There are a number of ways to identify hazards at the mine. Some of these include:

- consulting with workers at the mine as they can provide valuable information about potential hazards.
- conducting a visual inspection of the mine focussing on inundation and inrush
- reviewing available information including incident records and accident reports, and
- reviewing mine survey plans.

Trends or common problems can be identified from the information collected and may show that locations or areas that are more hazardous. It could indicate a problem with the design and layout of that work area or the way work is a carried out there. These trends may help in deciding which areas to address as a priority.

The location of some hazards including water and tailings dams and disused workings will be shown on the survey plan prepared for the mine. Users should always verify historical material by making and relying upon their own separate inquiries prior to making any important decisions or taking any action on the basis of this information.

2.1 Sources of inrush

Potential sources of inrush should be identified on mine survey plans. An inrush can arise from the following sources.

- the working seam in a coal mine or the area being mined in any other mine
- other seams or strata or limestone voids that hold water
- old workings
- raisebore shafts or holes
- unstable strata or ground unravelling
- bulkhead or barricade failure
- connection to the surface
- other non-mining, man-made structures, and
- may involve any combination of the list above.

Mine survey plans are key sources of information for many inrush hazards. There are two types of typical plan errors that should be considered, errors in information about other old or current workings and errors in your own workings information.

Sources of inrush for the working seam or area being mined

The following inrush hazards should be considered in the seam being mined or the area being mined in any other mine:

- abandoned mines
- workings of adjacent current mines, and
- existing workings of your own mine.

<u>Abandoned mines</u>

Inrush hazards from abandoned mines include:

- an old adjacent underground mine, not on the current lease
- an abandoned mine where the barrier or barricade has been breached and/or subsequently plugged
- a mine on the lease, abandoned before or since acquisition of the current lease,
- an abandoned adjacent surface mine, on or off the lease
- abandoned single or multiple seam high wall coal mining operations of an adjacent open cut mine, or
- an adjacent underground mine with incorrect seam or mine workings correlation.

These hazards can exist in recorded or unrecorded workings.

Current mines

Inrush hazards from workings of adjacent current mines include:

- goaf or other inaccessible areas of an adjacent coal or other mine
- areas of accumulated water or liquid materials in accessible or inaccessible areas
- hydraulic and paste fill operations
- high wall mining operations of an adjacent open cut mine, or
- a discontinued part of an adjacent open cut mine.

These hazards can exist in recorded or unrecorded workings.

Existing workings of your own mine

Inrush hazards from existing workings of your own mine include:

- goaf in a coal mine or other inaccessible areas of the mine
- areas of accumulated water or liquid materials in accessible areas
- hydraulic and paste fill operations
- impoundment areas including dams
- unrecorded roadways or drivages, or
- other openings such as shafts, drift and decline sumps.

Sources from other seams or strata, orebodies or ground either above or below the working horizon

Inrush hazards from other strata or ground include:

- aquifers, buried channels and other natural sources of ground water,
- workings above or below the mining horizon or mine workings on the same lease, or
- workings above or below the mining horizon or mine workings in an adjacent mine,
- including an overlapping lease.

These hazards can be affected by faults, geological structures, bore wells, exploration or blast drill holes, drainage holes or shafts, rises or ore passes acting as conduits.

Sources from the surface

Inrush and inundation hazards from the surface include:

- tidal waters, oceans and connections to the ocean
- surface creeks, rivers, ponds, lakes as well as potential flooding situations
- surface impoundments or reservoirs, or
- man made or natural unconsolidated material that could flow when wet, including emplacement areas, tailings dams and mine water dams.

These hazards can be affected by:

- faults and other geological structures
- active drainage holes acting as conduits
- rainfall using a 1-in-100 year event as a guide, including surface structures and other measures used to store or channel water, and
- permeability should also be considered.

Sources from man-made structures

Inrush hazards from man-made structures include

- exploration boreholes, water boreholes or gas drainage holes
- shafts, wells, raisebore shafts or holes

- pipelines, tunnels
- underground repositories, or
- quarries and other earthworks.

2.2 Identifying inundation or inrush hazards

Identification of inundation and inrush hazards involves a process of gathering and analysing information. This section contains flow charts illustrating potential steps for identification of the existence of an inrush hazard from the following sources:

- inrush hazards from abandoned mines
- current workings of an adjacent mine, and
- existing workings of your mine.

Following these charts are lists of actions for the remaining inrush sources:

- hazards in other seams or strata, orebodies or ground
- from the surface, and
- from non-mining man-made structures.

The option of drilling to confirm potential inrush hazards is included in some of the following charts where other means of clarifying uncertainty are not adequate. If you decide that drilling is required to confirm position and/or check for unsuspected sources of inrush the following information should be considered.

Scheme of protective drilling

Modern practice utilises survey controlled in-seam or targeted drilling of long holes or advance drilling of development headings (often 1km or longer) or from the working place through the orebody and into surrounding host rock. The holes are drilled through standpipes set in off-face drives or protected cuddies. These holes can be used to identify suspected workings by direct holing out or proving the ground to be free of unrecorded workings.

Note: It is not appropriate to use past practice of small diameter, limited length boreholes drilled directly from the working face either by hand held or small portable drill rigs when approaching potential inrush sources. Typically these holes are not drilled through standpipes. Sealing, if to occur at all, was by hammered in timber plugs. In any working place it is necessary to drill through adequately rated standpipes to ensure positive control of any inrush source.

The scheme of protective drilling should:

- take into account the actual or possible pressure, volume, toxicity or explosive potential of the fluid material being drilled towards
- include protection against the uncontrolled release of water or gas and employ methods to permanently fill and seal drill holes if the need arises, and
- provide appropriate training for persons involved in giving effect to the scheme.

Note: an important principle of risk management involves erring on the conservative side when considering principal hazards. If you are not reasonably certain an inrush hazard does not exist, then manage as if the hazard does exist.

