Practical Mine Dewatering by Means of Surface Drilled Wells

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Mine dewatering has long been a problem with mines and some of the shallowest mines have the biggest problems. Machinery was developed by the ancients for raising water by rope buckets with treadmills or by horse whim. From the 1700's on into the early part of this century, massive cornish pumps or equivalent were the vogue powered by steam.

One Australian mine pumping system was claimed to be the largest in the world just after the turn of the century. It was installed at Beaconsfield in Tasmania and the mine, like so many other mines of the period, were beaten by problems and cost associated with mine dewatering. The owners of that mine are looking at the feasibility of dewatering using surface drilled wells.

Much simpler and smaller pumps are the order now and it is feasible to use boreholes instead of shafts to contain the pumps or else to use the holes to convey discharge waters to the surface from pumps located in drives or stopes.

Contrary to what drilling salesmen may tell you, drilling technology is not a fast moving industry. Techniques used at the turn of the century are in most cases still used and few techniques are available that are really new.

That is not to say it is a stagnant industry. Rigs are still necessary at the head of the hole, air, water or mud is still used as a flushing medium, cable tool and rotary rigs are still really the only choice. No super systems based on lasers, high pressure jet abrasion, ultrasonics or other have been proved commercially viable, yet however, much has been done to increase the performance of traditional methods.

This paper addresses some of the simpler and more practical methods available now both here and overseas and some of the advantages and pit falls inherent in such systems.

AIR DRILLING SYSTEMS

The major tool used in air dilling is the down hole hammer. Down hole hammers have been available now for nearly 50 years in their basic current form and apart from metallurgy, little has changed really. Of note however, is that people at long last are becoming conscious of the inherent straight hole drilling properties of such tools. This realisation, together with the use of good heavy and stabilised drill strings often of oilfield derivation, means stopes and drives can be reliably hit at considerable depths without recourse to slow and expensive deviation techniques to steer a hole to target. Accuracies of one in 400 can be achieved. Of considerable importance too is the availablity of big down hole hammers up to 750 mm and larger diameter. These tools, despite their size, retain the characteristics of maintaining good hole alignment allowing single pass drilling at large diameters eliminating pilot holes previously considered necessary. Penetration rates of 1 to 2 metres per hour are readily obtainable in hard rock and for depths of 200 - 300 metres from the surface in rock hammers are really the only way to go these days.

Drill rig requirements are simple, an ability to handle drill string weights with reserve to break out tool joints quickly and trip and lay down drill rods. Large compressors (2000 CFM @ 250 PSI approximately are needed to operate the larger tools. The drill string needs to be heavy to preserve the hole alignment and should consist of as heavy drill collars as available or than can be handled by the drill rig and with stabilisers fitted at regular intervals along the lower reaches of the drill string.

It is usually necessary to sleeve the drill pipe to a larger size to ensure a return air velocity of at least 3000 ft/min is attained or rig a dual pipe air lift system to bring cuttings to the surface. If large quantities of ground water exist, it is unlikely depths much greater than 250 m below the water table will be achievable practically using air when a reversion to fluid drilling using roller bits or similar may be necessary. Good hole alignment can still be maintained, provided most of the collar weight is held back by the rig and lighter than normal bit weights be used. A penalty of such drilling will usually be lower penetration rates than are possible with a hammer in the dry. Compressors of higher pressure are available and can extend depths considerably, however, hammer performance does drop off with increase in water back pressure.

If the mine can tolerate an inflow of water from the hole being drilled, a smaller hole may be drilled using air or fluid as necessary through into the mine and then the hole be opened out using a large hammer. The advantage with this process is the cuttings do not need to be blown back to the surface being dropped down the pilot hole instead.

As the hole is effectively drained of water by the pilot hole, there is fundamentally no limit to the depth the large diameter hammer can be operated to from the surface, and as the return velocity of air back up the hole is not a consideration lighter and more conventional hence cheaper drill pipe may be used, a very important factor in deep holes. With this process, it is imperative that cuttings are not allowed to bridge in the pilot hole blocking it off. If water is run continuously down the hole, say 400 to 800 litres per minute, it will largely prevent bridging but it is all the more water that will enter the mine and need to be removed ultimately.

