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Pike River mine re-entry and emergency mine re-entry guidelines application and learnings

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PIKE RIVER MINE RE-ENTRY AND EMERGENCY MINE RE-ENTRY GUIDELINES APPLICATION AND LEARNINGS

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ABSTRACT: Prior to the Pike River Mine Disaster the Queensland Mines Rescue Service and The NSW Mines Rescue Service undertook a project to develop a guideline and a practical prototype software tool to demonstrate how decision makers could be better assisted during a mine emergency which required re-entry to the mine by competent mines rescue trained personnel. The research and development of the prototype software tool (funded through ACARP grant C19010) coincided with the unfortunate events at Pike River Mine on and after the 19th November 2010.

This paper will discuss the relationship between this project's outcomes and the re-entry strategy and operation at the Pike River Mine, along with learning's the researchers gained from this operation undertaken by the New Zealand Mines Rescue Service and Pike River Coal Limited (in receivership).

INTORDUCTION

The aim of ACARP project C19010 Emergency response - mine entry Data Management (Nugent, *et al.*, 2011) has been to provide industry with a practical and cost effective example of how software based information management systems could be developed and utilised to assist Incident Management Teams (IMT) with effective information management and critical decision making during an emergency.

This research project was successful in developing a functioning proof of concept software tool titled "Mine Re-entry Assessment System" (MRAS), which supported and reflected the paper based guideline for Emergency Mine Entry or Re-entry (EMER), developed by Queensland Mines Rescue Service (QMRS) and New South Wales Mines Rescue Services (NSWMRS). The proof of concept software tool has been developed in Microsoft Access which is inexpensive and commonly available software to most computer users. The need for such a tool and process has been identified and recommended in disaster investigations, emergency exercise reports and research reports alike, highlighted by the following examples:

- From Moura No.2: Inquiry Task Group four (Mines Rescue Strategy Development) 1994; Knowledge of conditions in a mine following an incident is essential in planning any rescue effort. Information systems must be provided to support implementation of the most appropriate rescue measures;
- From Moura No.2: Inquiry Task Group four Recommendation (17) 1994; Industry should develop an effective computer-based emergency decision support system for incident management and training;
- From finding No.8: Upper Big Branch, Independent Report to the Governor 2011; The Upper Big Branch disaster raised concerns about how decision-making was conducted in the command centre and the manner in which mine rescue teams were deployed underground. Standard protocols were not followed, effective records were not kept and rescuers' lives were placed in jeopardy.

PROTOTYPE TOOL DEVELOPMENT AND FUNCTIONAL SPECIFICATION

Approximately 70% of required relevant information to make an informed risk based decision during an emergency could be known before an incident occurs. Therefore the identification of, along with the maintenance and accessibility to this relevant routine information can significantly enhance an incident management team's ability to reach critical decision points in a timely manner (Nugent, *et al.*, 2011).

Queensland Mines Rescue Service and NSW Mines Rescue Service have been working together with other parties on a three phase project to develop new guidelines for emergency mine entry and re-entry

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using risk management logic based on a formal documented risk assessment (risk assessment for emergency mine re-entry, 2009) as well as a "tool" for information management. Use of such a tool to minimise the time to make a decision, may in many circumstances eliminate the issue of not acting because of what is not known.

To have the critical information required to make informed decisions, the controls from the mine re-entry risk assessment were analysed to identify who was responsible for the collection or interpretation of the information (i.e. someone from the mine site, mines rescue or an external provider). The ability to have and maintain this information prior to a response was also determined as was whether the information could be generated automatically or had to be collected manually. A significant volume of information may be required so the importance of the information required was also ranked to help those involved to set priorities for information collection.

A task group then performed a gap analysis on what information was identified as required and what information was available. A cross section of mining operations in Queensland and New South Wales were selected and a total of eight mines visited by the task group to establish what information was and wasn't available. The site visits identified there were some very good systems for making some of the information available but also identified some common trends in relation to deficient emergency response information management.

It was found that although a lot of information was captured or available it could not be provided within an acceptable period of time. Critical information or knowledge was sometimes held by only one or two people and thus dependent on their availability. This availability is made worse by the dependence on persons in key roles (particularly technical, such as ventilation officers), who are responsible for many tasks in the response with little or no backup.

It was also identified that not always do the people responsible for monitoring understand what it is they are monitoring. There were also areas where information required was not available. This was particularly the case for information required for validation of operational systems.

Information relating to the actual event unfolding is often missed due to inefficient and inconsistent debriefing of key witnesses. Communication officers or control room operators through whom most communications from underground go are often so inundated with communications that key information is either missed or not identified as important and not passed on to decision makers.

