

The Risk Management Process for Practising Geotechnical Engineers

By Wouter Hartman, Senior Geotechnical Engineer
wouterhartman@aol.com

INTRODUCTION

Geotechnical engineers, when subjected to a risk management process, are generally concerned with rock-related incidents, mechanisms of failure which include rockburst and gravity falls of ground and the severity or impact of any rock-related incident on the mining operation. The Geotechnical Risk Management process should be a structured and formalised process and should be an integral part of the organisation's overall risk management strategy. It is a fully integrated system and does not stop at the geotechnical engineer's book shelf, but is rather a revolving and proactive process.

In December 2001, a MERIWA project report (Towards the Elimination of Rockfall Fatalities in Australian Mines – No. 223) highlighted certain key learning points about the critical factors causing rockfall or rock-related incidents. Of the 22 key learnings, only six referred to risk issues, whilst the remaining 16 targeted specific rock-related hazards. Those six key learnings are briefly highlighted below:

- “The collection and the analysis of rockfall data (even of variable quality) can be used to clearly define where most of the risk lies, and evaluate the impact of changes in industry practices by plotting trends in time.”
- “Of the six characteristics used to describe ground conditions in this study (shear/faulted ground, poor ground, blocky ground, good ground, groundwater, highly deformable ground), the risk of rockfall injuries is significantly higher in poor ground and blocky ground.”
- “The risk of being injured by small rockfalls remains higher near the active face, however it is not confined to this area. Further away from the active face, there seems to be a recurrent risk of rockfalls resulting in at least two injuries per annum.”

- “The Authors of the report believe that further improvement in surface support practices, within the framework of risk management, offers the best long-term opportunity to further reduce the risk of rockfall injuries. The continuous emphasis on training, awareness and best rock mechanics practices is equally important.”
- “The activities that present the highest risk are: barring down, rock bolting and charging. They account for over two thirds of the rockfall fatalities since 1993.”

The above-mentioned report specifically targeted rock-related incidents at mine sites. I have found with numerous rock-related incident and accident investigations, which ranges over an extended period and at various locations, (ie underground deep and shallow gold mines, underground shallow to intermediate platinum mining, shallow coal mining and open cut mines) that their conclusions are similar to my own. However, I would like to add a human factor, which is present at almost every incident. With this article I would like to highlight some of the human factors involved in rock-related incidents and pathways we as engineers and managers can take to minimise geotechnical risk situations overall. Certainly the geotechnical hazard identification and risk assessment processes, if applied properly and is part of the company's risk management process, can offer huge economic benefits.

THE HUMAN FACTOR

The human factor I am referring to is the knowledge and experience contribution to all mining rock-related practises. This includes works as early as the exploration drilling program and the follow-on feasibility study; mine design process; the excavation and mining process; the review or reconciliation process and some training initiatives.

I have found from most incident investigations that the following factors

are almost always present (ranking in no particular order):

- A general lack of understanding of how the rockmass behaves;
- The difficulty in identifying geological hazards;
- Inexperienced personnel;
- Experienced personnel becoming complacent; and
- Failure to communicate any change in rockmass behaviour.

This lack of understanding of rockmass behaviour and difficulty in geological hazard identification includes a wide spectrum of mine personnel, such as the underground operators, mining engineers, planning engineers, mine managers, geologist, rock mechanics / geotechnical practitioners – and some geotechnical consultants are not excluded from this spectrum.

Geotechnical input into mining practice according to a study (SIMRAC, 1998) is viewed as occurring in three phases:

- During strategic planning, a broad approach is required for which a checklist method is appropriate to allow risks associated with alternative strategies to be compared.
- At a planning and design phase a detailed process interrogation method is warranted to allow creation of procedures, operating practices and standards.
- During the operations phase, continuous review is needed to identify deviations from the optimum design and facilitate corrective action.

