COMPARISON OF DESIGNS FOR THE DEWATERING OF COAL, GOLD AND DIAMOND MINES IN SOUTHERN AFRICA

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Although the fundamental premises underlying the choice of mine dewatering design are the same for all mines, experience on Southern Africa Mines has shown that there are differences between the designs adopted by gold, coal and diamond mines. These are primarily in the areas of approach, methodology, design and application. The major contributing factor to the choice of dewatering design adopted is the initial perceived life-of-mine. Two mines of the same age can have very different designs depending on the original planned life of mine. Case histories are given with details of the dewatering designs.

1. INTRODUCTION

Accurate mine dewatering, depressurisation and ground water control, can save mines millions of dollars in reduced waste stripping, faster loading and improved safety. Typically, the three most expensive costs to an underground mine are labour, compressed air and water control (water control includes storm water control and mine dewatering).

The term dewatering means the removal of water from a high-wall or from underground. It can also be used to include depressurisation. Depressurisation means the reduction of pressure by lowering the head of water. In this paper, the term dewatering is used to include both dewatering and depressurisation.

Historically, mine dewatering design in Southern Africa has been achieved when water has become a problem during mining. The low rainfall and absence of very high yielding aquifers, has meant that the control of mine water inflows were often accommodated in the run-of-mine design.

Designs for coal, gold and diamond open pits are very similar. Water is collected at the lowest point in the open pit or underground mine, then pumped to surface. However, where profit is sensitive to the cost of extraction of water, there are often innovations, notably in the coal mining environment. Because of the rapid degradation of some types of kimberlite in the presence of water, diamond mines have also had to become innovative with their designs for the control and extraction of water.

The standard techniques used for mine dewatering are :

- Storm water control
- Sump pumping
- Inclined drain holes in high walls
- In-pit pumping boreholes
- Pit perimeter boreholes or pumping from shafts
- Wellpoints
- Drainage galleries and adits

These are summarised in Figure 1. Individual mines use a combination of methods, depending on the specific hydrogeology of the mine and the experience of the operator.

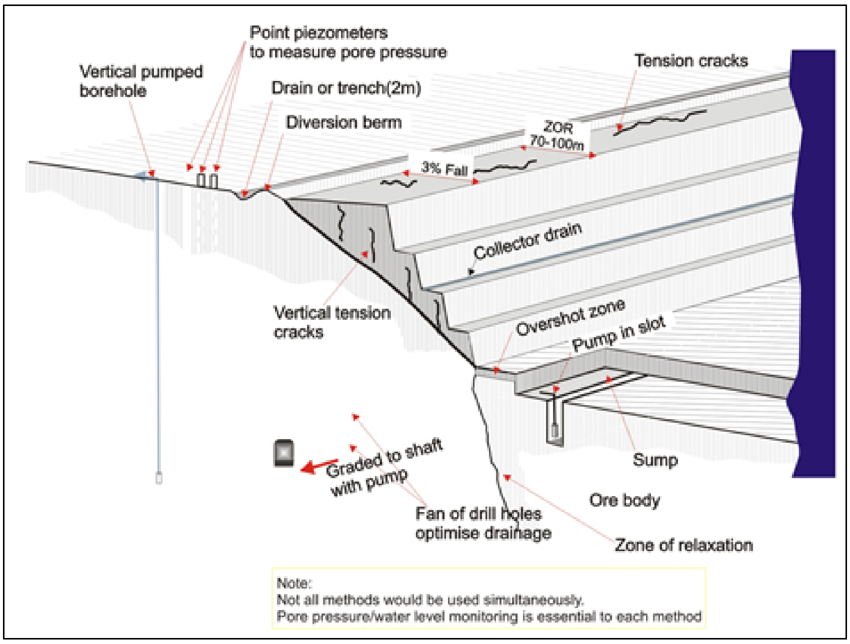

Figure 1. Summary of methods of mine dewatering

Coal Mine Drainage

Figure 2, shows the distribution of coal fields in Southern Africa. They are primarily located in secondary or fractured rock aquifers; however the coal seam itself can often be a minor aquifer. Figure 3 shows the stratigraphy of an East Rand coal mine (Smith and Whittaker 1986). The ground water is associated with the coal seams, sill contacts and lineaments. The hydrogeology could therefore be a layered system; with an upper perched aquifer, lower unconfined aquifers and deeper confined aquifers. This complex system often requires separate dewatering of each horizon. Individual structures such as faults and sill contacts can be dewatered; using boreholes sited using geophysical surveys.

Coal mine water control requires the separation of clean and dirty water. Dirty water is the water that has come into contact with the coal or carbonaceous sediments and has become degraded in quality, particularly in colour, pH and Total Dissolved Solids (TDS). All water pumped from underground is classified as dirty water and requires treatment before being released down stream. Industry best practice is to prevent as much clean water as possible from becoming dirty water.