Since the down hole hammer is inherently a straight hole drill and always tends towards straightness, it may not follow a pilot hole. It is thus necessary to have a pilot piece on the end of the hammer bit. These are not always the most satisfactory part of such a bit as the blow energy cannot be conveyed to the rock by the pilot portion and they are prone to fatigue off. It is for that reason and also the roughness of drilling and resultant wear and tear on equipment, that we do not recommend pilot hole and then ream operations if there is any way they can be avoided.

For similar reasons, a conventional hammer bit should not be used for any reaming operations as the central buttons on it's face over the pilot hole may be ejected by the hammering acting ruining a very expensive bit. It is also not possible to use light weight drill strings enabling lighter rigs to be used as there is a very considerabe reflected energy from these large hammers which will cause fatigue problems in the lower reaches of the drill string. The use of large drill collar assemblies, whilst being necessary for maintaining hole alignment, also help to absorb some of this reflected energy and reduce the strain on the drill string. There are various forms of bumper subs and absorption couplings designed to absorb this energy, however, none are truly rigid and if used, must be placed above the drill collar string at which point they are of little benefit anyway.

At this point it should be pointed out that the above relates mainly to holes drilled vertically where the rig is set up accurately at the surface above the drilling target and then use correct tooling to allow sufficient accuracy to hit that target. There are many alternatives that can be considered to aid well alignment and success at hitting targets and these are now discussed.

If the well rather than being planned as a vertical well is started off at an angle say 10 to 14 degress off vertical, it becomes possible to cheaply steer a well to a target without the use of expensive deviation tooling, in hole turbo drills or the like. This is achieved by using again as above, a large drill string with stabilisers but using gravity combined with location and size of stablisers to control direction in the vertical sense.

If say a stabiliser was fitted to the lower part of the drill string immediately above the hammer, in an inclined hole, the drill collars will sag causing the hammer to tend to increase the angle. Alternately, placing stabilisers further away from the hammer will cause the hammer to drop decreasing the angle. Such holes retain the advantages of single pass drilling at large diameters, surveys of hole direction are usually done at regular intervals without pulling the tools from the hole. If the angle needs correcting, the stabilisers are moved up and down the string appropriately. It is important to note no sideways deflections are possible, however, substantial deflections in the vertical sense can be achieved easily. If such a hole was located at right angles to a drive where sideways deflections may be tolerated, successful intersections can be assured and at much less cost and more quickly overall than the usual method of turbo drill deviation methods then reaming to size.

Turbo drills or mud motors are commonly used both in deviated drilling in small size and in larger sizes in the oilfield. They have several disadvantages. The ones currently available have poor efficiency with low energy out compared to energy in. They require high pressure pumps, cannot be used with air and are very expensive to hire or buy. The limited output means drilling performance cannot match that of the basic rig alone, hence, the tool is useful only for controlling direction of a borehole. Any deviation should be very gentle as severe strains may be placed on drill pipe as the hole is deepened from operating in an other than straight hole, when conventionally drilling.

Turbo drills can be operated at any angle and can drill hard or soft formations with suitable choice of bit. If other means can be used to eliminate their use, they should be carried out to speed operation and save cost. For continual deviation to meet ore bodies, follow wandering strata or shaft alignments, they are undeniably a very useful tool. Care must be taken if reaming out a turbo drilled pilot hole as quite sharp deviations may exist and the reaming bit must have a flexible pilot ahead of the reaming cutters to ensure following the pilot hole.

It should perhaps be noted at this stage, the benefits of drilling such large holes. They can be used variously for purposes such as ventilation, services access, man retrieval in case of mine accident quite apart from pumping or discharge line use. As a mine developes, a pumping well may become redundant and could be used for other purposes as above.

Let us recap the advantages of large hole drilling for dewatering purposes:-

1. Cost effective composed to alternatives

2. Quick construction times

3. Accuracy of alignment

4. Potential for savings in shortened services and reduction of congestion in main shaft resulting from such services

5. Larger horsepower pumps can be installed in the well

6. Dewatering can be effected prior to shaft construction

7. Cuttings are a form of bulk sampling and can be used as a cross check on core results

8. Holes can later be used as stope backfilling holes or for other purposes

There are other advantages of large hole drilling which are less obvious which should be mentioned.

World wide there is interest in reopening old mines either for production or revaluation.