There were many similarities between the findings of the gap analysis and reported findings from Queensland's level one emergency exercises for both good and deficient practices.

The software system eventually developed was never intended to make decisions for those tasked with making decisions during an incident, instead it is a decision support system, providing the information required or identification of absence of information allowing the decision makers to make informed decision. The functional specification incorporated in the checklist is developed as part of the guidelines phase of the project as well as store information from mine site sources into a central repository. This repository would allow mine site personnel to make an objective assessment of the conditions for re-entry, based upon the quantity and quality of the information available.

The intent of the software development was not to create or develop a new standalone software package unique to an emergency mine re-entry information management and decision making tool. The researchers assessed and evaluated the capability and capacity of commonly available software tools for their suitability and level of functionality against the objectives of the project.

The three main software tools considered for trial were Microsoft Excel, web based and Microsoft Access. The researchers engaged three separate technical experts for each software tool to assist with the evaluation of software suitability along with design and creation of the functional specifications required of the software. This evaluation led to the further development of the Microsoft Access prototype primarily due to its flexibility and reporting functionality (Brady, *et al.,* 2012). The functional specification requirements were determined to include:

- Identify and access or collate relevant information already existing within the mine's safety and health management system;

- Identify and access the critical information relevant to the specific incident, to avoid unnecessary information overload;
- Provide reports that quickly summarise the information status relevant to identified hazards to assist the decision makers determine what information is known or unknown;
- Assist decision makers to prioritise required and outstanding information to facilitate efficient resource management;
- Maintain an up to date log of an incidents status;
- Force decision makers to formally acknowledge the adequacy of information;
- Prompt a formal process for the assessment and acknowledgement of explosibility risk;
- Provide a formal approval process for entry or re-entry into a mine during or after an incident.

It must be recognised that this, or any tool, developed to support and facilitate the process of information management and decision making during an emergency at a mine can only be effective when:

- As a minimum its content and structure reflects the current requirements set out in the risk based guideline the tool has been established from;
- The users of the tool have a good understanding of its functionality and purpose along with a high understanding of risk management processes and practices.

Pike River

During this project a significant mine disaster occurred in New Zealand claiming the lives of 29 men. The Pike River Mine disaster which occurred on the 19th November 2010 came only two days after the QMRS and NSWMRS Emergency Mine Entry or Re-entry (EMER) Guideline was presented to industry at the QMRS Inertisation Seminar in Mackay, Queensland. At this stage, although the EMER Guideline was developed in full in a paper based format, the proof of concept software tool development was only in its infancy.

One of the key roles carried out by the researchers at the Pike River Mine rescue and recovery operation was advice and assistance in the strategy for and development of an effective mine re-entry management plan. The assistance provided to Pike River mine management and NZMRS by the researchers included:

- Risk Assessment facilitation and participation;
- Gas Analysis and interpretation;
- Hazard management plan and procedural development and review;
- Incident Management Team Participation.

NZMRS who were responsible for the establishment of the Pike River Mine Re-entry Hazard Management Plan (HMP), after consultation with the researchers elected to base the logic and process for the development of the re-entry plan on this project's research outcomes.

Whilst the Pike River mine Re-entry HMP was being developed by the NZMRS in consultation with this project's researchers, the development of the MS Access MRAS software tool was also being further progressed with both completed at the end of May 2011.

Due to the Pike River Mine Re-entry HMP being closely aligned with the strategies and processes outlined in the EMER Guideline, the risk logic and process applied during the re-entry was also compatible with the newly developed MRAS software. Because of this, the Mine Re-entry Control Team (MRCT) in control of the re-entry operation agreed to utilise the MRAS software to assist the MRCT with information management and decision making processes.

MRAS practical application at Pike River re-entry

The primary objective of the re-entry operation was to install a fit for purpose seal within 300 m of the main portal to provide a more effective seal preventing oxygen ingress and to augment the natural stabilisation of the underground mine atmosphere. Additionally, the successful installation would allow Pike River Coal Limited (in Receivership) employees to reclaim the temporary seal at the portal and install fit for purpose double vehicle doors for potential future access.

Regardless of the distance mines rescue teams are required to travel into a mine after a significant incident (e.g. 300 m or 3 000 m) the precautions taken and the diligence demonstrated must be no less comprehensive in either circumstance as the consequences of potential hazards, if realised, would be no less severe.