2.3 Identifying the existence of inundation and inrush hazards

There are several types of sources of inrush hazards from other seams or strata, above or below the working coal seam or mine workings. In order to look for aquifers, buried channels and other sources of natural water, the following should occur:

- check mine history, including mine exploration and development phase
- check if any hydrology surveys are available for the area, and

- consider known faults, geological structures, boreholes and drainage holes, which may act as conduits.

Consider water sources both above and below the working seam or mine workings.

If no hazard is identified, document the basis for the decision that was made.

If an inrush hazard in a coal seam or strata above or below the working seam or mine workings has been identified, determine the safety barrier or barriers and the necessary monitoring arrangements.

Integrate the information into the current mine plan with appropriate control zone.

Appendix B provides three flowcharts outline the processes to identify hazards associated with inundation and inrush:

- Flow chart 1 – identifying an inrush hazard from an abandoned mine
- Flow chart 2 – identifying an inrush hazard from another adjacent mine, and
- Flow chart 3 – identifying an inrush hazard from your own mine.

The existence of inrush and inundation hazards from the surface can be identified. All of these hazards should be accessible and definable including 1 in 100 year rainfall or storm events. To do this, establish the solid rock head between the surface water or materials and evaluate the impact of the mining method to determine the septum.

If no hazard is identified, document the reasoning. If an inrush hazard from the surface has been identified, assess the risks and if appropriate determine controls before proceeding with mining.

The existence of inrush and inundation hazards from the non mining and man-made structures can be identified. In order to look for these types of inrush hazards and their possible magnitude go to local public authorities, for example, water, sewage, electrical supply authorities.

2.4 Identifying the magnitude of inundation and inrush hazards

It is critical that the existence of hazard is not only identified but the magnitude is also identified. The magnitude of a hazard is the size, nature, energy content and description of the mechanism by which it might manifest. Establishing the magnitude involves erring on the conservative side. Assume the maximum potential if the area is not accessible or there is reasonable uncertainty of the magnitude. Maximum potential means the worst case considering maximum volume, impurity, pressure.

The area should be accessed to identify:

- the nature of the hazard (water, gas and/or materials)
- the volume and relative level in relation to the mine operations, and
- estimate the pressure.

If the area is not accessible either:

- drill into the area (note: apply drilling precautions for pressure release), or
- assume the worst case, for example, a worst case situation might be flooding to the water table with water and dissolved gases - estimate the volume and pressure in the worst case condition.

For hazards from the surface or other inrush hazards affected by weather, identify at least the 1-in-100 year flood event levels.

As an example, water-filled old workings might be identified as a relevant inrush hazard. Before assessing the risks, the following should be identified:

- the amount of water in the workings
- the purity and contents of the water
- the pressure, and
- possible pathways that might exist between the water and the mine workings.

2.5 Documenting the inundation and inrush hazards

If no hazard is identified, the reasoning must be documented. If an inrush hazard from a non mining, man-made structure has been identified, the safety barrier must be determined. All information should be integrated into the current mine plan with appropriate control zone.

3. ASSESSING THE RISKS

Regulation 9.2.11 of the WHS Regulations require that when conducting a risk assessment for the purposes of preparing a principal mining hazard management plan, the mine operator must use investigation and analysis methods that are appropriate to the principal hazard being considered. The mine operator must also consider the principal mining hazard individually as well as cumulatively with other hazards at the mine.

The risk assessment must:

- state the likelihood of the principal mining hazard causing or contributing to any harm to the health and safety of any person, and the severity of the harm
- describe the investigation and analysis methods used in the assessment
- describe all control measures considered to control risks associated with the principal mining hazard, and
- state reasons for deciding which risk control measure to implement.

3.1 Factors to consider

Assessing the risks will help the mine operator take the correct action to eliminate the risk or where this is not reasonably practicable, minimise the risks from inundation or inrush hazards. When undertaking a risk assessment to determine control measures, the following factors as outlined in Schedule 9.2 of the WHS Regulations must be considered:

- the potential sources of inundation including extreme weather, overflow or failure of levies and dam structures, failure or blocking of flow channels (either regular, overflow or emergency)
- the potential sources of inrush including current, disused or abandoned mine workings along the same seam or across strata, surface water bodies, backfill operations, highly permeable aquifers, bore holes, faults or other geographical weaknesses
- the potential for the accumulation of water, gas or other materials that could liquefy or flow into other workings or locations
- the magnitude of all potential sources and maximum flow rates, and
- the worst case scenarios for each potential source especially including the accuracy of plans of other workings, variation in rock properties, geological weaknesses or similar unknowns.

The risk assessment should be undertaken with a team of competent persons. The team should include workers and possibly an external expert. The process should also include the viewing of any relevant plans, files or other materials held by the Regulator.

3.2 Documenting the risk assessment

The inrush risk assessment and/or inundation risk assessment should be documented. The following should be included in the assessment as a minimum:

- identification of all possible significant inrush and inundaton hazards
- identification of the nature and magnitude of the identified inrush or inundation hazard (if not clear the exercise should define assumed hazard, rationale and basis for assumption, including methods/information used to investigate the hazard)
- identification of specific loss scenarios for all inrush/inundation hazards considering planned or expected mining operations that will be affected or that will affect the hazard
- assessment of risks considering conservative probabilities and reasoned worst case position, including single or multi-fatality consequences
- prevention - controls to prevent an inrush or inundation event
- monitoring - controls to monitor status of inrush/inundation hazard to identify changes

- first response - controls to respond to an inrush or inundation event in the early stages
- emergency response - controls to respond to a principal inrush event
- documentation of the above information, and
- conversion of the risk assessment results into a useful mine inundation and inrush management plan.

If the mine operator is of an opinion as to whether or not it is reasonably practicable to remove or render harmless each identified potential source of inundation or inrush or of the opinion that it is not reasonably practicable to remove or render harmless a potential source of inundation or inrush, the documentation should state the reasons for being of that opinion and the retention of that document at the mine including:

- an objective summary of the nature and magnitude of the identified risks of inundation or inrush
- the measures to be taken to prevent inundation or inrushes
- the identification and maintenance of inrush control zones between the mine workings and each identified potential source of inrush
- any special systems of working developed for mining and working in inrush control zones, and
- any assumptions made in the development of measures to prevent inundation or inrushes.