The shafts are commonly blocked with cave in, old collapsed timbers, general junk and backfill. They are usually flooded and very hard to clean out unless the water can be lowered. By drilling into a nearby old drive and placing a pump, levels of water can be lowered allowing orderly clearing of shafts. The drilling accuracy possible allows the old drives to be reliably intersected if their positions are known. Large diameter hammers can have several special advantages in old workings. They are less affected by voids such as old stopes. The hole sizes are readily changed as may be necessary if coring is found necessary and they have the ability to drill through many varities of junk as may be found in mines such as old pipes, ore buckets and the like. When dropped through the roof of a drive and drilled on, they are far less likely to wander off line with attendant relocation and casing problems later.

Mine Managers, when considering the use of large diameter drilling in particular to dewater or gain access to lower workings, do have an obligation to themselves and the drilling contractor to carefully assess likely strata to be encountered, water inflows likely and the accurate location of underground works. It is a very expensive exercise to lose a drill string from an unstable formation, a thin seam of sand or sudden intersection of old stope or drives. In good solid ground, air drilling has the greatest advantages of speed, accuracy of drilling and economics, however, if doubtful ground is likely, alternative methods of drilling such as mud rotary may be far more economical in the long run. Records must be located, researched and passed onto the contractor for his assessment before committing to work.

A FEW CASE HISTORIES

In 1985 we drilled two 420 m deep x 500 mm diameter holes for methane drainage at the Tahmoor Mine in N.S.W. through hard sandstone rock. The holes were vertical and drilled using the above techniques. The upper 90 m was drilled by downhole hammer and a fully stabilised drill string. Roller bits and fluid circulation was then used with the same stabilised drill string to final depth at 311 mm diameter. The holes were then reamed to 500 mm using roller bits and fluid but still with a fully stabilised drill string. 457 mm OD casing with 16 mm wall was run to 420 m and the hole alignment was such that it could be turned freely by hand when in place. Surveys of the holes were not carried out until completion of both holes using gyroscopic Eastman equipment and tolerances were maximum deviation .7 m one hole, 1.2 m the other. A light spiral around the centre line of the hole was evident and we have no reason to believe it would have increased with depth.

The holes were later connected to drives at 420 m.

Other holes have been drilled into drives at various mines accurately without deviation in vertical holes at many locations for fill holes, ventilation, rising mains for pumps and dewatering purposes.

At Cobar, we have used the angle drilling techniques and deviation by stabiliser placements hitting underground drives "Dead On" to allow installation of raise drill heads underground without further works. These holes were regularly surveyed with corrections made as necessary to preserve the necessary high degree of alignment for the raise drill rods.

A little while ago at Bendigo, we drilled some holes into an old drive for dewatering an old mine. These holes were associated with disposing of water into a nearby but not connected mine whose drives extended some distance away across town from the work area. The water resulting from mine shaft dewatering was thus transferred underground in a built up area without the need for difficult and expensive surface pipe works likely to cause trouble with nearby residents. The holes were drilled using a 270 mm diameter drill string, drill collars, stabilisers and 311 mm hammer and bit. Price worked out little over $3,000.00 per hole for 90 m deep wells, a very cheap exercise for the mine owner.

Whilst the amount of drilling done in Australia to date on this type of work is not immense, we have been able to prove the practicality of targetting large holes without using pilot holes or expensive and slow deviation equipment and being able to rely on the accuracy of the results.

If planning the use of such large holes in your mine, we strongly recommend well designs that do not intersect old stopes drives or like areas on the way to target if at all possible, as such obstacles do prejudice accuracy and add significantly to the costs and risks of such holes. A further consideration, if contemplating such holes, is the corrosion effects of mine gases, water and sand. We have installed all stainless pipe strings in some holes, A.B.S. and F.R.P. in others as necessary. If cementing in place is required to prevent groundwater flow down the back of the pipe into the mine, consideration must be given to the hydrostatic pressures exerted by such grouting prior to set and if the holes are deep enough pressure from the groundwater itself.