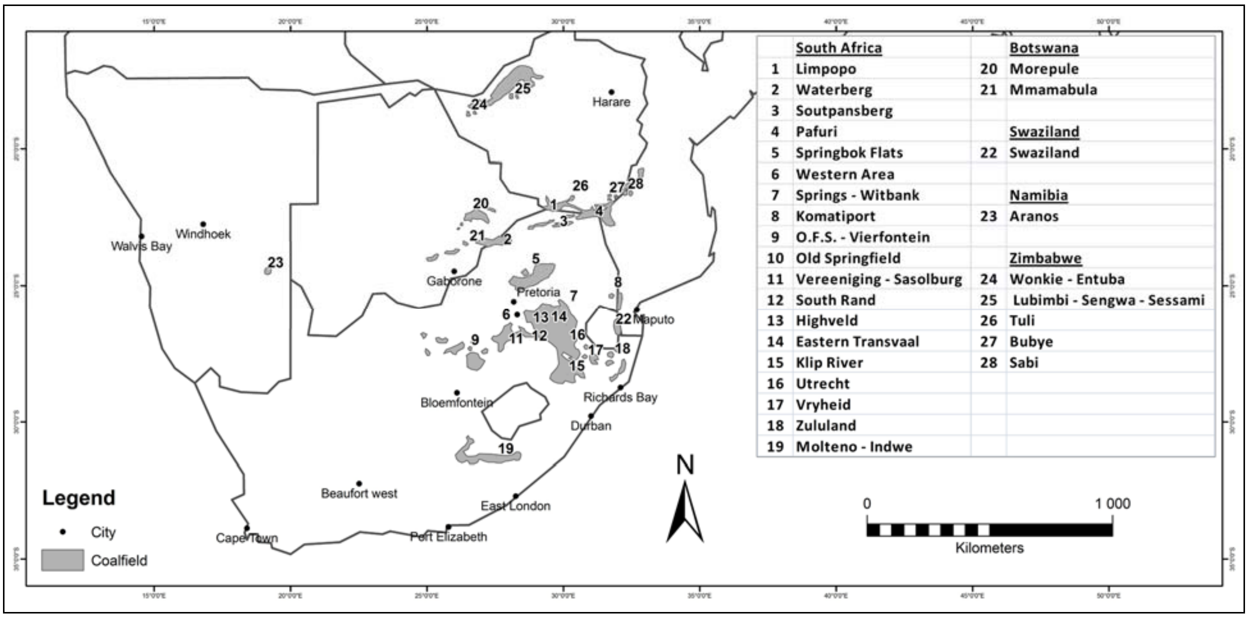

Figure 2. The distribution of coal fields in Southern Africa (Smith and Whittaker 1986)

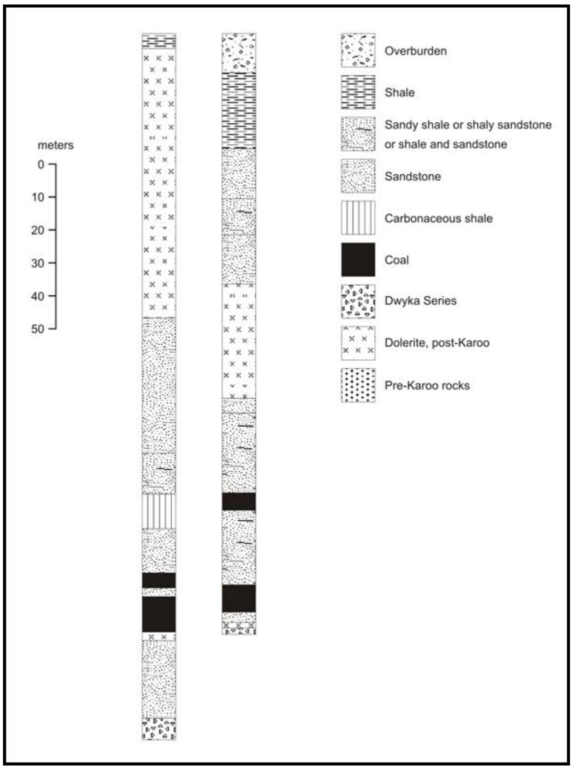

Figure 3. Stratigraphy of an East Rand coal mine (Smith and Whittaker 1989)

For open pit mines, the main concern is accurate storm water control. This is further divided into control of clean and "dirty" water. Surface contouring is done to protect the pits from overland flow from rainfall events entering the pit and the Zone of Relaxation (ZOR). The drains are kept open by regular maintenance, particularly prior to the onset of the rainy season. Mine dewatering is done through the use of sump pumps located in the lowest point of the pit, but preferably off the contact zone with country rock or regional lineaments that could be water bearing. Plates 1, 2, 3 and 4 are of sump pumping from Grootgeluk coal mine in the North West of South Africa.

Plate 1

Plate 2

Plate 3

Plate 4

In some areas overlying sediments have high clay content and require the depressurisation using well points. Figure 6 and 7 show the cross section of a wellpoint dewatering system, and an isometric of a multi- layered system. Wellpoints would be used in combination with good storm water control and sump pumping.