Based on this logic the NZMRS initiated and facilitated a comprehensive re-entry risk assessment for the re-entry of the Pike River Mine. This risk assessment underpinned the establishment of the NZMRS Pike River Mine re-entry HMP which also incorporated the following hazard management plans, procedures and Trigger Action Response Plans (TARPs):

- Pike River Mine Atmospheric Monitoring HMP;
- Pike River Mine Atmospheric Monitoring TARP for Re-entry;
- Pike River Mine Atmospheric Monitoring Check Sheet;
- NZMRS Re-entry Explosibility TARP and Check List;
- NZMRS Mine authority to Enter;
- Strata Management Plan and TARPs;
- Pike River Mine Water Management Plan;
- Pike River Mine Seal design and installation SOP;
- NZMRS seal installation and operational Risk Assessment and Guidelines.

The overriding structure outlined in the NZMRS Re-entry HMP was to ensure that:

1. A MRCT was responsible for managing all activities required to control the Pike River Mine re-entry from an operational perspective. It would manage and co-ordinate the interface between the MRCT functional groups (Operations, Planning and Logistics) and with stakeholders outside of the mine re-entry management structure;
2. A defined process and logic was established to ensure the gathering and assessing of relevant information and decision making was systematic, unambiguous and well informed.

The management of the re-entry operation was conducted via the established Queensland Mines Rescue Service Mine Emergency Management System (MEMS), Figure 1. The established information management and decision making process was founded on process outlined in the QMRS and NSWMRS Emergency Mine Re-entry Guideline and is outlined in Figure 2.

Prior to the initial decision by the MRCT to re-enter Pike River mine the Pike River Information Management check sheets (listed below) were completed and all information collated deemed adequate by the MRCT for the assessment of known information against all applicable control procedures and TARPs:

- Mine atmospheric monitoring check sheet;
- Mine ventilation management check sheet;
- Explosibility check sheet;
- Mine strata management check sheet;
- Mines rescue operational deployment check sheet;
- Mine re-entry critical support and resources check sheet.

The objective at this stage was to evaluate and determine a number of issues:

- Where there was outstanding information, what was its significance for making an informed decision on the risk to rescuers entering or remaining in the mine;
- Did the outstanding information impact on an authorised person's ability to evaluate and conform to the requirements of the mine re-entry control procedures.