DIRECTIONALLY DRILL HOLES

Recent developments overseas in monitoring hole deviation continuously whilst drilling, open all sorts of possibilities not considered economically feasible previously. Holes can be accurately drilled to target using traditional hole survey instruments both magnetic and gyroscopic and holes "steered" to target by using wedging or mud motors with bent subs. This is time consuming but high accuracy is possible and some excellent work has been carried out in Australia at several mines steering holes to intersect ore bodies, several being intersected from the one surface collar. If accurately placed holes are located in very close proximity to a shaft, lesser quantities of water need be pumped or grout placed to control water. Development and ready availability of continuous in hole monitoring equipment, has the potential to lower costs of drilling such wells dramatically. Mud motors available in Australia do not seem to live up to their promise and at the moment can be considered as little other than a deviation tool and not a drilling tool. It is not unusual to require to ream out such slim deviated holes and quite different techniques are necessary to straight drilling due to the initial poor alignment of the pilot holes. If large stiff and stabilised drill strings are used, the reaming operation is unlikely to follow the small pilot hole wanderings so a special bit arrangement is necessary. Hole reaming is best done by rotary and not percussion methods. Unstabilised but heavy drill collars should be used to provide adequate drilling weight on the cutters. The use of pulldown is undesirable because of strain on drill pipe and wear on the pipe from the walls of the hole. A hole opener should be fitted below the drill collar and may be of roller, P.C.D. or diamond.

Ahead of this should be long flexible shaft with a pilot bit gauged slightly larger than the pilot hole size. This should be followed by a stabiliser preferably of the roller type. The pilot bit must be gauged larger so it drills a little which keeps it screwed on tight.

If a deflection exists in the pilot hole, the pilot bit of the reamer will steer the collar and prevent it losing the pilot hole. This type of operation has been practiced little here but as the ability and cost effectiveness of small diameter deviated drilling improves from technological advances, we will see much more of it.

Any reaming system such as that above puts considerable strain on drilling equipment. Drilling is usually rough due to shoulders on the hole under the reaming bit breaking away in large lumps into the pilot hole. A reaming operation can be quicker than straight blind drilling but strong tooling is definately needed.

LARGE DIAMETER FLUID DRILLED WELLS

Open cast mines pose a different set of problems and large diameter wells have long been used to control hydrostatic uplift, promote slope stability and provide water sources for fire fighting, cooling and process water.

In Victoria, perhaps the best known are in the Latrobe Valley surrounding in particular the Morwell Open Cut. In the early days of development of this mine, ground movement due to groundwater was quite severe and farmers paddocks were said to rise and fall according to the water table. The first holes drilled at Morwell were drilled by cable tool using steel casing and whilst successful, were often found to have short operational lives due principally to ground movement steering or distorting the casings. A solution was felt to lie in the use of flexibly jointed casing and Hardie asbestos cement line lock casing was used until recently. This pipe is joined by nylon rope fed sideways into a groove in the coupling, locking the pipe together. Rubber rings inside the coupling provide a seal against joint leakage. Since the use of this pipe, the loss of holes has decreased significantly. A further factor undoubtably is the control of groundwater level is now possible as a full bore field is now installed and movement seems to have largely ceased as a result of the control of water table now being practiced. A non asbestos casing of similar properties and design is now being used in the construction of these wells.

These large holes have been drilled by the reverse circulation process using converted conventional rigs and depths to 300 m have been completed. Holes are drilled about 1000 mm diameter and 600 mm screens installed with gravel pack. Yields of the order of 100 lt/sec are produced. The borefields are surrounded by numerous observation wells and piezometers set at depths currently to 700 m. The current area of country being affected in some way by the dewatering exceeds 100 square kilometres.

An interesting variation of this system is proposed in Southern N.S.W., where similar water problems exist for a proposed open cut except the groundwater is quite saline and cannot be disposed of in the river system, so a second borefield is proposed in a nearby area to be used as injection wells. The aquafers here are even more saline and unlikely to be affected adversely by the injection of water.

GROUT INJECTION WELLS

Mine dewatering can be effected from surface drilled wells by using them not than as pumping wells but perhaps more productively as sealing or grouting wells. These wells are usually small in diameter and grout is injected under high pressure forming effectly a diaphragm wall if closely spaced. Such holes can, if suitably spaced, be very effective in sealing formations surrounding a mine site thus greatly reducing demands on pumping. Australia has developed a line of mobile rigs, I believe unmatched in the world principally for deep mineral testing using wire line diamond drilling methods and these rigs are producing meterage rates undreamed of only a few years ago. The rigs are all top drive hydraulically driven units with good speed and torque control of the rotation system, a very finely controlled feed system adjustable for both feed force and speed and good instrumentation. In hard rock these units are drilling holes at meterage prices the same as 10 and 20 years ago. In soft formations the kelly drive seismic style rig is hard to beat but usually drill slightly larger hole sizes. By setting packers in small wells and using high pressure pumps, grout of various kinds can be pumped considerable distances from each well which will reduce the permeability of the strata. Much work has been done on grouting of formations overseas and we believe the Australian industry has yet to discover the potential of grouting.