Checklists adapted to the appropriate level of monitoring are considered appropriate. However there are some limitations (SIMRAC, 1998) that everyone should be on the look out for when using a checklist to perform a baseline risk assessment:



The Risk Management Process for Practising Geotechnical Engineers *continued*

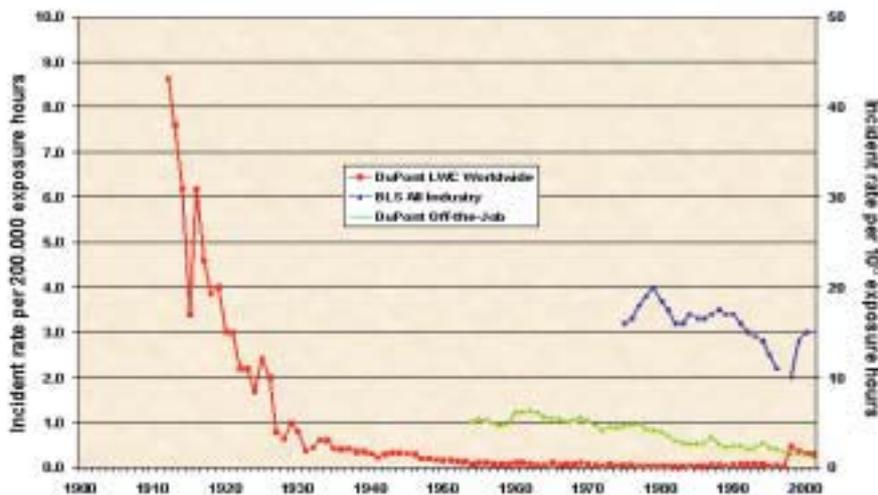
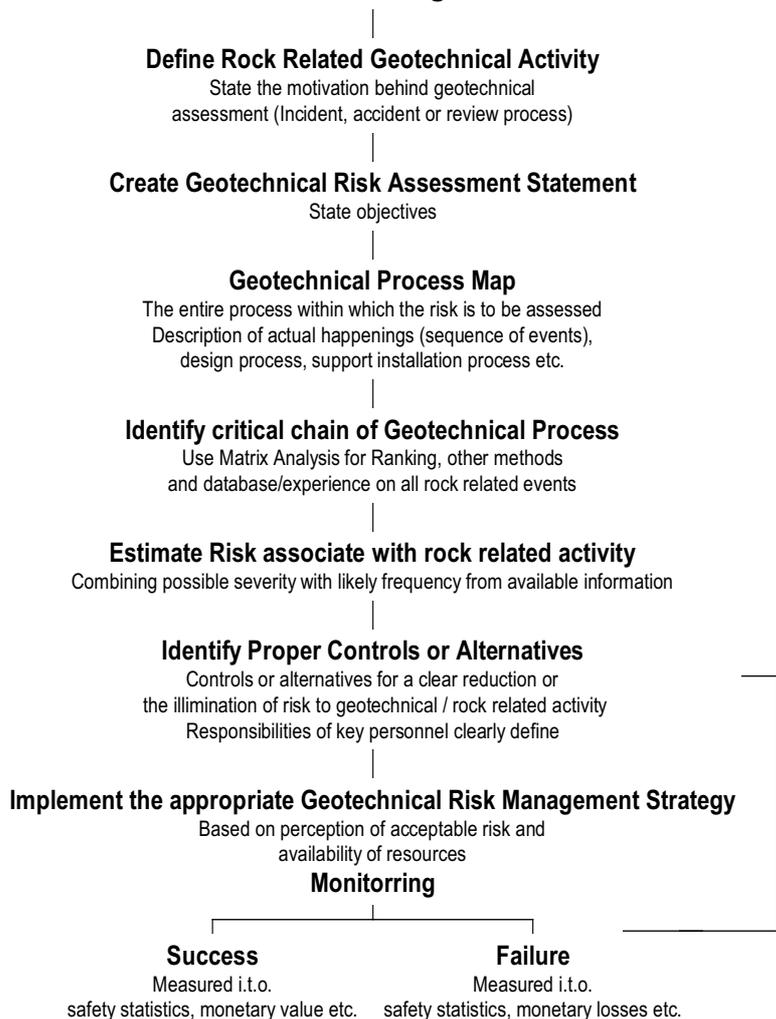


Figure 1: DuPont safety performance since 1912 (DuPont, 2002).

- There are likely to be omissions. These should become fewer as the checklist is used and updated. One such example is the regular update of your mine's stability graph and input parameters that reflect contributors to large falls of ground or stoppage collapses.
- The checklist is insensitive to situations that are subject to change and may, after some time, contain irrelevant questions.
- Perhaps the greatest disadvantage with a check list is that it tends to put "blinkers" onto the user who becomes disinclined to look beyond checklist items for hazardous situations.