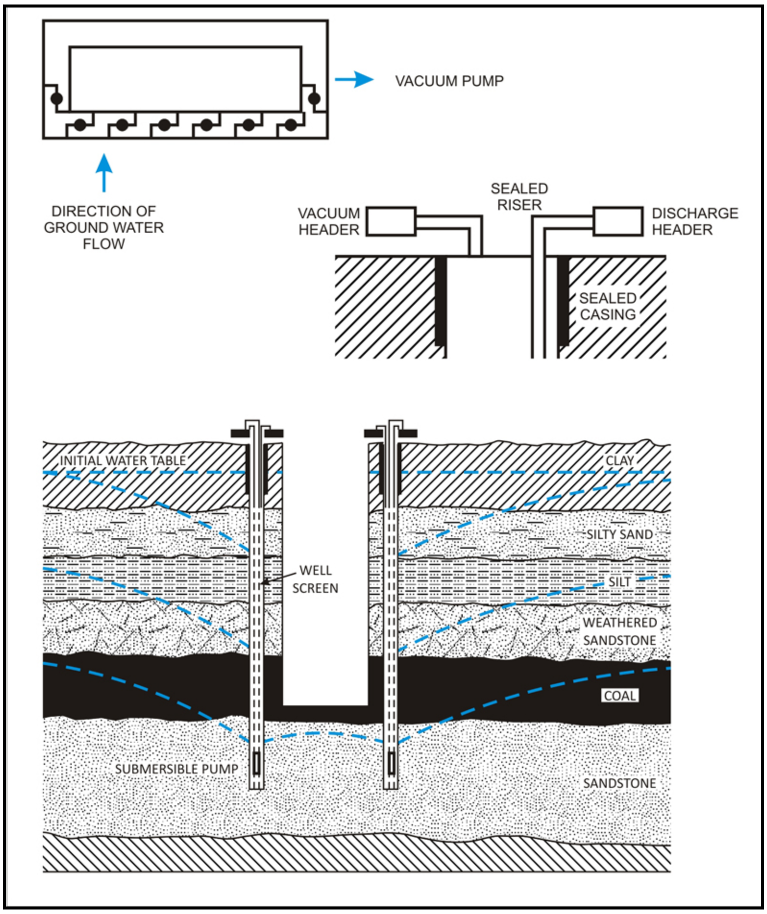

Figure 6. Design of well point system to dewater upper sediments

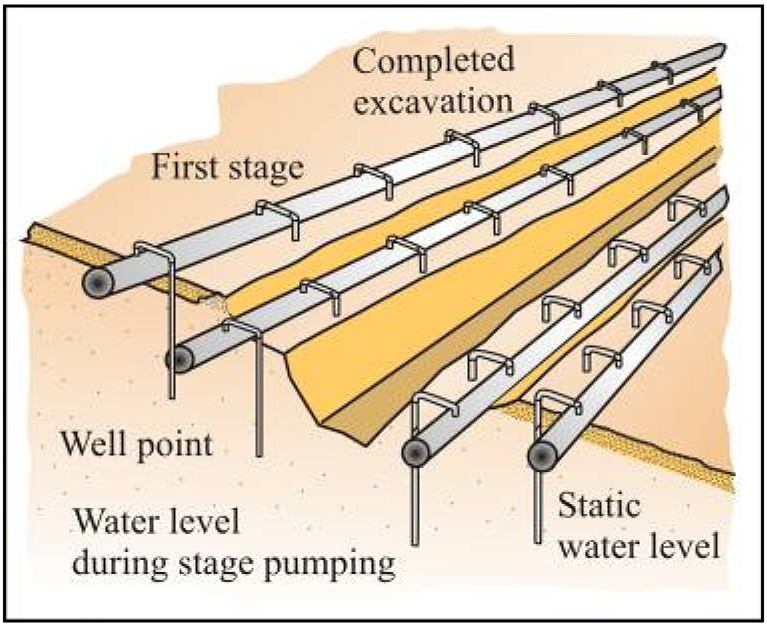

Figure 7. Isometric view of a two stage well-point system to dewater an elongated open pit

Best practice is mining up-gradient, where possible at a slope of >1.5 degrees to encourage the drainage of water along the undulating footwall, towards pumps at the shaft or decline. Local undulations in the footwall means that it is not always possible. Figure 4 shows a plan view of a room and pillar mine. In this example the main haulages are used to drain water towards the shaft but there are also areas of ponding, (shown in blue) that remain undrained. The mine also has an area of subsidence where there is stream flow capture, which is then drained to the main haulage. This is common but not ideal as it increases the amount of dirty water pumped from the mine. As soon as possible, the area of stream flow capture at surface should be graded and sealed to divert the surface water away from the collapsed ground.

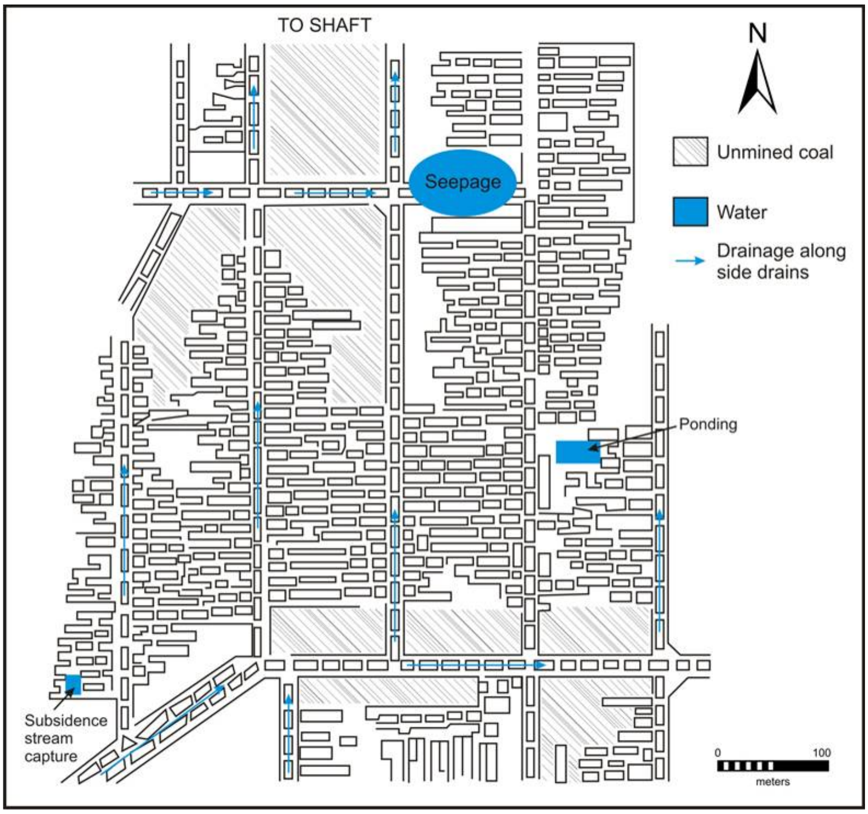

Figure 4. Plan view of a room and pillar mine showing seepages.

