A phased approach to mine dewatering – updated from IMWA 1993

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Abstract

Mining often requires penetrating the local and regional water table.This creates inflows, which if the area is wet and the country rock highly permeable, becomes at best a nuisance to operations and at worst an extreme hazard.Effective dewatering creates dry working conditions which are preferable as they reduce risk, reduce wear and tear on machinery, reduce earth moving costs, improve slope stability for open pits and therefore improve safety. Dewatering success is directly linked to a detailed understanding of the groundwater regime enabling application of the best strategy to intercept groundwater inflows. Options available are both passive and active methods including detailed stormwater design, drainage trenches, drain-holes, pit-perimeter pumping boreholes (wells), in-pit boreholes, sumps, dewatering galleries, or a combination of methods. A phased approach assists with logically managing the data, information and knowledge for use in dewatering design and implementation.

The potential effects of groundwater inflows should be assessed at the pre-feasibility stage but can be done at any stage of the mine life. A hydrogeological investigation is best tackled in three phases.The first phase is a desktop study to identify the problem, collect site data, create a detailed initial conceptual hydrogeological model then use the information to identify the most practical options for water control.

Phase 2 comprises numerical modelling of the conceptualisation, supported with accurate and interpreted monitoring data. The objective is to use predictive simulations of dewatering options to determine the best strategy for water control. Phase 3 sets dewatering targets to support the mine design, creates an initial dewatering design then implements a prototype to test the concept. Success is evaluated, and the design improved to increase efficiencies and enable full implementation. The phased approach is iterative as the conceptual and numerical models are regularly updated, recalibrated with the latest monitoring information, and used to review and implement the dewatering strategy. The monitoring network is continually improved, and the phased approach repeated annually to ensure water control objectives are met for each stage of mining. This paper is an update of the IMWA paper Morton et al. (1993) which is still widely read.

Keywords: Mine dewatering, conceptualisation, numerical modelling, dewatering methods, dewatering scenarios.

Introduction

Mining often requires penetrating the local and regional water tables. This creates inflows of groundwater, which if the area is wet and country rock is highly permeable, can become at best a nuisance to operations and at worst an extreme hazard. Dry working conditions are preferable as they reduce risk, reduce wear and tear on machinery, reduce earth moving costs and improve slope stability for open pits, and reduce water risk for underground mines. Water is typically the third biggest cost to a mine but is often excluded from detailed financial analysis. The paper is an update of the IMWA paper Morton et al. (1993) which is still widely read.

Inflow rates vary across the world. The highest inflows are experienced in high rainfall areas with limestone hosted aquifers such as Konkola copper mine in Zambia and Freeport McMoran in Indonesia. Fig. 1 shows inflows for a variety of mines and their host country.

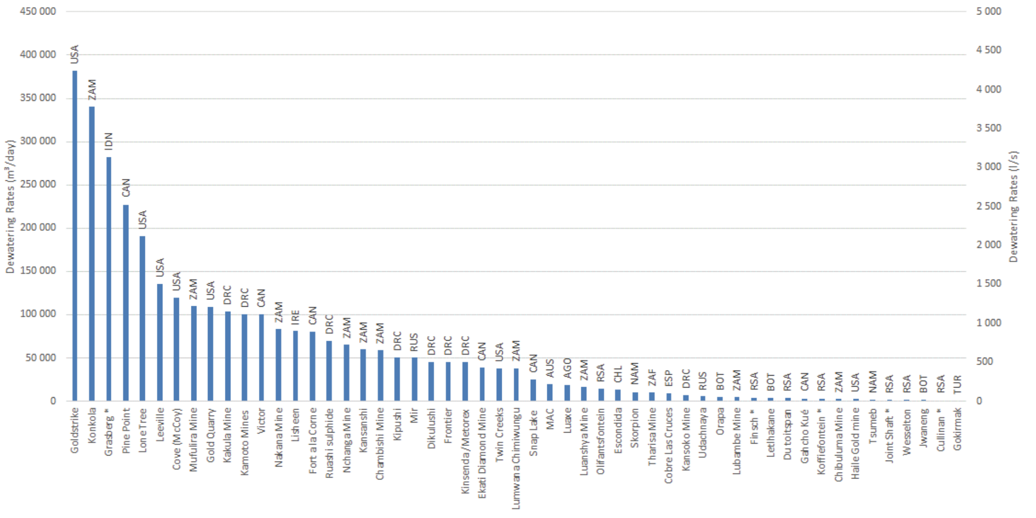

***Figure 1** Inflow rates for mines around the world (acknowledgment to LC Atkinson for compiling the initial rates)*

Many mines have low inflow rates, but groundwater still poses a relevant risk if the ore body is susceptible to swelling caused by contact with water, for example, kimberlite mines. All mines require a bespoke dewatering design to ensure risk reduction for ore handling, geotechnical safety factors and improve safety of people.