Geotechnical Risk Management Process



An interesting study was conducted whereby "on the job, off the job and an all industry performance" from 1912 through to 2000 exposure hours are compared (see Figure 1). Until the 1970s, it was generally felt that the human component was reliable, and almost error free, particularly in relation to the high frequency of dysfunctions that occurred in other components (electrical, electronics, mechanical etc.).

Analyses of failures and accidents demonstrate that human error may be regarded as either a generating or a permitting factor. Statistics related to human error are not easily interpreted due to the variability of the psychological and physical state of subjects at the moment of accidents. Stress compounds these parameters, and stress levels may differ substantially between daily routine activities, maintenance and repair functions or accident/crisis status. As a result, numerical values related to human errors are simply estimates that can vary greatly as a function of (Mine Info, 2004):

- available time to react;
- ergonomics of facility (design of human-machine interface);
- experience and level of instruction; and,
- stress.

Figure 2: Geotechnical Risk Management Process.



The Risk Management Process for Practising Geotechnical Engineers *continued*

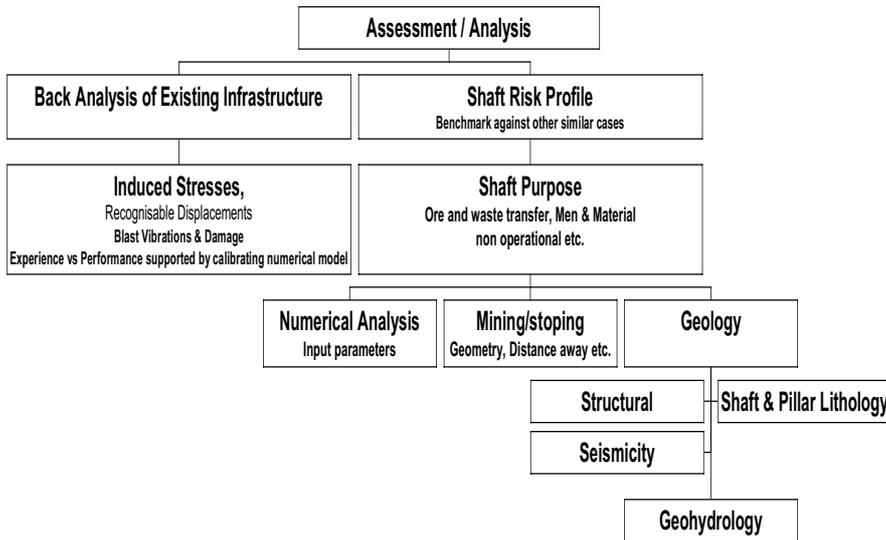


Figure 3: Example geotechnical process map of shaft pillar design.

This leaves us with an open-ended question – “Will a Geotechnical Risk Management Process assist you and your geotechnical team to make sound geotechnical assessments and implement appropriate strategies to minimise geotechnical risk?” The following section will certainly expand the thinking process and highlights the step-by-step process involved.

THE GEOTECHNICAL RISK MANAGEMENT PROCESS

The Geotechnical Risk Management Process (see Figure 2) starts with a complete geotechnical activity statement (eg *designing* a shaft stability pillar).

It continues into a comprehensive Geotechnical Risk Assessment Statement (eg *All geotechnical factors*

are considered for an intact shaft pillar, which will influence the stability of an operating shaft). This is followed with a fairly detailed activity process map¹ (eg shaft pillar design activity process, see Figure 3).

Each activity in the process is rendered significant to the overall goal of the operation and should be given a risk ranking to identify the high risk and where the focus in the process should be (see Table 1).

An estimation of the activity’s risk to the operation is conducted using a combination of methods. The proper controls are carefully considered prior to final implementation. In completion of the Geotechnical Risk Management Process, successes and failures are assessed and channelled appropriately. The Geotechnical Risk Management

Process should be used as a guideline when assessing any rock-related activity or process (including geotechnical designs).

