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A PHASED APPROACH TO MINE DEWATERING

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ABSTRACT

The construction of an excavation often means penetrating the local or regional water table. This causes inflows, which if the country rock is significantly permeable can become at best a nuisance to operations and at worst a hazard. Dry working conditions are preferable as they reduce wear and tear on machinery, reduce earth moving costs and often improve slope stability and therefore safety. Options available to mine management are dewatering, diversion, sealing or a combination of methods. To achieve the most effective, least cost method it is essential that the origin of the ground water is determined. The success of a dewatering exercise is directly linked to an understanding of the ground water regime. Mines cannot afford to use "blanket methods" when dealing with ground water. It is essential to target the actual inflows and not divert or seal off water indiscriminately.

The potential impact of ground water inflow to a mine can often be assessed at the pre feasibility stage. A hydrogeological investigation is best tackled in three phases. The first phase is a desk study and borehole census and can be initiated by the mine or quarry developers. The main objective is to determine water levels and regional hydrogeology. It is very important that the Phase one hydrogeological investigation is started at the same time as the geological investigation. All exploration drilling records should include comment on where water was encountered and in what volume.

The objective of Phase two is to indicate at a first level of confidence the probable impact of mining on the ground water and vice versa. The level of confidence is determined by the quality of data collected in Phase one. At the end of Phase one management will be able to assess if water is going to prove a hazard to mining or not. If it is going to be a hazard then Phase three will be activated. The objective of Phase

three is to plan how to reduce or remove the hazard and either handle or divert the probable inflows.

Phase three can be accomplished through trial dewatering, computer modelling or through the application of practical experience. The level of sophistication at Phase three is determined by the potential costs and risks involved.

INTRODUCTION

The development of a mine often means penetrating the local or regional water table. This causes inflows of ground water, which if the country rock is significantly permeable, can become at best a nuisance to operations and at worst a hazard. Dry working conditions are preferable as they reduce wear and tear on machinery, reduce earth moving costs and often improve slope stability and therefore safety. Wet working conditions are to be avoided for the following reasons:

- unsafe working conditions
- difficulty in ore handling
- increased explosives cost
- possible slope instability
- reduced operating life of machinery
- nuisance factor
- possible floor heave

This paper describes the steps necessary to plan an effective dewatering system for a mine. The approach is a phased investigation that builds up a picture of the potential problem. The phased approach allows gradual expenditure appropriate to the confidence level required.

PHASE ONE

The potential impact of ground water 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. An initial appraisal (or Phase one investigation) can include a desk study and borehole census of the area to determine local and regional ground water levels. The main objective is to determine the regional hydrogeology and assess its potential impact on the mine. It is also important to assess the potential impact of the mine on the ground water.

In areas where ground water is considered a vulnerable resource a national government's Department of Water Affairs and Forestry or Department of Mines usually require an impact assessment and assurance that mining activities will not damage local aquifers or cause excessive pollution of either ground and surface water.

From experience and from a cost point of view it is very important that, if possible, the Phase one hydrogeological investigation is started at the same time as the geological investigation. Any exploration drilling records should include comment on where water was encountered and in what volume. It is not uncommon for a hydrogeologist to be asked to review the site and be given borehole logs which have no ground water information on them at all.

One potential mine site in Natal, South Africa had 146 boreholes drilled on it, there were no records of water strikes and not one borehole had been cased or left open so no water levels could be measured. To obtain information on the site another 11 boreholes had to be drilled at a cost of R 55 000 (in 1984). This expenditure would have been totally unnecessary if only some of the boreholes had been correctly logged for water data.In essence a Phase one investigation is a desk study of all readily available information without the expense of drilling and test pumping of the aquifer. The objective of a Phase one study is to determine at a preliminary level if ground water is likely to prove a significant problem. If the first phase indicated that ground water would prove to be a problem and therefore incur additional operating costs a second phase can be initiated. The Phase one study for an operating mine that encounters ground water inflows would be a borehole census and desk study to establish a preliminary assessment of the ground water regime for the area ie a first level assessment of the problem using readily available data.

PHASE TWO

The objective of Phase two is to indicate at a higher level of confidence the probable impact of mining on the ground water and vice versa. The level of confidence is determined by the quality and quantity of data collected. At the Phase two level information collected during the desk study would be augmented with new information collected from a few strategically placed boreholes on and around the proposed site. Phase two would aim to determine a preliminary estimate of aquifer parameters such as the volume of ground water in storage, flow characteristics and the dimensions of the aquifer or aquifers.