The risk assessment is not the inundation and inrush management plan for the mine, however, it should be referenced in the WHSMS and also possibly placed in its appendices.

4. CONTROLLING THE RISKS

Control measures or prevention controls are intended to avoid an inrush or inundation event by reducing its risk level or likelihood and severity. There is an accepted approach to determining the type of prevention control that is most effective for any unacceptable risk. This approach involves five types of controls (from most effective to least effective):

- eliminate the hazard by removing the damaging energy (for example, water, materials)
- minimise the magnitude of the hazard (for example, less water, less pressure)
- minimise the likelihood of the event through engineering or "hard" barriers
- minimise the likelihood of the event through procedural or "soft" barriers, or
- minimise likelihood through warnings.

Note: The use of the last 2 soft controls alone are not considered to be adequate for principal hazards.

4.1 Consideration of control measures

Consideration of controls should include but not limited to reviewing the following issues. The following are examples of controls intended to assist in choosing an appropriate control measure for the specific situation.

Note: Some have almost exactly the same issues mentioned and therefore could be combined to minimise the redundancy.

Draining to remove inrush hazard
Draining or otherwise removing the inrush hazard is clearly the most effect way to prevent inrush. This option is strongly recommended. If not drained, the mine operator who decides that it is not practical to drain or otherwise remove an inrush hazard should document the reasons for forming that opinion. This information should be included in the risk assessment document.

Prevention of water build up above raisebore cuttings by draining water is essential. This is done by drilling drain holes into raisebore shafts, so that if the cuttings build up to above the brow, water can still drain away. However, further controls may have to be in place, such as tele-remote bogging capability to reduce the risk of an inrush of water and mud if the water build up has developed more than the drainage capacity is capable of handling.

Inrush controls in the seam or work area being mined
For inrush hazards in a coal seam or work area being mined such as abandoned mines, workings of adjacent current mines or existing workings of your own mine, or a body of water in a limestone cavity alongside a mine, then consider the following controls:

- draining old workings (including ventilating where appropriate) or limestone cavities and installing dams, seals, plugs
- establishing and maintaining a solid coal or rock barrier of at least 50 metres (or further) between the workplace and the assessed worst case position
- ensuring ground support is sufficient in wet ground conditions that may exist between the work area being mined and any body of water, and
- assessing risks, designing and justifying any plan to work within the 50 metre solid coal or rock barrier which then becomes the control zone.

Inrush hazards in other coal seams or strata
For hazards in other coal seams, strata or ground consider the following controls:

- draining off the hazard

- plugging or otherwise isolating shafts, drifts, staples, raises, winzes, boreholes and other mining connections
- sealing or otherwise isolating potential geological conduits with grout and/or good ground support and/or other measures
- maintaining a barrier of at least 50 metres or further of solid strata or ground between the workplace and the assessed worst case position after risk assessing all aspects of the situation, and
- assessing risks, designing and justifying any mine plan to work within the 50 metre solid strata barrier which then becomes the control zone.

Hazards from the surface

For hazards from the surface consider the following controls:

- draining or diverting hazards, where appropriate
- isolating surface openings, including subsidence cracks and other types of fissures, from potential water inrush, including a consideration of estimated 1 in 100 year flood heights and monitoring procedures during flooding periods
- sealing or otherwise isolating potential geological conduits
- sealing or otherwise isolating potential man-made conduits such as boreholes
- maintaining adequate thickness of solid strata or ground of at least 50 metres or more between the workplace and the assessed worst case position after risk assessing all aspects of the situation, and
- assessing risks, designing and justifying any mine plan to work within the 50 metre solid barrier which becomes the control zone.

Non mining, man-made hazards

For hazards from non mining man-made hazards consider the following controls:

- draining, where appropriate
- detection and isolation of man-made potential conduits
- sealing or otherwise isolating potential geological conduits
- maintaining adequate thickness of solid strata of at least 50 metres or more between the workplace and the assessed worst case position after risk assessing all aspects of the situation, and
- assessing risks, designing and justifying any plan to work within the 50 metre solid barrier which is to become the control zone.

Drainage Systems

Where appropriate, design effective drainage systems taking into account factors including:

- volume to be drained
- timeframe for drainage with respect to mining scheduling and meeting environmental standards
- in case of draining water, the potential hazard arising from the release of dissolved gases particularly carbon dioxide (CO_2), or the capture of oxygen by the water, and the dropping of atmospheric oxygen concentrations to unsafe levels
- the hazard potential of residual water or other fluid after the drainage
- the need for an adequate standpipe design for underground de-watering
- the need for adequate and appropriately placed sump or water standage for underground de-watering and gas monitoring, and
- the need for supplementary ventilation when draining gas or water containing dissolved gases.

Adequacy of the 50m barrier
Where relevant for the above hazards, decide whether a minimum 50 metre barrier is adequate taking into account factors including:

- pressure, quantity and nature of the hazard
- long term stability of the barrier under worst case natural and induced stress regimes
- rock mass strength, rock quality designation, rock mass quality, rock mass rating and geological strength index
- presence of geological weaknesses likely to affect the barrier
- nature of the roof and floor contacts
- seam and strata permeability, and
- seam grade or dip.

Confirm that the barrier size meets the design width by systematically drilling, supplemented where appropriate by geophysical and geochemical techniques.

Any drilling strategy or other method for confirming barrier size should also be designed to detect major survey errors in plans of old workings or the presence of unrecorded workings.

The inrush risk assessment may identify a possible requirement to work inside the 50metre inrush control zone.

This includes the possibility of developing and applying a "special system of working". If such a system is to be developed, a risk assessment on that system should be used for derivation or draft review.