One of the underlying successes of the Risk Management Process is the identification of rock-related hazards or activities. The methodology or process, which relates to some auditing factors, listed below, should be kept in mind:

- All geotechnical hazards that can create rock-related incidents that could effect health and safety are identified.
- The hazard identification methodology should be a structured process.
- The methodology must be capable of prioritising geotechnical hazards to health and safety.
- The results of the geotechnical hazard identification process are independent of team members involved.

Some of the techniques, which will assist in identifying the hazards, are typical fault tree analysis, event tree, failure mode effect and critical analysis (FMECA) and HAZOP’s². The techniques, however, should not stand alone but rather in combination to identify possible root causes and outcomes. Previous studies have revealed that geotechnical hazard identification in itself is not a goal but rather a foundation from which to construct event-incident and cause-consequence-frequency relationships. It is essential that the process of

	A	B	C	D	E	F	G	H	Total
A		0	0	1	1	0	0	1	3
B	1		1	1	1	1	1	1	7
C	1	0		0	1	1	0	1	4
D	0	0	1		1	1	1	1	5
E	0	0	0	0		0	0	0	0
F	1	0	0	0	1		1	1	4
G	1	0	1	0	1	0		1	4
H	0	0	0	0	1	0	0		1

- A – Back Analysis of Existing Infrastructure
- B – Shaft Risk Profile (shaft purpose)
- C – Numerical Analysis (input parameters and model)
- D – Mining/stopping (Geometry, distance away)
- E – General Geology - Rock type
- F – Structural Geology
- G – Seismicity
- H – Geohydrology

Table 1: Example of shaft pillar design activity process map ranking.



The Risk Management Process for Practising Geotechnical Engineers *continued*

geotechnical hazard identification and risk assessment follow a systematic format to ensure that all possible situations, activities and/or scenarios are identified and analysed. A process interrogation methodology is a preferred method but could be impractical for most operations due to time constraints and limited resources.

Practical steps that can be taken to ensure that geotechnical risks are minimised are given below:

- Management accepts accountability for the organisation's geotechnical risks.
- It is almost a general consensus that each mining site must have a ground control management plan. Two of the topics that should be listed in the beginning of the document are: all the rock-related hazards (even installation of ground control counts as a hazard), and a rockfall incident register³ from which empirical ground support design methodology and reviews can be made.
- Geotechnical audits or risks assessments take place by an independent reviewer.
- New, inexperienced engineers and operators receive additional best

practice training and offsite supervision (the loss of experienced engineers and operators compromises safety).

- Contractors' health, safety and environmental management systems are aligned with those of mining company – inclusive of adhering to ground control standards and procedures.
- Discuss all rock-related incident investigations and outcomes (ie standards or procedures) at management safety meetings and engineer/operator toolbox meetings.

CONCLUSIONS

Experience in managing rock-related risks showed that existing practices had some degree of harm, and some hazards were found negligible and sometimes not included in an organisation's global risk management strategy. The geotechnical risk management process shows that it would allow the practising geotechnical engineer to identify key rock-related risks to the operation and / or organisation. This process will be associated with previous experiences and identifying the human factor in each of the rock-related activity of the process.

REFERENCES

- Du Pont de Nemours, E.I. and Company, 2002. DuPont Safety Resources. EAGOSH, Nov 2002.
- Meriwa Report No. 223, 2001. Towards the Elimination of Rock Fatalities in Australian Mines.
- SIMRAC (1998): Hazard identification for Rock Engineering. Final Project Report,
- Project GAP 339, Department of Minerals and Energy, Johannesburg, 1998.
- Mine Info, 2004. Risk Management in Mining. Course notes.

FOOTNOTES

- ¹ Process Map is a hierarchical method for displaying processes that illustrates how a product or transaction is processed. It is a visual representation of the workflow either within a process – or an image of the whole operation. Process Mapping comprises a stream of activities that transforms a well-defined input or set of inputs into a pre-defined set of outputs.
- ² HAZOP is an abbreviated term for **HAZ**ard and **OP**erability study. It is a technique that identifies the potential hazards and operating issues with the design and construction of equipment and plant and involves the interaction of a multi-disciplinary team (Process flow technique).
- ³ A rockfall incident register is record of all natural rockfalls in underground and surface mining. The record should include fall location, date and time, geometry (length, width and thickness), origin, rock type etc. ■