Phase two for an operating mine would take into account all information available on ground water strikes and inflow occurrence. Operating mines can offer a lot of information on the local aquifer by installing pressure gauges to measure ground water heads and flow gauges to measure the volume of water made on each level or in specific sections. Mapping of inflows underground, coupled with structural mapping of the geology, gives very valuable information for determining the structures which control the volume and occurrence of inflows. Information essential to the understanding of the ground water regime at a mine is the regular monitoring of ground water levels in boreholes sited around the mine and water pressure gauges located at key positions underground. Phase two would identify the water levels and pressures which should be monitored by the mine. The amount of monitoring data required would be determined by the cost implications of ground water inflows and the amount of data already collected in Phase one. The result of Phase two would be to estimate the volume of water the mine or quarry can expect to encounter over the initial operating, development years or life of mine.

PHASE THREE

The objective of Phase three is to plan an initial design to divert or dewater the planned excavation. Once the required information is available Phase three can be accomplished through computer modelling. Where necessary a trial dewatering system can be set up. The application of practical experience throughout phase three is essential to it's success. The level of sophistication at Phase three is determined by the potential costs and risks involved. If ground water is shown to be a significant problem there are basically two ways of dealing with it. The ground water can be either removed or diverted. Ground water that cannot be moved or diverted, cost effectively, can be sealed off from the workings.

GROUND WATER DIVERSION

Diversion means the deflection of the ground water flowing towards the excavation. Methods of diversion are:

- grout curtains,

- grout injection,
- cover drilling, and
- grouting piling.

The success of a grout curtain of grout injection is dependent on the penetration made by the grout. It is most effective when diverting ground water that flows along geological structure. Phalaborwa copper mine and Northam platinum mine are examples of sites where ground water is diverted by grouting.

Cover drilling and grouting is typically used for underground mining in the development of new haulages. The problem with diversion underground is that often inflows are merely delayed and that the diverted water may build up ahead of the development causing a greater potential hazard. It is therefore important to measure water pressures and monitor any build up of pressures.

Diversion may be a suitable method for a mine in which the bulk of the ground water flows through known underground channels. In other cases where the ground water movement is more diffuse a dewatering and grouting system may be a more effective option.

The main considerations for ground water diversions at a mine are cost and effectiveness.

DEWATERING

Dewatering means the removal of ground water from an area through the lowering of the water table. Methods of removal are:

- wellpoints
- deep boreholes
- dewatering galleries
- drains
- sump pumping
- a combination of some of the above

Wellpoints and boreholes dewater through the principle of pumping interference. As a borehole is pumped a cone of depression in the water table develops. 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 the effectiveness of this method and can dewater significant areas. Letlhakane diamond mine in Northern Botswana is one example of the successful use of this method.

Wellpoints utilise the same principle. They are small diameter screens that can be driven or jetted into unconsolidated sediments. The water is usually abstracted with a vacuum pump. The effectiveness of a wellpoint is determined by the permeability of the material and controlled by atmospheric pressure.

The maximum drawdown which can be achieved is the difference between the suction head and the static water level. In practice the greatest suction head that can be developed is about 6,1 to 6,7 m. Wellpoint dewatering is therefore used to dewater near surface saturated sediments. It is often used in combination with deep borehole dewatering to effectively dewater a multi layered aquifer. Wellpoints have been used to dewater alluvial aquifers adjacent to some coal mines along the Vaal river channel in the Northern Free State.

A dewatering gallery can be described as a ring tunnel, often completely encircling the excavation. This effectively intercepts all ground water flowing towards the quarry or open pit. The ground water is then pumped to surface. This method was more popular when the cost of ground breaking was not as high as today.

Drains are a shallow aquifer solution but may be used in combination with deep well watering to provide a cumulative dewatering effect.

Sump pumping is the most often used method in the low permeability formations encountered in the bulk of Southern Africa. Very simply, any ground water seeping into the excavation gravitates to a low point and from there is pumped to surface.

One disadvantage of sump pumping is that the water can become polluted during either it's travel time in the pit or it's residence time in the sump. A typical example would be the creation of acid water from water in contact with coal in an open cast mine. The water then has to be treated prior to disposal at a very high cost.