Note: The system should include a Scheme of Protective Drilling if the potential inrush source is in the same horizon. Other controls are probing with drill holes, monitoring and alarms.

4.2 Trigger action response plan

A trigger action response plan (TARP) is a useful management tool that summarises the overall monitoring arrangements but also adds the actions developed when certain triggers are reached. It should be developed after deciding on the monitoring controls.

The overall advantage of developing a TARP is that it provides a summary of the considered and planned early responses if monitoring has indicated that a trend is occurring towards unacceptable levels of risk of a major inrush occurring. The many advantages of developing a TARP is that it:

- clearly summarises the overall system for controlling and preventing an inrush or inundation from occurring in the mine
- summarises the inrush and inundation hazards within the mine which can make a more effective review particularly if other hazards begin to emerge and interact with each other
- summarises the proposed monitoring and the systematic approach that is required to monitor and prevent an inundation or inrush
- provides for a system that can indicate early trends of changes in risk levels associated with an inundation or inrush
- provides for early and well considered responses if the risk levels become unacceptable. The main advantage of this is that the hazard is always under control and therefore prevents the possibility of an inrush from occurring

- summarises actions that have been well planned and require implementation when specific circumstances occur. These circumstances are generally well before any situation worsens and when risk levels become unacceptable
- summarises each planned action or additional control or monitoring that has been researched and determined from a tangible and scientific basis and not merely from an opinion based only on experience
- enables corporate memory to be continuous despite changes in management. The TARP remains a live document and the planned responses and actions as summarised within the table are known by management to be documented for sound reasons previously researched
- may provide a notification system with the Regulator that is agreed upon and may be over and above legislation requirements. This enables the Regulator to be kept informed of trends developing and the actions being implemented well before a situation becomes unmanageable
- clearly summarises the overall system for managing inundation and inrush hazards which can then be reviewed cooperatively on a regular basis by the Regulator to ensure there is continual vigilance in managing such hazards and new inundation or inrush hazards that are identified early and also form part of the TARP. The Regulator provides an independent review that would assist the mine operator to meet their legislative duty, and
- provides better control of inundation and inrush hazards and increases confidence that the mine is safe from any inrush incident occurring.

Note: Inrush hazards in the TARP are those that could result in multiple fatalities, and hazards that would require monitoring of conditions for any changes that may lead to a major incident. It does not include hazards that do not require monitoring if simply hard barriers would be sufficient to control the inrush hazard and regular monitoring of this hard barrier is unnecessary.

Appendix A provides an example of a TARP.

5. MINING UNDER THE SEA AND OTHER LARGE WATER BODIES

Mining under the sea and other large water bodies, including lakes, waters impounded by dams, estuaries and large rivers, represents a special risk since:

- the potential inundation/inrush source is, for all practical terms, inexhaustible, and
- in the event that connection between the mine and the sea or water body is made, the control of the inflow of water into the workings is likely to prove impossible and the entire mine could be lost permanently.

The critical issue to be addressed in under water mining is to establish the minimum thickness of solid strata that should exist between the seam roof and the floor of the water body to ensure no connection can develop.

The minimum thickness of solid strata necessary to prevent connection between the mine and the water body will vary from mine to mine and should be determined in every instance. The following factors should be assessed.

- mining method
- geological anomalies
- Mining height, and
- roof strata type.

5.1 Mining method

Any underground excavation may influence the permeability of strata lying over that excavation. In general, the wider the excavation the greater the height of deformation or softening that will occur in the roof rock. Deformation (which results from the overlying strata's tendency to deflect or sag into the excavation), will increase the roof strata's permeability.

In first workings, if roadways are adequately supported, the height of deformation may be measured in metres. However, should a fall occur particularly at an intersection, then the height of deformation is substantially increased.

Note: Although this Code deals only with first workings, i.e. development the following information has been included for second workings, i.e. extraction and production.

In second workings, for instance where goaf or back caving may or will occur, the height of roof deformation is extended even further. In this instance it is important to note that the height of deformation extends well beyond goafing height. For this reason, considerably greater solid strata will be required above second workings when compared to first workings.

Additionally in second workings, the impact of surface and sub-surface subsidence should be considered. Extensive cracking in surface and near surface rocks can be associated with mining induced subsidence. The minimum solid strata designed for should ensure that areas of surface/near surface cracking and the zone of deformation above the seam roof never intersect. To achieve this result in practice, an appropriate safety margin should be included within the designed minimum solid ground or strata thickness. Therefore a substantial zone of impermeable rock must exist between the workings and the rockhead.

5.2 Geological anomalies

Any assessment of the height of deformation above the workings and the depth of cracking below the rockhead can be adversely affected by geological anomalies.

Features can link the zone of deformation above the goaf or stope and zone of surface cracking thus negating the zone of impermeable strata created by the design process, for example, faults, dykes, shear zones, igneous plugs. If this link occurs, water from the sea or other surface water body may enter the mine.

A diligent search for geological features capable of linking the rockhead and the workings is required and if found a conservative estimate of their influence should be made. Where such geological features exist mining design within the zone of influence of the anomaly may have to be revisited or possibly abandoned.

5.3 Mining height

In secondary workings the height of extraction will influence both the height of deformation above the workings and also the level of surface subsidence. In general, the greater the extracted height, the greater the level of surface subsidence and height of roof deformation. Minimum solid strata or level thickness should be adjusted accordingly. It should be borne in mind that both pillar strength and stiffness (for a given pillar area), will decrease as the height of the pillar increases. In coal mines thick seam pillars are more likely to compress than those in thinner seams. This greater level of compression may adversely influence strata deformation and permeability above thick coal seam pillars.

5.4 Roof rock type

Typically, laminated strata is more likely to extend the height of deformation than is more massive ground. "Chimney" type falls are generally associated with laminated strata and instances of such falls extending at least 20m above the seam have been documented in first workings roadways.