This paper describes the steps necessary to plan an effective dewatering system for a mine. The approach is a phased investigation which enables gradual expenditure appropriate to the confidence level required. Fig. 2 illustrates the 3 phases and highlights specific tasks within each phase.

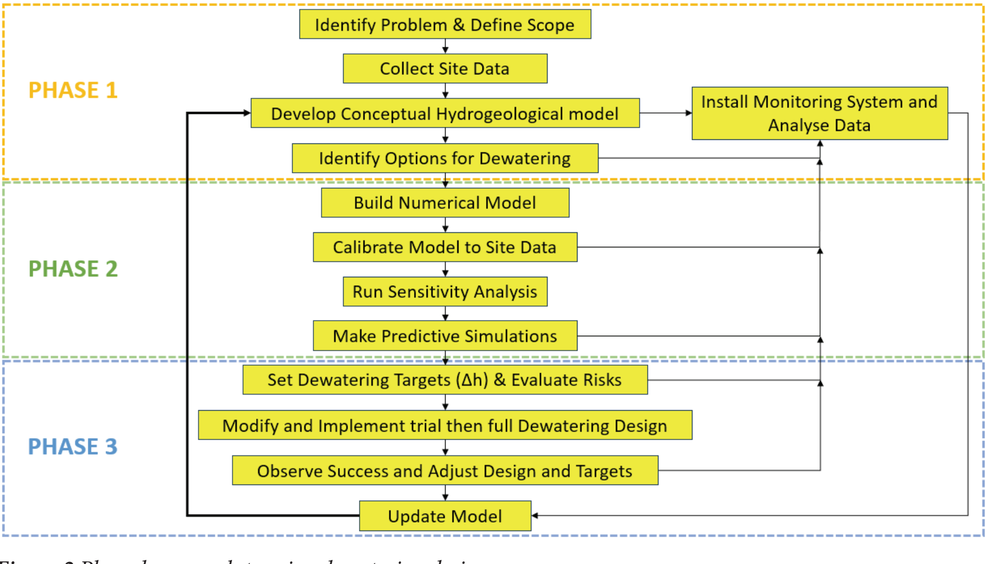

***Figure 2** Phased approach to mine dewatering design*

Phase one

The potential effects of groundwater inflow to a mine can often be assessed at the pre-feasibility stage. The pre-feasibility stage can be designed to include a preliminary hydrogeological appraisal of the site using exploration drill hole information (Morton 2021). The phase 1 investigation defines and compiles an initial conceptual hydrogeological model to design a site investigation and install a monitoring network. Phase 1 defines Hydrogeological Units (HU's) and allocates estimates of hydrogeological values as described in Morton (2008).

Design of an initial dewatering system requires the collation of important information on the mine including:

- Dimensions of the area to be dewatered and timing.
- Depth to which the water levels must be lowered for each stage of mining.
- Volumes of water to be removed.
- Chemistry of the water that must be removed.
- Plans for disposal of the water removed and opportunities for re-use (zero discharge).
- Whether the installation will be permanent or temporary.

Operating mines can obtain a lot of information on the local aquifer and flow directions by installing Vibrating Wire Piezometers (VWP's) to measure groundwater heads, and flow gauges to measure the volume of water made on each level or in specific sections of the pit or underground. Mapping of inflows, coupled with structural mapping of the geology, gives very valuable information for identifying geological units or structures which control the volume and occurrence of inflows. The amount of monitoring data required is determined by the cost implications of not intercepting groundwater inflows. Data from VWP's can be used to develop pore pressure grids, which can be used to better assess slope stability and potentially reduce waste stripping (Morton et al. 2008). Fig. 3 shows a diagram of the conceptual model for Venetia diamond mine, South Africa (Morton and Muller 2003). The curved flow lines illustrate how the groundwater reaches the pit bottom and the kimberlite contact zone.