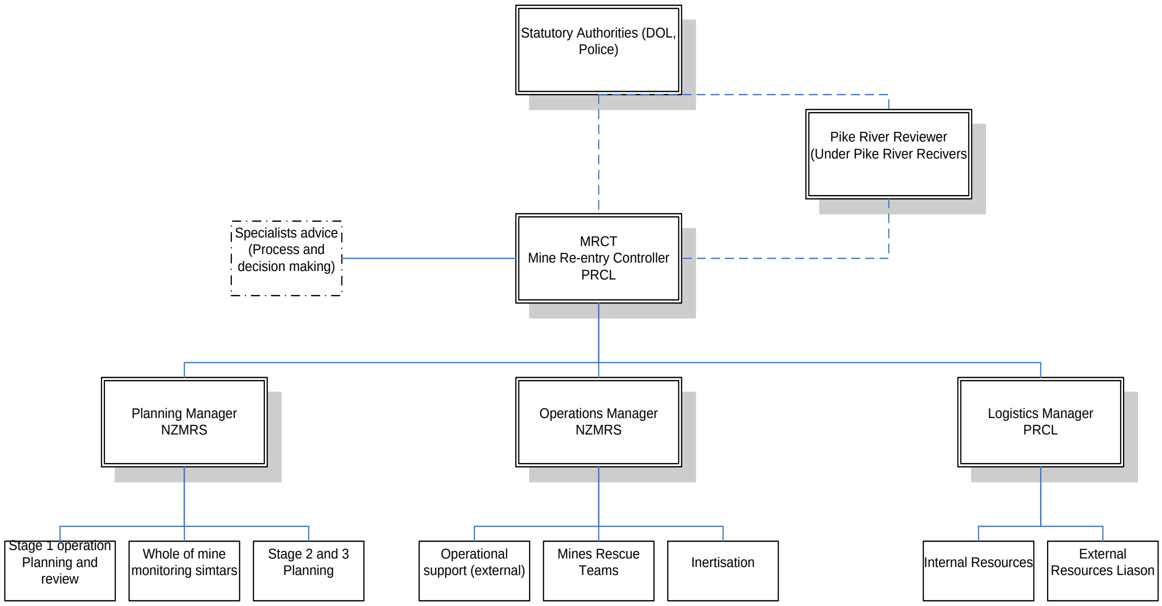


Figure 1 - Mine re-entry control team structure

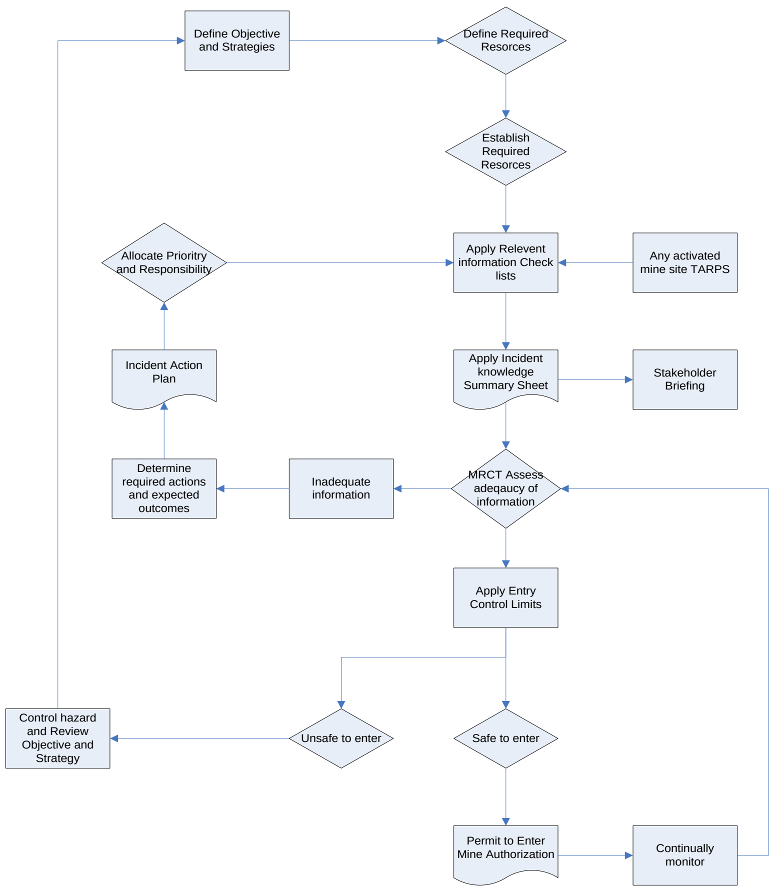


Figure 2 - Information management and decision making process

This process was conducted and maintained via a paper based gap analysis process (consistent with the EMER guideline) developed by the NZMRS and reviewed as a minimum on a daily basis or where change occurred.

Once it was determined by the MRCT that all required information was adequate to make an informed decision the data and information would be applied to the established control measures for the MRCT to decide whether the risk to rescuers re-entering the mine was within acceptable limits.

The key functional elements of the MRAS software utilised by the MRCT to assist with decision making, further information management and document control were:

- Re-entry control questions for the assessment of explosibility risk;
- Explosibility graph (MS Excel) for assessment of explosibility, trending and rate of change at each sample point;
- Management of actions required, priority and status as set by the IMT;
- Current situation reporting and recording;
- Authority to enter document.

The assessment of explosibility risk

When the MRCT assessed the risk of explosibility to rescuers the following conditions had to be met and acknowledged:

1. Any analysis system of a potentially explosive atmosphere must consider all flammable gases present in the atmosphere and determine;
    - The flammable gas content expressed as a percentage of the Lower Explosive Limit (LEL) present;
    - The oxygen content expressed as a percentage of the Oxygen Nose Point (ONP) present.
2. All samples, from the same location, for both LEL and ONP must be plotted and trended together against time on the same graph. The same graph should have the capability to plot barometric pressure trends against time.
3. When determining the explosibility risk level the following controls must be observed:
    - Prior to entry the assessment of relevant knowledge for mine re-entry must be completed and all information deemed to be adequate to determine explosibility risk level;
    - Atmospheric conditions must be continuously monitored by rescuers underground and monitored and trended on the surface by a competent person at all times while people are underground;
    - When it cannot be confirmed there are no potential ignition sources which may come into contact with a potentially explosive or explosive environment it must be taken that an ignition source exists;
    - The level of assessment must be based on the highest level of risk within the mine not just the area which the rescue team is going to enter;
    - These control limits may only be modified when a full re-entry RA is undertaken for the specific emergency situation. The original risk assessment must be reviewed as part of this process;
    - Currency of the data must be taken into account when assessing gas results e.g. Tube bundle lag times and the time bag samples were taken;
    - Sufficient time must be allowed for rescuers to exit the mine or atmosphere before the environment enters higher levels of risk.

MRAS has been designed to allow decision makers to assess and address these requirements in electronic format and produce a PDF report for acknowledgement with signature by the decision maker. The software also allows decision makers to directly access the explosibility analyses graph designed during this project (Figure 3).