The drains along the main haulages are shaped in cross-section, as flat, shallow sloped troughs to facilitate easy drainage, but not so as to impede traffic (Figure 5). Where the footwall and side walls of the haulages have a high permeability, the drains are concrete or gunite lined.

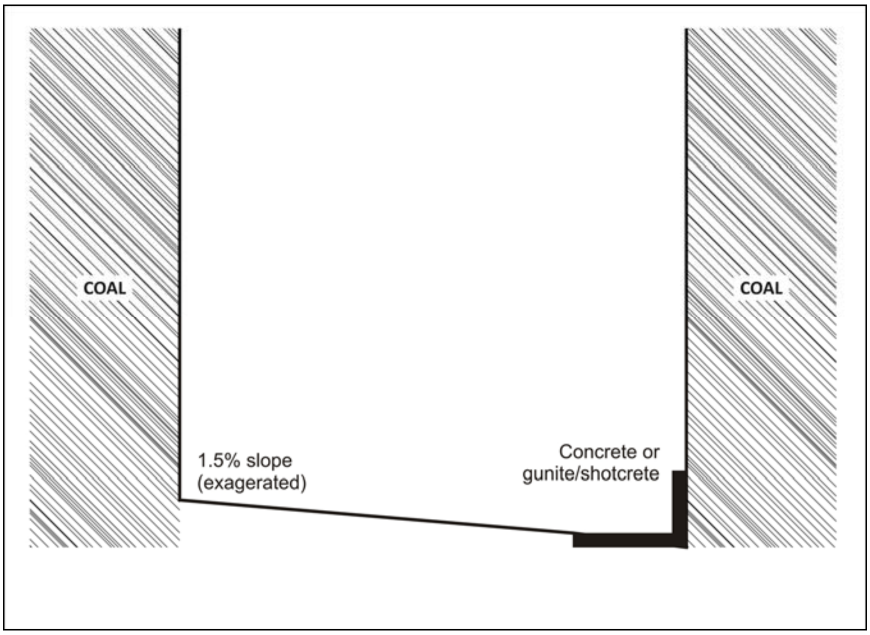

Figure 5. Cross-section of drainage gulley in main haulage

Gold Mine Dewatering

The design of gold mine dewatering systems in Southern Africa has been heavily influenced by the history of inrushes experienced on the West Rand (Wolmarans 1984). Figure 8 shows the distribution of early gold mines along the west rand and their association with dolomite compartments. The hydrogeology consists of secondary type aquifers in dolomite, often compartmented by dolerite sills and dykes. These may be influenced by regional extensive contact zones with the overlying Ventersdorp lavas.

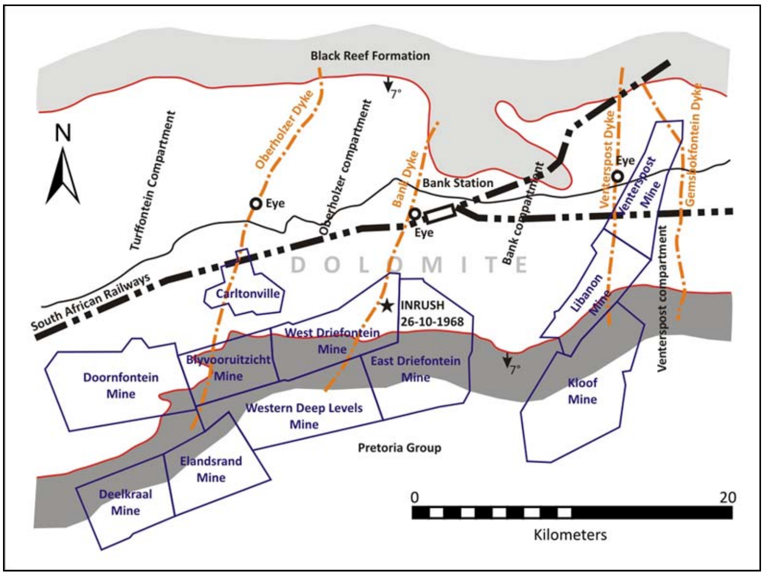

Figure 8. Distribution of gold mines along the West Rand (Wolmarans 1986)

The early mines did not produce sufficient water to supply the processing plants, therefore water was pumped from boreholes sunk into the deeper dolomites (Wolmarans 1986). Figure 9 is a cross section of the mine dewatering lifts at a hypothetical West Rand gold mine.