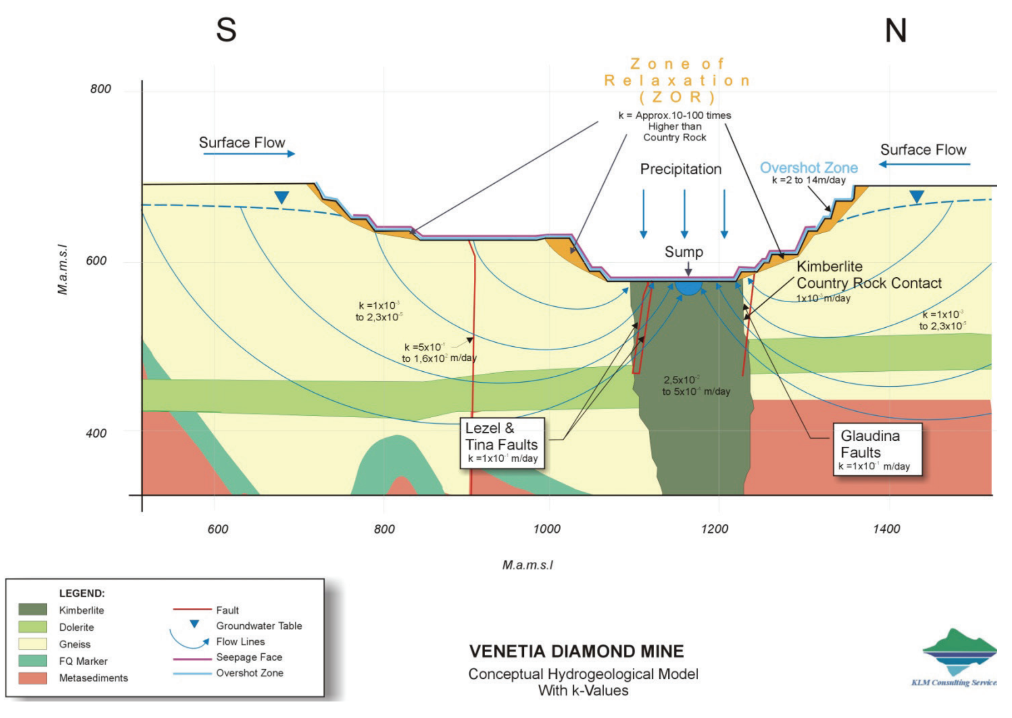

***Figure 3** Conceptual hydrogeological model, Venetia mine (Morton and Muller 2003)*

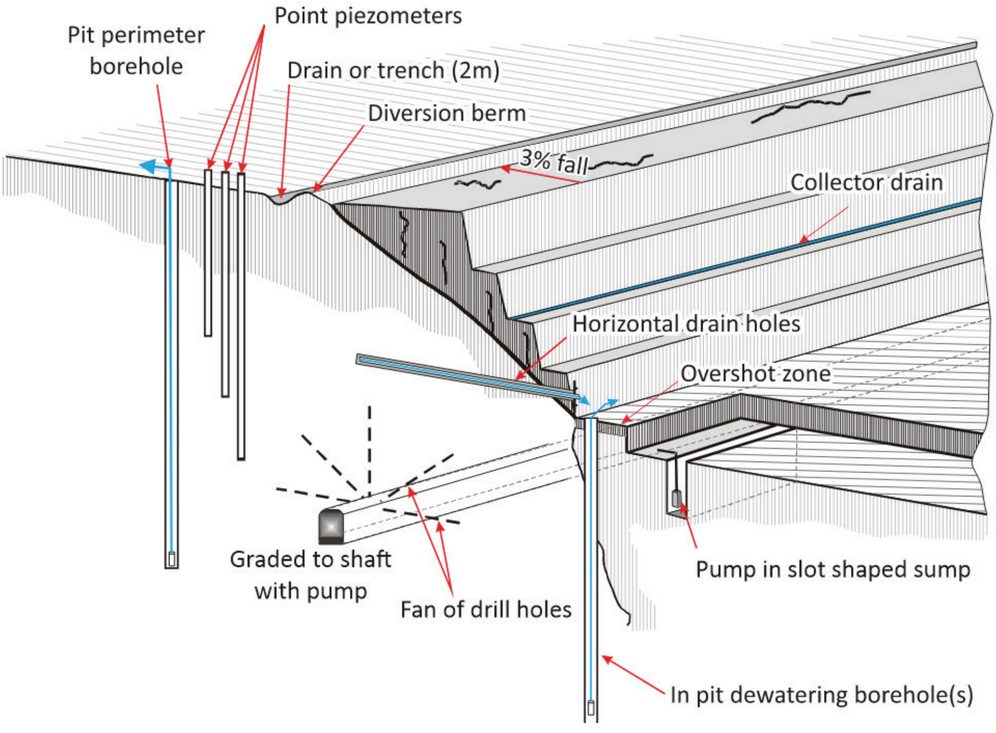

Figure 4 *Dewatering methods for an open pit*

The outcome of phase 1 is a list of options for the proposed dewatering design which can then be used in the numerical modelling which is conducted in Phase 2. Fig. 4 shows the different types of dewatering methods for an open pit. Often a combination of methods is required. Accurate storm water control is assumed.

Tried and tested dewatering methods for an open pit include:

Passive (post excavation)

- Sump pumping (preferably a deep slot not a scrape)
- Horizontal drain holes (+150 m long)

Active (in advance of mining)

- Wellpoints (popular for coal mining)
- Pumping boreholes – pit-perimeter, bench or in-pit/pit floor and underground
- Dewatering galleries (popular for kimberlite mines)

Sump pumping is the most often used dewatering method. One disadvantage of sump pumping is that the water will become polluted during either its travel time in the pit or its residence time in the sump. The water may then require treatment prior to disposal. Sump pumping is often poorly managed and can result in unnecessary production losses. Because of the ease of set-up sump pumping is often the most obvious and cost-effective method of dealing with groundwater inflows. However, in the long run it may also become an expensive method and it is best supported by additional methods that intercept the water before it reaches the pit floor. This includes accurate stormwater control is installed first.

When pumping boreholes are placed close to each other, the individual cones of depression combine to produce an interference effect and therefore lower the water table between them more effectively than if only one borehole was used. The use of several pumping boreholes increases effectiveness and can dewater large areas. Letlhakane diamond mine in Northern Botswana and Goldstrike in Nevada are examples of the successful use of pit-perimeter dewatering wells.