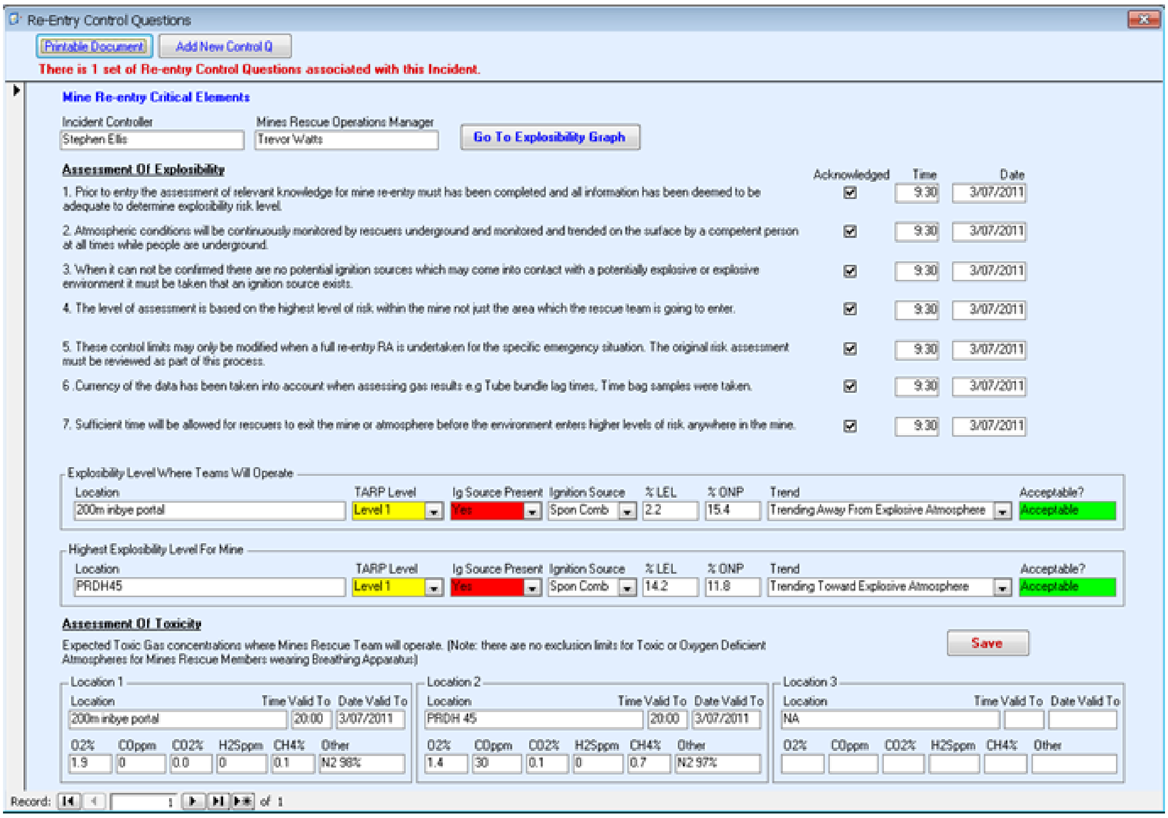


Figure 3 - Explosibility assessment tool

In an effort to equip decision makers with tools to assist in applying these criteria a relatively simple Microsoft Excel spreadsheet was set up to trend both the LEL and ONP with the ability to add trend lines. Figure 4 shows a plot of data collected for a sample location where it appears that the LEL will exceed the trigger levels before the ONP drops below its trigger. By using the trending forward feature in Microsoft Excel it is possible to predict when this would as shown in Figure 4.

Often gas results are influenced by barometric pressure so decision makers are aided if the plots include barometric pressure trends occur as shown in Figure 4 (Brady, *et al.,* 2012).