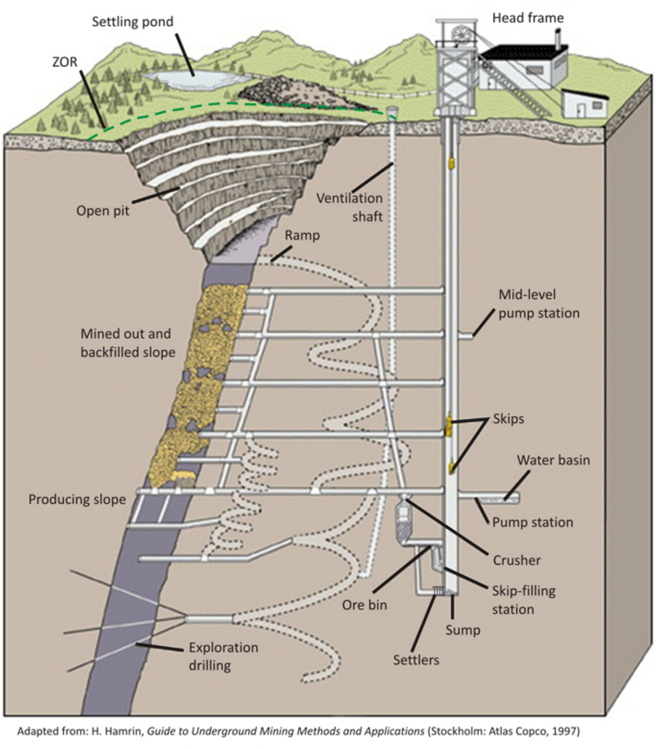

Figure 9. Cross-section of mine dewatering layout

Diamond Mine Dewatering

Kimberley Mines

The dewatering design for diamond mines in Southern Africa has been influenced by the history, (since the 1880's) of the inrushes and flooding experienced in the Kimberley region (Williams 1906). Plate 5 shows the flooded De Beers Mine pit in 1837.

Plate 5 Flooded De Beers Mine pit in 1837

The five deep Kimberley mines – De Beers Mine, Kimberley Mine, Dutoitspan and Bultfontein, (also known as Joint shaft) and Wesselton all experienced water inflows and mud rushes. These started to occur when the excavations breached the weathered horizons and entered into the unweathered kimberlite and shales. Water tunnels were installed at multiple levels. Wesselton mine's water tunnels were installed at 19m, 20m, 27m, 30m, 40m, 50m and 55m Levels, in the shales and melaphyres (lavas) to completely encircle the pit or in the case of Joint shaft mine, the combined pits. The water tunnels were typically 2.5m high and 1.5m wide and sloped towards a central shaft specifically used for abstraction of the water. Figure 10 shows a cross section of the Kimberley mine layout, at its final depth of 1070mbgl looking east. Figure11 is the plan view of the water tunnels that encircle Wesselton mine and the location of the shafts used to transfer the water to surface.