5.5 Notes of caution

Once a minimum thickness of solid rock has been selected, it is essential that the exact reduced levels of the rockhead under the waterbody and the roof of the horizon be determined to ensure that the minimum design thickness of solid rock does in fact exist. The order of accuracy of any method used to determine the reduced levels should be established and applied conservatively to the value of solid rock measured.

The erosive capacity of water driven by a permanent and substantial pressure head is strong and constant. The capacity of water to scour joints, cracks, etc, has been long established in dam engineering. Any contemplation that a minor inflow of water directly from the sea or other like water body is acceptable should be dismissed immediately and action taken to secure the area affected or abandon and seal it safely.

Caution needs to be exercised when assessing standards for mining under the sea and other large surface water bodies that have been developed in foreign countries. Such standards (for example the United Kingdom Code of Practice), are based upon the nature of strata and ground conditions existing in those countries and may not be appropriate for conditions prevailing in Australia.

6. REVIEWING AND MONITORING CONTROLS

Reviewing controls

It is important to monitor risks and check the control measures to ensure they remain effective. Regulation 9.2.4 of the WHS Regulations requires a review of the control measures to be undertaken whenever there are any changes associated with inundation and inrush.

In undertaking the review, workers and their health and safety representatives must be consulted and the following questions be considered:

- Are the control measures working effectively in both their design and operation?
- How effective is the risk assessment process? Are all hazards being identified?
- Are workers actively involved in the risk management process? Are they openly raising health and safety concerns and reporting problems promptly?
- Have new work methods or new equipment made the job safer?
- Are safety procedures being followed?
- Has instruction and training provided to workers been successful?
- If new legislation or new information becomes available, does it indicate current controls may no longer be the most effective?

If problems are found, go back to any point in the risk management process, review the information and make further decisions about risk control.

Monitoring controls

Monitoring controls are intended to avoid an inundation or inrush event by identifying any indication of potential problems, including changes to the hazard, hazard-related conditions or effectiveness of controls.

There are different ways of monitoring principal hazards including:

- monitoring the status of the hazard
- monitoring the mechanisms by which the unwanted event occurs, or
- monitoring adherence to key controls.

One or more of these ways may suit a specific inundation or inrush hazard.

Examples of monitoring controls for the various types of inrush hazard whether in-seam, other seam or strata, surface or non-mining man made hazards include:

- monitoring (if accessible) the volume of water for unexpected changes
- monitoring the volume, on both an absolute and relative basis, and quality of water entering the mine in relevant areas
- checking for unrecorded or incorrectly recorded inrush sources with a scheme of protective drilling
- workers and statutory officials monitoring for relevant underground conditions that may indicate possible proximity to an inrush hazard or a potential inrush event. This will include reporting and analysing of the information, and
- monitoring status and condition of barriers and other key controls to ensure that their integrity is not compromised and they remain effective.

Note: Chemical fingerprinting of hazard water for comparison purposes may help to monitor hazard status, as well as identify the nature of a problem.

7. CONTROLS FOR THE FIRST RESPONSE (MITIGATION)

First response controls are intended to reduce the consequences of an inundation or inrush event by controlling the event in its early stages when the immediate impacts are still minor. This section provides advice in this area of inundation and inrush hazard management.

7.1 Early stage indications

Indications of an early stage of inundation or inrush might include the following:

- obvious changes in water make in the mine workings or at fill barricades in metal mines
- abnormal or unusual coal strata behaviour such as coal roof, face or side deformation or changes in ground water and ground conditions in metal mines
- change in water quality, i.e. colour, suspended solids, chemical analysis
- loss of or damage to inrush barriers or fill barricades and ground conditions around those barricades, and
- significant unexpected decrease in surface or other hazard water.

7.2 Trigger levels

First response controls can be 'trigger' levels built into the monitoring systems mentioned in the previous section. Following are examples of that approach.

- Pre-set alarm levels for water volume monitors (if the water hazard is accessible)
- Pre-set litres / minute flow rate triggers for evacuation of the area until the event has been investigated and the area deemed safe.
- Pre-determined conditions or sets of conditions, including barrier problems, for physical inspection and monitoring that require immediate evacuation of the area.

7.3 Response

For every trigger there should be a well documented and rehearsed action plan that follows. These should have defined minimum response times. Some may be immediate evacuation.

It is important to clearly define the circumstances by which persons should be removed from an area that might be affected by inrush.

A conservative approach is best, especially if the nature and the magnitude of the hazard is not clear or readily discernible.

An example response to potential inrush warnings might involve steps including:

- discontinue production or extension of workings in the affected area until such time as the hazard has been precisely determined and eliminated or otherwise controlled
- inform personnel and prepare to apply the emergency management system
- consider the locations of personnel and the possible inrush event; if necessary move personnel to a safe location
- assess the nature of the inrush warning symptoms, position(s) and direction(s) of any inflow(s) for example seepage through the coal seam or strata above or below the seam; water / gas issuing from conduits, for example, boreholes, fissures, faults.
- seal, as far as practicable, potential conduits, for example, boreholes, joint sets and shear zones, in the affected zone, and
- notify the Regulator, industry check inspector (where applicable), health and safety representative, site mine rescue team and the mines rescue station (where

available) if the situation warrants this notification or according to agreed arrangements.

7.4 Other considerations

Consider further activities to address the situation, for example:

- Acquire additional expertise to assist with determination and control of the situation.
- Determine flow rates of water / gas influx and undertaking chemical analysis where indicated.
- Determine or otherwise estimating the worst case scenario regarding source, location, pressure and physical magnitude of the hazard.
- Check mine plans against the known, suspected or potential hazard.
- Determine practicality of draining the hazard or otherwise rendering it harmless.
- Prepare, where appropriate drainage infrastructure to help control the hazard, for instance sumps, pumps, drainage paths.
- Determine the location for and preparation of (where appropriate) foundations for bulkheads and dam walls.
- Monitor all intakes for inundation or inrush flows.