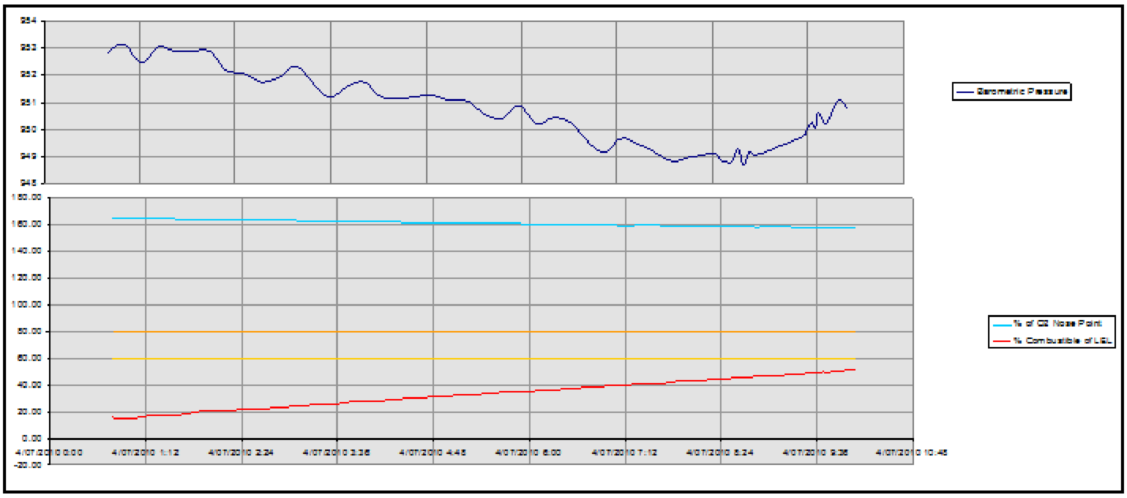


Figure 4 - Trend data with barometric pressure trend

The spreadsheet created features a summary page (Figure 5) that collates the data and displays latest results, trigger levels and TARP actions for each point. Also included is the overall status and trigger level which is the highest risk level of all points.

		Last Data:	4/07/2010 11:00			Overall Status:		3			No Entry into the Mine	
Point Number:	Name:	Lag Times:	Date & Time:	Ignition Source Possible	%LEL:	%ONL:	O2:	CO (ppm):	%CO2:	Status:	Tarp Actions	Graph:
Point 1	Location 1	42 mins	4/07/2010 11:00	Yes	80.22	153.22	18.7	4.30249	0.51	3	No Entry into the Mine	Graph 1
Point 2	Location 2	32 mins	4/07/2010 11:00	Yes	300.81	77.84	9.5	4.30249	0.6	3	No Entry into the Mine	Graph 2
Point 3	Location 3	21 mins	4/07/2010 10:05	No	51.06	157.56	19.28	0.00716	0.065	1	Rescuer may enter environment / Rescuers may operate adjacent to the environment	Graph 3
Point 4	Location 4	40 mins	4/07/2010 11:00	Yes	38.24	160.09	19.59	0.0051	0.058	1	Rescuer may enter environment / Rescuers may operate adjacent to the environment	Graph 4
Point 5	Location 5	47 mins	4/07/2010 11:00	Yes	102.80	148.30	18.12	0.1	0.75	3	No Entry into the Mine	Graph 5
Point 6	Location 6	54 mins	4/07/2010 11:00	Yes	80.22	153.22	18.7	4.30249	0.51	3	No Entry into the Mine	Graph 6
Point 7	Location 7	51 mins	4/07/2010 11:00	No	81.87	160.09	19.59	0.0051	0.058	3	Rescuer must not enter the environment / Rescuers may operate adjacent to the environment	Graph 7
Point 8	Location 8	47 mins	4/07/2010 11:00	Yes	300.81	77.84	9.5	4.30249	0.6	3	No Entry into the Mine	Graph 8
Point 9	Location 9	57 mins	4/07/2010 11:00	Yes	300.81	77.84	9.5	4.30249	0.6	3	No Entry into the Mine	Graph 9
Point 10	Location 10	49 mins	4/07/2010 10:05	Yes	51.06	157.56	19.28	0.00716	0.065	1	Rescuer may enter environment / Rescuers may operate adjacent to the environment	Graph 10

Figure 5 - Summary page

Authority to enter

Where it was deemed the risk to be acceptable for rescuers to enter the mine an "Authority to Enter" was completed in MRAS with a PDF report produced for and signed off by the Incident controller and NZMRS appointed person. This document formed part of the mine re-entry action plan along with other relevant information which included:

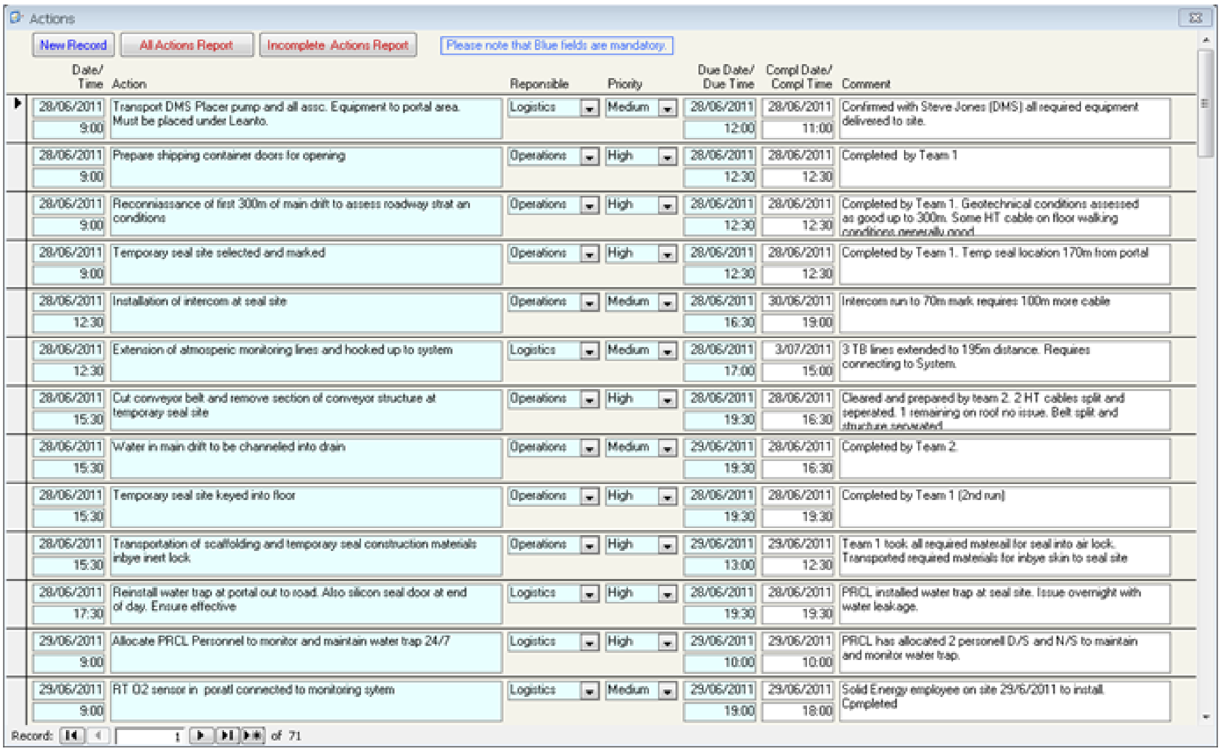
- Up to date mine plans;
- Current status;
- Relevant and current environmental readings and trends;
- Status of mine ventilation and mine services;
- Barometric pressure and trend;
- Known and unknown additional environmental conditions such as expected visibility and temperature, roadway conditions, water hazards and strata hazards.

The objective of an authority to enter was to ensure the instruction for mines rescue teams to enter the mine is unmistakable, deliberate and well informed.

Additional to the core functionality of information management, a structured decision making process for the assessment of explosibility risk and authority to enter, the MRAS software tool was also utilised for management of the status of general actions required of each functional area and also the maintenance of a record of the current situation throughout the operation.

The required actions put into the software appear in chronological order and allow the user to allocate actions to the responsible functional area with a due date and time and priority. The action on completion can be closed out with a date and time when completed along with any comments as shown in Figure 6.

A useful reporting function on the actions screen allows for a report to be generated showing only the incomplete actions grouped within the responsible functional area and in order of priority as shown in, Figure 7. Additionally the current situation throughout the operation could be maintained as regularly as required within a dedicated function within the MRAS software and the ability to generate an accompanying report.



Actions

New Record | All Actions Report | Incomplete Actions Report | Please note that Blue fields are mandatory.