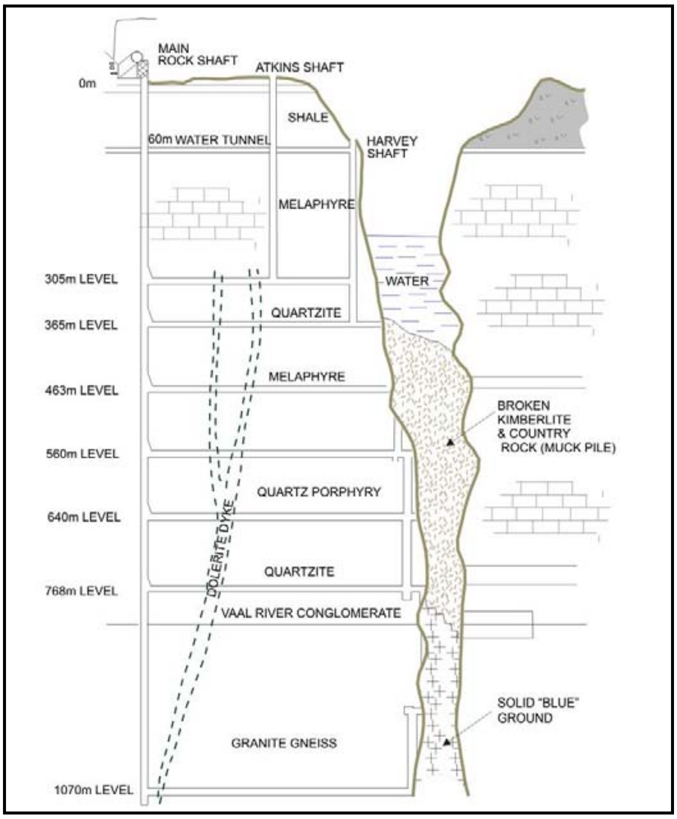

Figure 10. Cross section of the Kimberley mine layout looking East

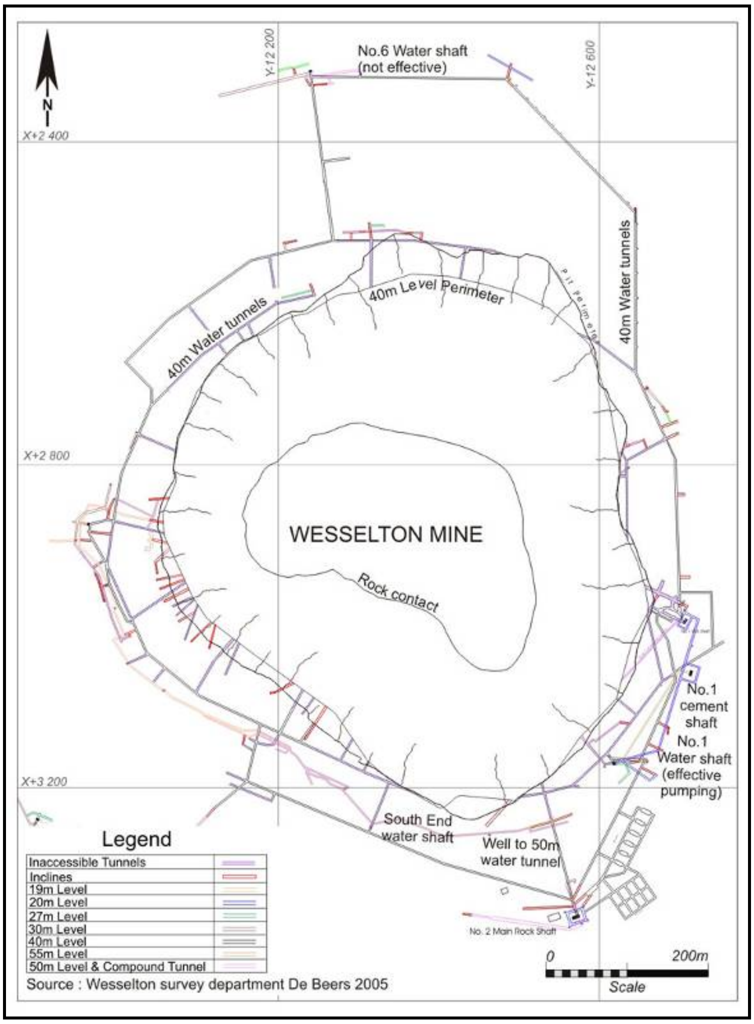

Figure11. Plan view of the water tunnels that encircle Wesselton mine

Below 350m below surface, Southern African diamond mines typically used underground mining methods. Ground water was still pumped from the water tunnels, (which continued to operate for the life of the mine) but water below the water tunnels and from within the glory hole, gravitated through water passes to a series of dewatering levels, where it was captured in lined dams. These were excavated in cubbies; the water was then pumped to surface. Scavenger trenches and boreholes were used up gradient of the pits, to intercept seepage water flowing towards the glory hole.

To summarise the early Kimberley mines used a combination of sump pumping, drainage galleries, pit perimeter trenches and boreholes; as well as gravity fed drainage to settlers and sumps at the lowest point of the mine. The water was pumped to surface using one to three mid level pumps. The madala (old) workings were drained, using water passes connected to the overall mine drainage system.

Finsch Mine

Finsch mine is a deep (+880mbgl) underground diamond mine, 120km SW of Kimberley. Plate 5 shows the open pit and main shaft from the air. The geology is banded ironstone over passage beds over dolomite. The dolomite has karsted horizons and there are large cavities (c 50m3) found to below 680mbgl.

The mining method used was open pit to 350m; then blast hole open stoping, followed by block cave. The dewatering of the mine was planned some twenty years in advance of need and the mine has benefitted from this foresight. In the early 80’s, a decline was installed down to 29 Level (290mbgl). It successfully drained the upper passage bed aquifers. The 65 Level (650mbgl) ring tunnel was completed in the mid 80’s and initiated the early drainage of the dolomite well, in advance of the block cave. Figure 12 is a plot of mining levels and water levels from 1964 to 2004, showing the gradual decline in water levels as the mine deepened.

FINSCH MINE 2003 (Looking south west)
(K.L.Morton)

Plate 6 Finsch mine

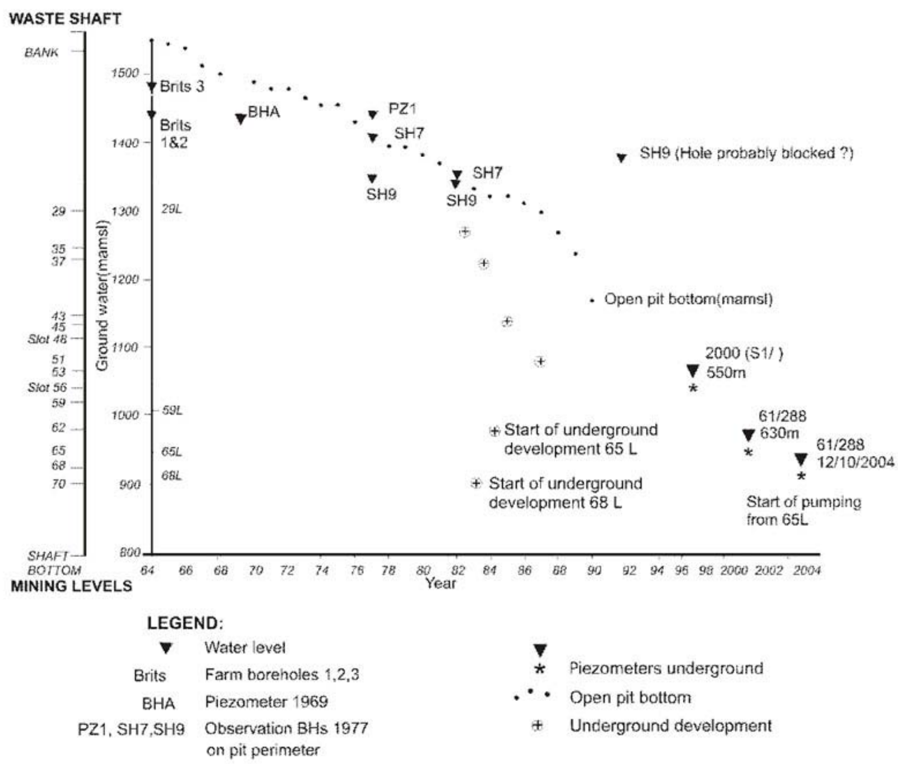

Figure 12. Mining levels and water levels from 1964 to 2004

In 2002, the first block cave at Finsch Mine started at 610m Level. With the advent of the block cave method, the dewatering design was changed from simple passive drainage, using gravity, to include active pumping from below 65 Level (650m below surface). Six large diameter boreholes were drilled from 65 Level and equipped with submersible pumps (Morton 2008). The water levels (potentiometric heads) were recorded in piezometers set between the pumping boreholes. The monitoring plots from the piezometers showed that when all boreholes were pumping, the water levels dropped to 40m below the block cave extraction level. Figure 13 is a diagrammatic cross section of the mine, showing the decline, shafts and underground levels, as well as the approximate water levels when all the pumping boreholes are active.