8. EMERGENCY RESPONSE

8.1 Emergency management plan information

Every mine with a potential inundation or inrush situation should have an Emergency Management Plan which includes information covering a principal inundation or inrush hazard. This information should be derived by considering the potential location, magnitude and nature of worst case inrush events, for example, CO_2, water, materials and mud. The system should include as appropriate, the following information:

- communication requirements,
- assembling underground to egress (if immediate egress not essential),
- egress routes,
- refuge locations should egress be blocked,
- use of transport considering inrush conditions,
- special equipment to assist in egress or rescue, etc.
- training of workers in the emergency management system requirements and regular exercises.

A conservative approach is best, especially if the nature and the magnitude of the worst case event is not clear.

8.2 Response to an inundation or inrush

An example response to a principal inundation or inrush event might include:

- Initiate the mine emergency management plan.
- Evacuate from the mine, or relevant part of the mine, all persons other than those essential for dealing with the emergency where deemed safe to do so.
- Consider the effect of the inrush event on mine systems such as ventilation and egress.
- Inform the relevant stakeholders and emergency support services.
- Where appropriate and when safe to do so, activate any pumping and drainage system installed at the first response stage or otherwise seek to contain the extent and effects of the inrush / inundation.
- Secure any relevant barricades, bulkheads or dam walls that may have been installed at the first response stage.

8.3 Other considerations

Consider further activities to minimise consequence and move toward recovery for example:

- Determining the likely timing, progression and extent of the inundation based on the available information and an assumed worst case scenario.
- Installing monitoring apparatus to enable remote recording of the status - progress and nature - of the inrush / inundation.
- Preparing mine plans showing likely development and extent of the inrush / inundation.
- Seeking to dissipate the energy of the hazard away from the active mine workings, for instance, diverting the hazard into disused workings that are suitably located and disposed.
- Informing and seeking cooperation of any neighbouring mine that might be affected by or have potential influence on the event.

9. ADDITIONAL INFORMATION TO SUPPLY WHEN WORKING WITHIN THE INRUSH CONTROL ZONE

9.1 Plans

The following plans are required at a scale of 1 in 4000.

- The proposed workings layout plan, paying particular attention to the location of barriers to be left against impounded waters.
- A depth of cover isopach plan.
- A solid rockhead depth of cover isopach plan (if relevant).
- A working thickness isopach plan.
- A working grade contour plan.
- A detailed geological structure plan, particularly in strata to be left as a barrier.
- A plan of relevant borehole logs of the strata above the workings to the surface, below the workings and the workings itself. Fine detail for the workings, strata or ground 50m above and 20m below will need to be provided. This should include the written log for these latter areas. Particular attention should be paid to rock that may degrade and/or change nature under the influence of moisture, pressure and flow. Consideration should be given to providing relevant cross sections for the area, linking several borelogs on the one plan.
- A plan showing surface features (if relevant, for example shorelines, the extent of surface impoundments or reservoirs etc).
- A plan showing other workings, including those in the same and adjacent horizons.

The proposed workings plan should be capable of being overlain on the other plans.

9.2 Data

The following data is required.

- Barrier dimension in metres. This measurement should be the minimum barrier dimension.
- Barrier mining height in metres. Dimensions here should be from either side of the barrier if they are not the same.
- The maximum credible pressure head that acts, or could act, upon the barrier in MPa.
- A conservative estimation of the volume of water in cubic metres held within the impoundment that could enter the mine should the barrier fail in any way.
- A discussion of the nature of mine strata or rock forming the barrier, for example, cindered, heavily sheared or structure affected.

APPENDIX A – EXAMPLE OF A TRIGGER ACTION RESPONSE PLAN

Trigger Action Response Plan for air inrush (airblast), mudrush or water inrush situations (from MDG1031 Guideline for Managing the Risk of an Airblast (NSW))

INRUSH HAZARD MONITORING & TRIGGER LEVELS AT A METAL MINE USING A CAVING METHOD						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE REGULATOR**	**COMMENT (Can be for corporate memory)**
Identify any voids within cave that could develop and allow conditions that potentially could result in an airblast	Bulking factor changes using (1) Open hole plumbing, (2) Fly-over surveying surface subsidence, (3) Volume calculations of surface subsidence	Quarterly	Bulking factor 1.24 to 1.30	Continuously track the trend. Should numbers deviate from 1.24 then seek outside expert's opinion to examine process and possible reasons for change as last four measurements have been 1.24.		Original estimate of caved muck pile = 1.30.
			Bulking factor +1.3 to 1.4	Identify the source of greater than historical bulking factor eg oxide products	When over 1.3 then notify Regulator of density.	
			Bulking factor 1.4 and more	Identify void space within the cave. If associated in-situ with material on the edge of the cave, then use hydro-fracturing or drill and blast techniques to break the in-situ material.	When over 1.4 notify Regulator with details of planned response.	
			Bulking factor +1.4	If the factor continues to rise above 1.4, then stop production until the void has been successfully caved.		