Grouts may consist of cement slurrys, bentonite clays, natural clays, resins and chemical grouts. Grout curtains are regularly installed beneath dams, on large construction sites but in Australia, no widespread use has yet been made in old mine areas where water has been a problem in the past. In Australia we have the machinery, but the expertise is yet to be fully developed.

DRILLED HOLES FOR SURFACE WATER REMOVAL

The traditional method of dewatering shallow areas is by installation of sand spear farms usually joined together and pumped by a single centrifugal pump. These spears are really small screens washed into place by circulating water through a ball valve in their base but in harder ground, predrilling with augers is often performed prior to washing down.

A variation on this common process which is cheap also, is to drill large diameter say 1 metre diameter or larger holes and lowering concrete rings in as drilling proceeds. Water soaks into such wells effectively and centrifugal sump pumps are used to remove the water. Very large quantities of water from shallow workings and pits is easily and cheaply removed with these systems.

A further method gaining acceptance, is the use of wick drains which are fibrous woven belt like material inserted into the ground vertically. Water by capilliary action works its way to the surface and is conveyed away by surface drains. No pumping is necessary and installation costs are low. The system is best used as an aid to slope stability rather than removal of large quantities of water. Wicks are installed by driving tubes containing the wick into the ground by a vibrator or piling hammer and then withdrawing the tube leaving the wick in place. Many hundreds can be installed in a day with a single machine.

PIEZOMETERS

To analyse the water quantities to be removed from an aquafer, to study the recharge rates and assess the costs to be incurred in opening up a new mine, it is very advisable to drill holes around the area and use them to assess the magnitude of the water problem. Mineral holes are drilled usually all over the area to assess the potential of the ore body but all too often are not used to assess the area for groundwater at the same time. If drilled solely by air, an approximation may be obtained of yield by monitoring water flows over a V notch wier. If fluid drilled information is not so easily obtained but standing water levels can be recorded, lost circulation zones noted and holes electrically logged. An indication of aquafer performance can be made in a clean hole by back pressurising with water, the reverse of pump testing.

Purpose drilling water wells with appropriate casing screens and perhaps gravel packs are the best way of evaluating water yields, recharge and quality. By test pumping at various rates, a picture of the scope of dewatering problems can be built up. Major sites around Australia are now routinely investigated usually in conjunction with mineral test drilling and results are assessed by hydrogeologists as part of the mine feasibility investigations. Drilled wells are the best way to assess mineral quantity and water quantity and it should be done concurrently. Accurate assessment of quality as well as quantity is needed for environmental considerations also as the water must be disposed of in a manner acceptable to the public and in these days of public awareness, this is of probably greater importance than the costs of raising it from the mine.

Dewatering a mine may effect landowners nearby reliant on ground water for stock or domestic from wells. Effect on groundwater must be evaluated. Holes drilled for mineral testing and sampling are quite suitable for conversion to piezometer use for monitoring purposes. The S.E.C. are currently turning most of their deep cored coal investigation holes into groundwater monitoring holes at little extra cost. Such holes can be used as references for ground water quality as companies are increasingly being accused causing pollution and having harmful effects on the environment. Monitoring wells installed now are their protect for the future. Drilling methods vary but in general the best results will come from wells drilled by air or by fluid using a degradable drilling fluid, and the well sealed from external influences.

This paper does not attempt to be a text of how to dewater mines. Its aim is to highlight the shifts in technology slowly taking place in the drilling industry and the effects such changes have and the possibilities being opened up with changing cost structures. Even more, it is desirable to remove men from underground because of cost and danger and from space considerations to place as much machinery and services on the surface. By drilling large holes from the surface, very substantial economies can be made underground and in some cases the hole can be in place and services supplied by the time mining reaches the hole location saving considerable production time.

Australia has been putting her ingenuity to work and we have developed a drilling industry second to none. Our multipurpose rigs and tooling are second to none and I do not believe miners are aware of the possibilities such machinery now offers. The task is certainly before us given Australia's remarkable gold history and the huge number of underdeveloped and abandoned gold areas yet to see the benefit of modern technology, quite apart from better ore recovery techniques but the possibilities and ease with which groundwater problems can be dealt with by large pumping wells, the grouting techniques and other factors which combine to make those old abandoned fields very attractive again. The success of low cost mine redevelopment and operation will be even more dependant on the use of even larger diameter low cost drilling being available.