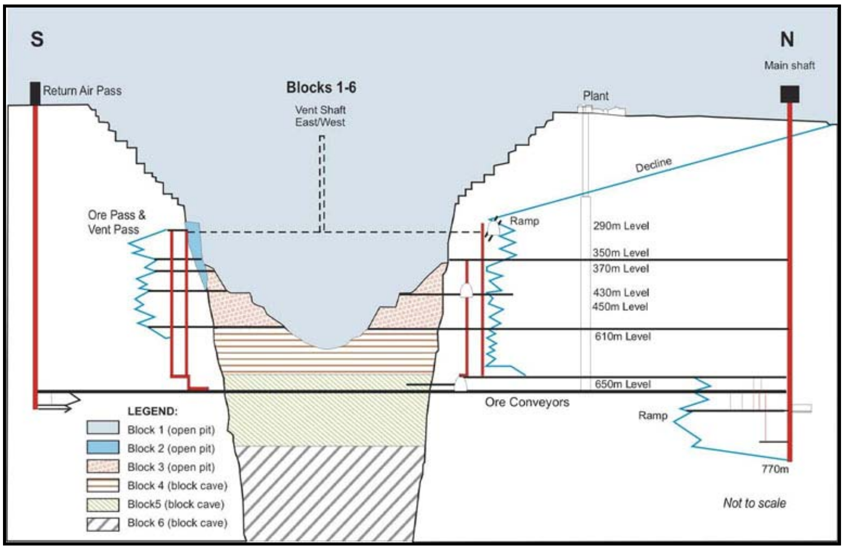

Figure 13. Diagramatic cross section of Finsch mine

Letlhakane Mine

Letlhakane mine is located in central Botswana. The kimberlite pipe intruded into horizontally layered sediments with three major aquifers; The Ntane sandstone, the Mosolotsane sandstone and the weathered granite contact zone.

In 1982, the mine had a choice of either pit perimeter dewatering boreholes or an underground dewatering gallery encircling the kimberlite pipe. Initially, a layout of eight pit perimeter boreholes was installed into the Ntane aquifer. Some of the reasons behind the choice of pit perimeter boreholes instead of a dewatering gallery, were the uncertainty on the life of mine, high cost of a gallery compared to drilling and lack of underground mining expertise.

Since the mine was first commissioned in the 1960's, the dewatering design has not changed. Figure 14 shows the cross section of the initial design (Connelly 1982), Figure 15 is the layout of the dewatering system in 1980 in plan view. Figure 16 shows the system as of 2006. The ring has been moved outwards to accommodate the larger pit and an additional number of boreholes have been added. The boreholes are drilled into the base of the lower Mosolotsane and granite aquifers. In-pit horizontal drain holes are used to assist with high-wall drainage.

Since 1980, Letlhakane mine has used pit perimeter boreholes. It is postulated that the cost of maintaining boreholes, pumps and the replacement of boreholes when mined-out, may have exceeded the initial cost of a dewatering gallery.

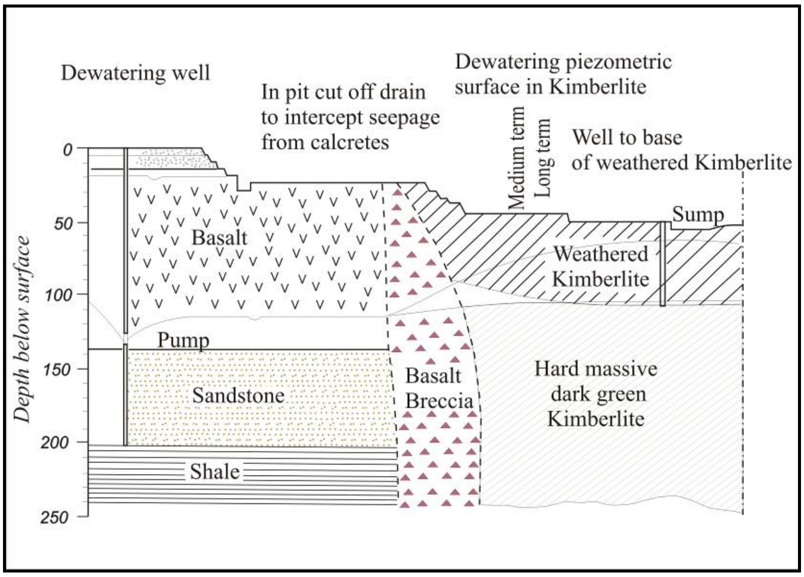

Figure 14. Letlhakane mine cross section of aquifers and dewatering system in 1980 (Gibson and Connelly 1982)