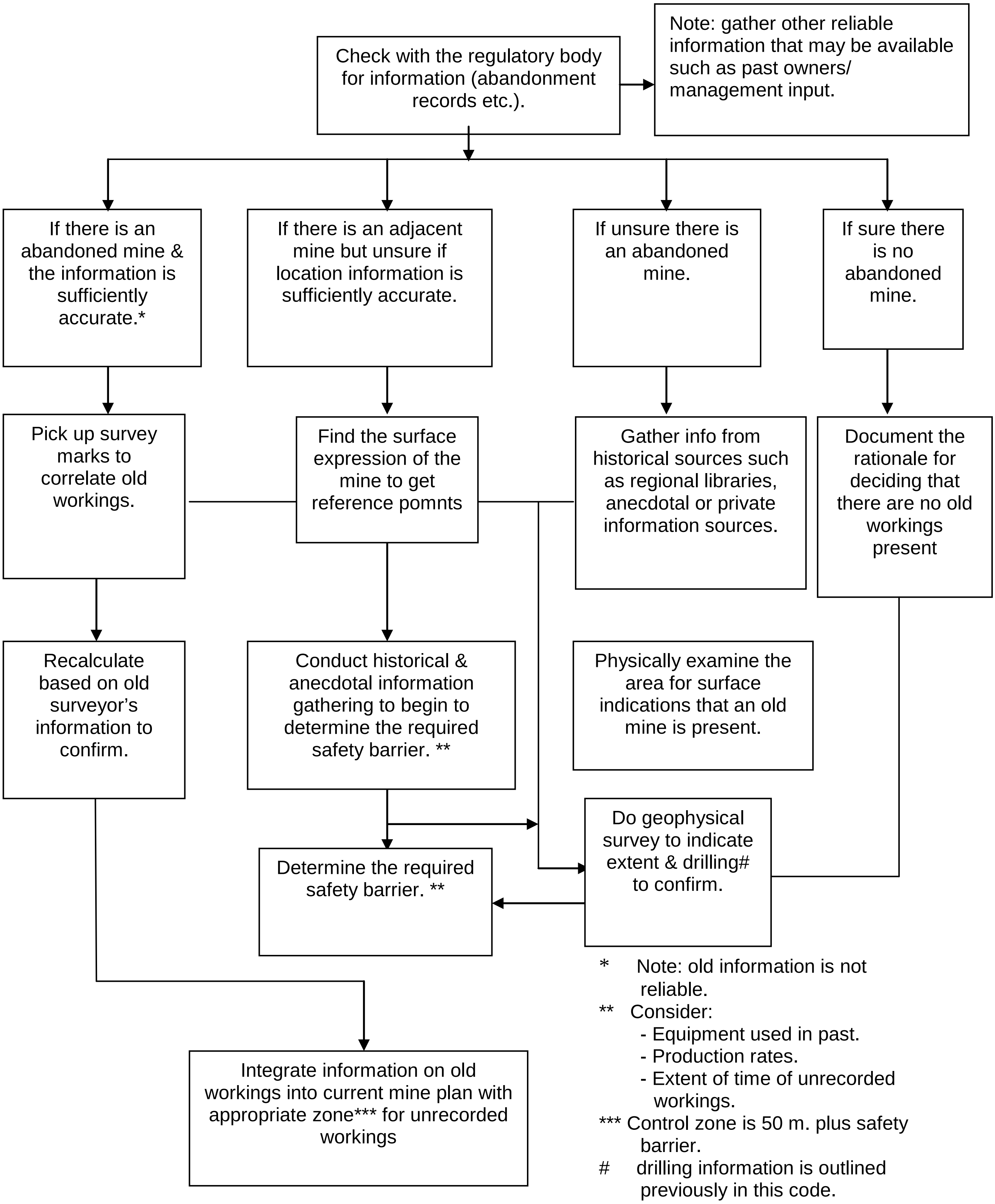
INRUSH HAZARD MONITORING & TRIGGER LEVELS AT A METAL MINE USING A CAVING METHOD						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE REGULATOR**	**COMMENT (Can be for corporate memory)**
Static load that could impact on main crown pillar	(1) Number of cracks in shotcrete	Monthly	Double the number of cracks in previous month.	Increase frequency of crack and convergence monitoring of the area to fortnightly reviews.		Measurement of width and position is also catalogued.
Static load that could impact on main crown pillar (cont.)	(2) Convergence modelling. Plotting of convergence trends – looking for acceleration in convergence. Hot / cold spot contouring.	Monthly	50 mm drive convergence in one month or total.	Increase monitoring frequency to fortnightly. Where shotcrete appears to have failed, inspection is to be made by Geotechnical engineer and repair identified where required		Over a 12 month period of reviews +/- 1mm on average per fortnight across the extraction level. Level responding to draw control plan. Monitoring of cracks ongoing. Any increase in cracking will result in increased monitoring. Note: However that fibrecrete becomes ineffective at deformations at this level.
Static load that could impact on main crown pillar (cont.)			200 mm drive convergence.	Barring down. Re-support with bolts, mesh and fibrecrete.	Notify Regulator when convergence reaches 200 mm.	200 mm has been recorded without structural support damage in other caving mines. Note: However that support tendons become ineffective at deformations of this level.

INRUSH HAZARD MONITORING & TRIGGER LEVELS AT A METAL MINE USING A CAVING METHOD						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE REGULATOR**	**COMMENT (Can be for corporate memory)**
Mud rush risk	(1) Shift supervisor inspections of drawpoints	Daily	Visual observation of suspected "damp" Drawpoints".	Inform line management of any concern and raise Hazard Report.	Nil	
Mud rush risk (cont.)	(2) Take sample from LHD bucket/s away from 'damp' drawpoint for fines and test for moisture content.	When hazard report is submitted.	Fine Damp or Fine Wet material present at drawpoint(s).	Remote loading procedures apply on fine damp and fine wet drawpoints.	Notify Regulator if remote loading commences	Fine Damp or Fine Wet Based on latest test work, defined in mud rush study as: Fine >30% (-50mm). Dry < 10%MC. Damp 10%-15%MC Wet> 15%MC. MC = Moisture Content
	(3) Drawpoint observations for fines & moisture content by Technical Services Group. Moisture content sampling of wettest drawpoints.	Fortnightly	Fine Damp or Fine Wet material present at drawpoint(s).	Remote loading procedures apply on fine damp and fine wet drawpoints.	Continue to notify Regulator of results	.
Water inrush risk	Monitor rainfall such that rainfall events producing more than 100mm over eight days can be identified.	Monthly	Rainfall event generating greater than 4.3 ML per day percolated into the cave catchment. ie >50 l/s.	Inform Production Superintendent to monitor pump usage on a shift by shift basis.		50 litres per second is two-thirds of pumping capacity.