Another disadvantage is the cost of the power required to lift the water from the lowest point in the mine or quarry to it's disposal point. Sump pumping, because of a lack of information on the volumes of water to be moved, is often poorly managed and can result in unnecessary production losses. However because of the ease of set up often sump pumping is often the most obvious and cost effective method of dealing with ground water inflows. In the long run it may often be the most expensive method.

SELECTION OF A DEWATERING METHOD

The selection of a dewatering system would come under the Phase three hydrogeological investigation.

The selection of which major type of dewatering system to use depends on many factors. Some of these factors are:

- Hydrogeological conditions
- Length of time pumping is required
- Volume of water to be removed
- Whether pumping equipment can be installed in the operational area
- Availability of drilling and dewatering equipment.
- Contractor experience

The characteristics of the water bearing formation that must be determined before designing a dewatering system are:

- Whether the aquifer is confined or unconfined
- Transmissivity and storage coefficient of the aquifer
- Static water level
- Seasonality of potential inflows
- Depth and thickness of the aquifer
- Sources of recharge to the aquifer and location of these sources

The bulk of this information would have been collected during the Phase two investigation. Phase two would also have shown up any areas of low confidence and made recommendations on say additional drilling required to firm up knowledge of the aquifers.

The design of a dewatering system will be specific to the mine under scrutiny. To achieve the best method of dewatering a multi disciplinary approach is recommended making best use of management and mine engineers. This requires the collation of important information on the mine or quarry including:

- o Dimensions of the area to be dewatered
- o Depth to which the water levels must be lowered
- o Plans for disposal of the water removed
- o Whether the installation will be permanent or temporary
- o Quality of the water that has to be removed

Once all the criteria have been assembled a scenario for dewatering can be designed. The effectiveness of the method chosen can be predicted through the use of a computer model.

COMPUTER MODELLING

A computer model can be set up to simulate inflows to the excavation over time as the quarry or mine enlarges. It can also be used to model the effect of say a ring of dewatering wells. More importantly it can be used to determine the number and depth of dewatering boreholes or wellpoints or a combination of both needed to draw water levels down below the planned base of the excavation. Modelling is usually done in three stages. At stage one the initial model is set up and used to plan the initial dewatering of the excavation. A trial dewatering system is set up and monitored as the initial cuts are made. At stage two the model is calibrated with real data and it's accuracy enhanced. Stage three is the interactive use of the model throughout the life of the quarry or mine.

The interactive model can be used to predict water levels for subsequent enlargement of the underground excavation. The basis to the interactive use of the model is the regular monitoring of water levels and volumes pumped. These figures are used to re calibrate the model to meet every stage of the mine's life.

The degree of sophistication of the model can range from very simplistic through to a complete finite element based model which itemises the ground water flow from each aquifer. The bottom line is cost effectiveness and it's usefulness to planners and management. Often the most simplistic 'black box' model is all that is required. In some cases computer modelling is not required but in all cases it is important to determine a water balance for the operation. One essential part of the water balance is the ground water flow into the mine or quarry. Only by understanding the source and volume of flows involved can the ground water be effectively managed.

GROUND WATER DISPOSAL

After removing the water there are several options available for it's disposal.

According to the South African Water Act of 1984 no water can be allowed to leave a mine or industrial area unless it meets the minimum standard as set by the act. If the water does not meet the required standard it must be treated until it does.

- o Methods of treatment include:
- o Evaporation
- o Reverse osmosis
- o Liming or de acidifying
- o Dilution

All are expensive. It therefore makes sense to prevent any deterioration in water quality. This can be done by reducing or preventing the contact of the ground water with any soluble minerals. This requires careful planning of the movement and storage of water but can be done with additional cost benefits.

CONCLUSION

The dewatering of an excavation is best approached with a phased investigation. The investigation starts as a low cost exercise to determine if ground water is going to be a problem or not. If a problem is anticipated the investigation can be advanced to the next phase. At all times the emphasis is on the cost effectiveness of data collection and the use of realistic confidence levels. The final phase is the design and implementation of a dewatering scheme. Where inflows are predicted to be a significant problem computer modelling is recommended. This will enable management to determine the optimal method of dewatering and to decide on the most cost effective design.