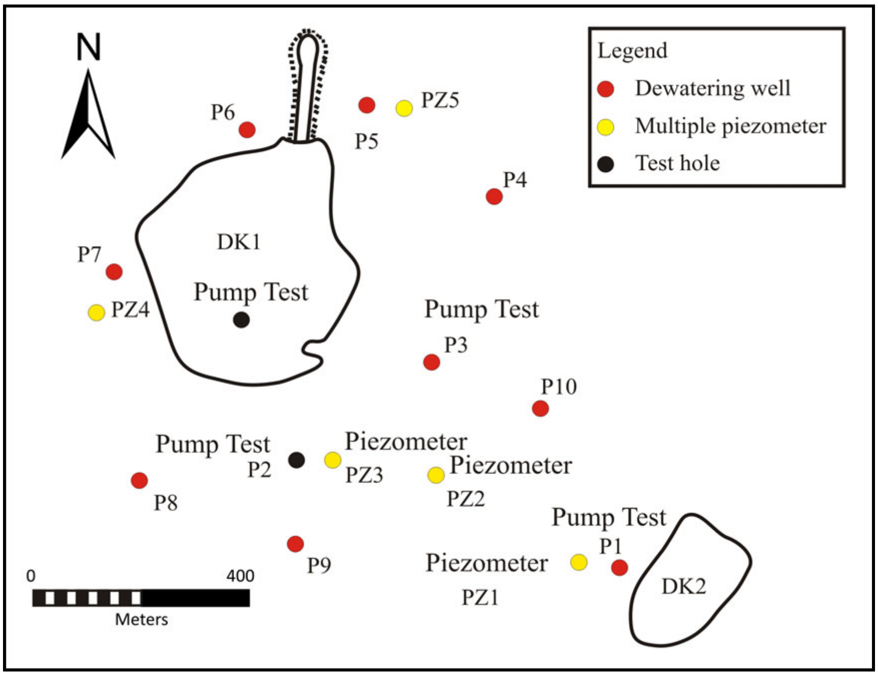

Figure 15. Letlhakane pit perimeter boreholes in 1980. Plan view (Connelly 1982)

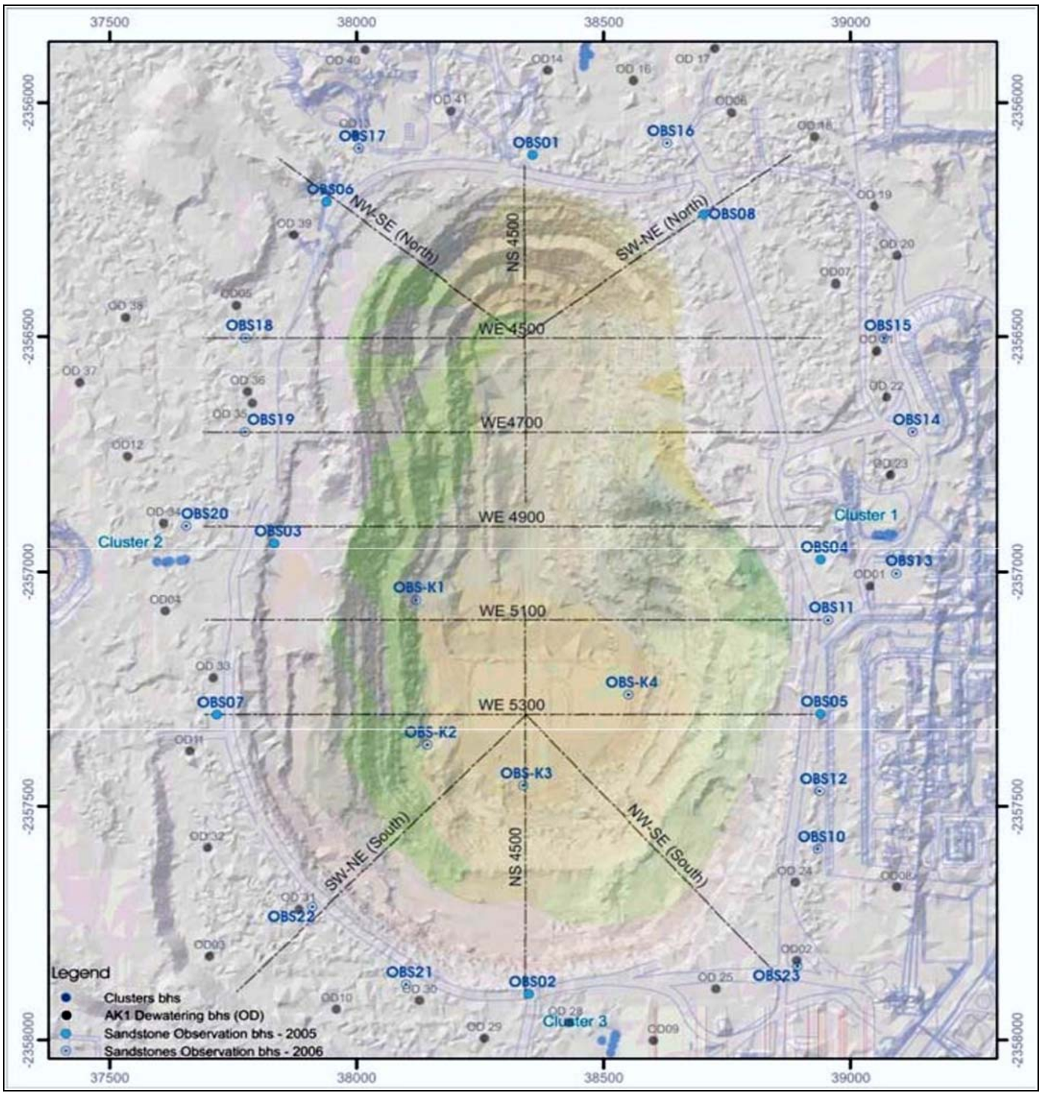

Figure 16. Letlhakane Mine; the ring of dewatering boreholes and monitoring boreholes in 2006

Comparison of Designs

The use of gravity is always the first option used, with pumping taking place from sumps and collector dams. When pore pressures are high and gravity drainage is insufficient, then active pumping from specific permeable horizons of structures, are used to supplement the drawdowns created by the passive drainage. Where ground water flow is predominantly vertical; then horizontal drainage is most effective, in for example, drainage galleries. When the dominant flow is horizontal, flow vertical methods of dewatering, such as vertical pit perimeter boreholes are more effective. As the directions of flow and mine development change with time, the methodology can be adapted to suit the new conditions.

Because of the long time frame that was used in the planning and execution, Finsch mine dewatering was very successful. Letlhakane mine, of similar age, has a different design possibly because of the use of shorter time frames.

2. CLOSURE

KLMCS would like to thank IMWA for the opportunity to present this paper and Debswana Mining Company for the permission to present the Letlhakane example.

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