INRUSH HAZARD MONITORING & TRIGGER LEVELS AT A METAL MINE USING A CAVING METHOD						
HAZARD	**FORM OF REVIEW**	**REVIEW PERIOD**	**TRIGGER LEVELS**	**PLANNED RESPONSE**	**AGGREED TRIGGER REPORTING TO THE REGULATOR**	**COMMENT (Can be for corporate memory)**
Water inrush risk (cont.)	Shift by shift monitoring of pump usage.	Continual – shift by shift.	If levels are forecast to exceed 2/3 of mine pump capacity at 50l/s.	Pump out the water using existing main pumps. Continuous monitoring of pump usage.	Notify Regulator if continues to be over 50 litres per second for two shifts.	Wetting of the cave dirt expected to take some weeks / months. Only 9 events in 100yrs over 2ML per day in catchment. Probability of exceeding 50l/s is 1 in 1000 if the maximum rainfall event was to occur. Even the maximum events recorded of 5.53ML and 14.1ML can be pumped from 2 to 4 days respectively.
Water inrush risk (cont.)	Continuous monitoring of pump usage.	Continual	Pumping capacity exceeded (>75 l/s).	Extra take up water storage can be placed in lower level and lower decline. Commission separate pump system as back up.	Continue to notify Regulator of results	
	Continuous monitoring of pump usage.	Continual	Pumping and storage capacity exceeded.	Evacuate Mine.	Continue to notify Regulator of results	This will allow organised steady evacuation of the mine – unlikely to result in sudden engulfment.

APPENDIX B – EXAMPLES OF IDENTIFYING INRUSH HAZARDS

Flow chart 1 - Identifying an inrush hazard from abandoned mines



* Note: old information is not reliable.

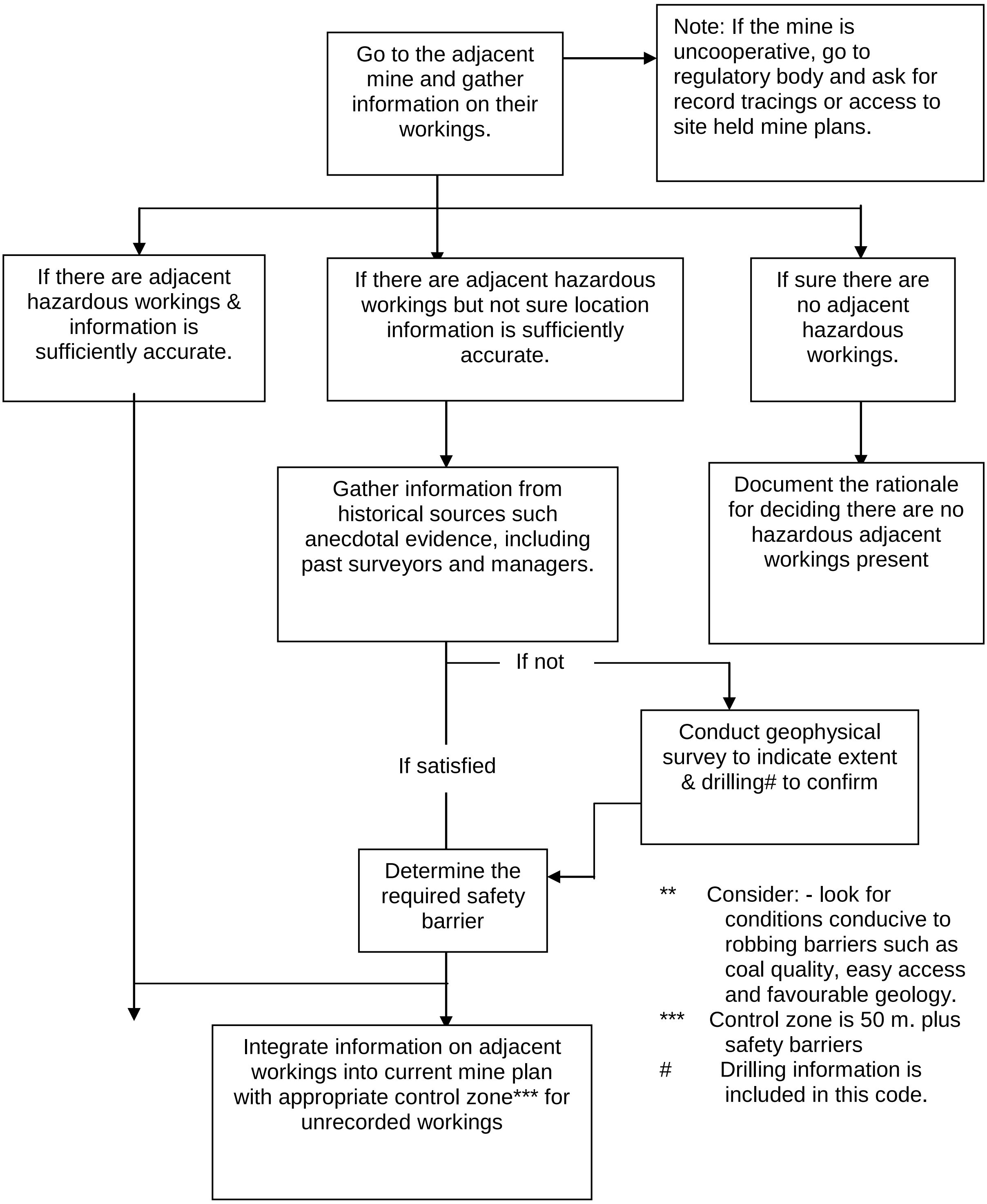
** Consider:
- Equipment used in past.
- Production rates.
- Extent of time of unrecorded workings.

*** Control zone is 50 m. plus safety barrier.

\# drilling information is outlined previously in this code.

safe work australia

Flow chart 2 - Identifying an inrush hazard from workings in another current mine



** Consider: - look for conditions conducive to robbing barriers such as coal quality, easy access and favourable geology.

*** Control zone is 50 m. plus safety barriers

Drilling information is included in this code.

Flow chart 3 - Identifying an inrush hazard from existing workings in your own mine