Date/ Time	Action	Reponsible	Priority	Due Date/ Due Time	Compl Date/ Compl Time	Comment
28/06/2011 9:00	Transport DMS Placer pump and all assc. Equipment to portal area. Must be placed under Leanto.	Logistics	Medium	28/06/2011 12:00	28/06/2011 11:00	Confirmed with Steve Jones (DMS) all required equipment delivered to site.
28/06/2011 9:00	Prepare shipping container doors for opening	Operations	High	28/06/2011 12:30	28/06/2011 12:30	Completed by Team 1
28/06/2011 9:00	Reconniassance of first 300m of main drift to assess roadway strat an conditions	Operations	High	28/06/2011 12:30	28/06/2011 12:30	Completed by Team 1. Geotechnical conditions assessed as good up to 300m. Some HT cable on floor walking conditions generally good
28/06/2011 9:00	Temporary seal site selected and marked	Operations	High	28/06/2011 12:30	28/06/2011 12:30	Completed by Team 1. Temp seal location 170m from portal
28/06/2011 12:30	Installation of intercom at seal site	Operations	Medium	28/06/2011 16:30	30/06/2011 19:00	Intercom run to 70m mark requires 100m more cable
28/06/2011 12:30	Extension of atmosperic monitoring lines and hooked up to system	Logistics	Medium	28/06/2011 17:00	3/07/2011 15:00	3 TB lines extended to 195m distance. Requires connecting to System.
28/06/2011 15:30	Cut conveyor belt and remove section of conveyor structure at temporary seal site	Operations	High	28/06/2011 19:30	28/06/2011 16:30	Cleared and prepared by team 2. 2 HT cables split and seperated. 1 remaining on roof no issue. Belt split and structure separated
28/06/2011 15:30	Water in main drift to be channeled into drain	Operations	Medium	29/06/2011 19:30	28/06/2011 16:30	Completed by Team 2.
28/06/2011 15:30	Temporary seal site keyed into floor	Operations	High	28/06/2011 19:30	28/06/2011 19:30	Completed by Team 1 (2nd run)
28/06/2011 15:30	Transportation of scaffolding and temporary seal construction materials inbye inert lock	Operations	High	29/06/2011 13:00	29/06/2011 12:30	Team 1 took all required materail for seal into air lock. Transported required materials for inbye skin to seal site
28/06/2011 17:30	Reinstall water trap at portal out to road. Also silicon seal door at end of day. Ensure effective	Logistics	High	28/06/2011 19:30	28/06/2011 19:30	PRCL installed water trap at seal site. Issue overnight with water leakage.
29/06/2011 9:00	Allocate PRCL Personnel to monitor and maintain water trap 24/7	Logistics	High	29/06/2011 10:00	29/06/2011 10:00	PRCL has allocated 2 personell D/S and N/S to maintain and monitor water trap.
29/06/2011 9:00	RT O2 sensor in poratl connected to monitoring sytem	Logistics	Medium	29/06/2011 19:00	29/06/2011 18:00	Solid Energy employee on site 29/6/2011 to install. Cpmpleted

Record: 1 of 71

Figure 6 - General actions management tool

Actions Report
Incomplete Actions

Incident Description: Explosions and subsequent fire at Pike River Mine. Mine has been sealed and fire brought under control.

Responsible	Date/ Time	Action	Priority	Due Date/ Due Time	Comment
Logistics					
	19/07/2011 17:00	Confirm helicopter for shft inspection 1000hrs 20/7	High	19/07/2011 18:00	
	19/07/2011 17:00	Source 6 BG4 and deliver to FAB	Medium	19/07/2011 19:00	
	19/07/2011 13:30	Procure 10 buckets mortar, 4 shovels and deliver to FAB	Low	20/07/2011 13:00	
Operations					
	19/07/2011 14:00	construct water trap at portal doors as per work plan 001	High	19/07/2011 20:00	
	19/07/2011 12:00	Extend inert line from portal to seal site and contect as per seal design 001	Medium	20/07/2011 12:00	
Planning					
	19/07/2011 17:05	Review data for TB line 10 and report to Incident controler	High	19/07/2011 18:00	
	19/07/2011 17:00	Develop contingency plan for seal re-design and completion in case of pump failure.	Medium	20/07/2011 12:00	
	19/07/2011 16:00	Integrity test all TB line and supply results to IMT	Low	21/07/2011 15:00	

Figure 7 - Incomplete actions report

CONCLUSIONS AND DISCUSSIONS

The researchers of ACARP project C19010 believe that due to the successful application of MRAS during the Pike River Mine re-entry operation (and Queensland level one emergency exercise) along with the level of interest and positive feedback from industry the outcomes of this project can be considered successful.

The standard of which the existing proof of concept model has been developed provides a solid foundation for realistic opportunities of commercialisation and implementation into a mine safety management system.

Although this ACARP project has come to a close the importance of the outcomes has been clearly recognised by industry with further support and momentum beyond this project now being provided by industry stakeholders with an aim of successful implementation.

Elements of industry have also recognised MRAS functionality, logic and processes have potential to greatly assist with the information management and decision making process for smaller more common incidents at a mine. E.g. Re-entry into a mine (or part of a mine) after an orderly evacuation when a mine site TARP has been exceeded.

When an incident occurs at a mine, decision makers must demonstrate proper diligence and take reasonable precautions. When a decision maker permits a rescuer to re-enter or remain in a mine after an incident, that person must ensure the risk to rescuers entering the mine after an incident is within acceptable limits and as low as reasonably achievable. The decision makers' authorisation to re-enter the mine must be unmistakable, deliberate and well informed.

The researchers believe that the results of this ACARP project have significant potential to assist decision maker's to discharge their obligations during an emergency by assisting them to make well informed risk based decisions by taking reasonable precautions and demonstrating proper diligence.

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