A dewatering gallery is typically a 4 × 4 m ring tunnel, often completely encircling the excavation which effectively intercepts the bulk of the groundwater flowing towards the open pit or underground. This method was more popular when the cost of ground-breaking was not as high as it is today.

Horizontal drain holes facilitate drainage of in-pit slopes and may be used in combination with deep well dewatering to provide a cumulative dewatering effect.

At the end of Phase 1, the options for dewatering are agreed and the monitoring network is improved to support the next phase.

Phase two

The objective of Phase 2 is to indicate at a high level of confidence the probable effects of mining on the groundwater and vice versa. The level of confidence is determined by the quality and quantity of data collected including an update of the monitoring network. A numerical hydrogeological model is created which is calibrated and evaluated for sensitivity for specific parameter ranges.

The numerical model is used to predict water levels and inflows for different scenarios. The model is designed to be updated regularly using monitoring of groundwater levels and the volumes of groundwater pumped out of the mine. These figures are used to recalibrate the model and simulate dewatering design options to support every stage of the mine's life.

The result of Phase 2 is a report on different dewatering scenarios for life of mine giving estimated volumes of water to be removed and estimated probable effects on the local water table. A good modeller produces a range of values, not precise figures, illustrating the levels of uncertainty in the data. Fig. 5 shows the range of inflows estimated for a planned open pit mine over 13 years.

Phase three

The objective of Phase 3 is to plan and monitor the effectiveness of an initial or updated design to divert flows or to dewater the planned mine or mining area. This is done by setting water level drawdown targets (Δh) for water levels for different mining sectors and mine schedules. This can be visualised in 3D with the cone of drawdown planned to be kept at least a few meters below the mine working areas. Fig. 6 shows the water level targets for a planned 600 m deep underground copper mine. Phase 3 uses monitoring and regular updates of the numerical model to evaluate the effectiveness of the dewatering design.

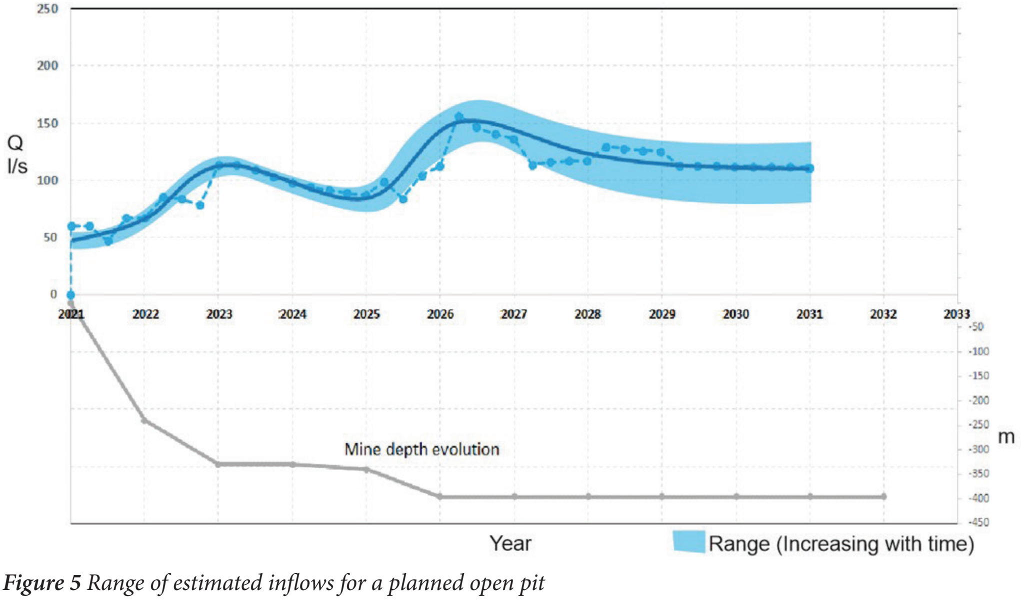

***Figure 5** Range of estimated inflows for a planned open pit*

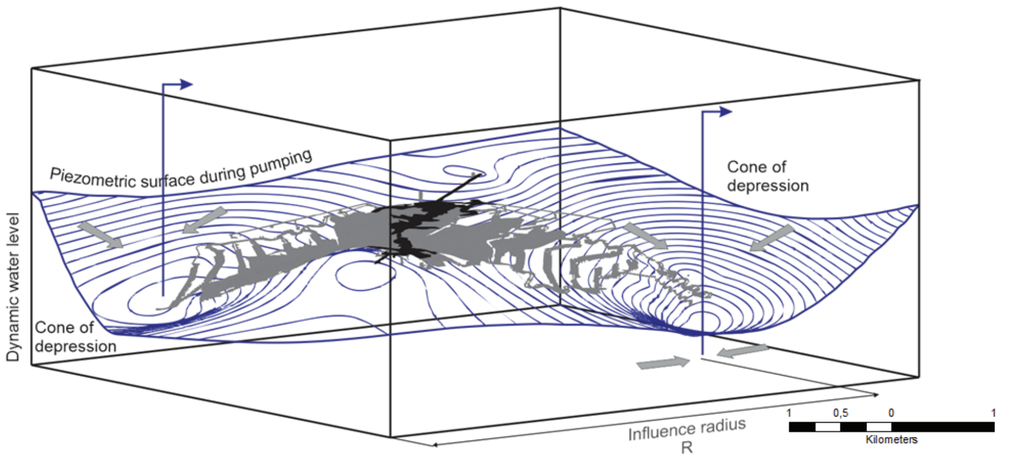

Figure 6 *Desired cone of drawdown for life of mine of a 600 m deep underground copper mine*

Where feasible, a trial dewatering system can be set up for a specific area of the mine. The trial can then be developed into the full-scale dewatering implementation. Once Phase 3 is completed the process starts again with updating the monitoring regime and revising the conceptual model. It is important to always question the conceptual model prior to updating the dewatering design. A comprehensive monitoring network enables evidence-based decision making for the evaluation of the dewatering design and successful operation. Phase 3 is also used to manage the dewatering operation and continually check back on the success and cost effectiveness of the design and implementation. Phase 3 is also used to plan and implement adaptations to the design or even change the dewatering strategy when the original design is no longer fit for purpose.

Conclusion

The dewatering of an excavation is best approached with a three-phase strategy. Phase 1 identifies the problem and defines the scope of the dewatering required. Phase 2 models the options and makes predictive simulations. Phase 3 sets dewatering targets and then produces the road map to achieve them. Phase 3 is also used to manage the dewatering operation with regular check backs to ensure the design is fit for purpose. At all times the emphasis is on use of evidence from a monitoring system measuring daily water levels and pumped volumes to support decision making. This will enable management to determine the optimal method of dewatering and to decide on the most cost-effective and appropriate dewatering system design.

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