The assessment of mine rebound and decanting in deeper coal mines

P.D. Vermeulen, I. Dennis

Institute for Groundwater Studies, PO Boox 339, Bloemfontein, 9301, South Africa
VermeulenD@ufs.ac.za

Abstract South African law requires that a long-term groundwater management and monitoring plan must be compiled in order to achieve the environmental goals after mine closure, as set out in the National Water Act of 1998. In this regard, the assessment of mining on the groundwater reservoirs must be investigated and quantified. Therefore it is important for mines to know and understand what will happen with the groundwater after closure, and if they will decant. Seven interlinked deep coal collieries are discussed. The main aim of the work was to develop suitable analytical and numerical decant models which can simulate the eventual decant of all seven collieries, and the consolidation thereof into one large model. The management of groundwater resources in the vicinity of these mines are important because of the possible acid mine drainage and poor quality decant that can occur once mining operations cease.

Key Words Groundwater management, rebound, decant

Introduction

South Africa is a country blessed with an abundance of minerals, and is the fourth largest coal producer in the world. Coal resources in South Africa are contained in 19 coalfields (Erasmus et al., 1981). The most important coalfields in the Mpumalanga province are the Springs-Witbank Coalfield and the Highveld (Eastern Transvaal) Coalfield (Figure 1).

The aerial extent and the period of mining operations that altered the hydrogeological environment of the coalfields impact on the operational life of the mines for several years after mining has ceased. South Africa is a water-scarce country, and therefore a significant impact on the environment has been forecast, as early as 1983 (Funke, 1983). However, in recent years, many mines have been striving to ensure that the negative impacts of their mining operations are kept within acceptable limits, also in terms of the water qualities.

The problem of mine closure

After mineable coal has been removed, mines are left to fill with water and seepage takes place into adjacent, polluting aquifers and rivers. South African law requires that a long-term groundwater management and monitoring plan must be compiled in order to achieve the environmental goals as set out in the National Water Act of 1998. In this regard, the assessment of mining on the

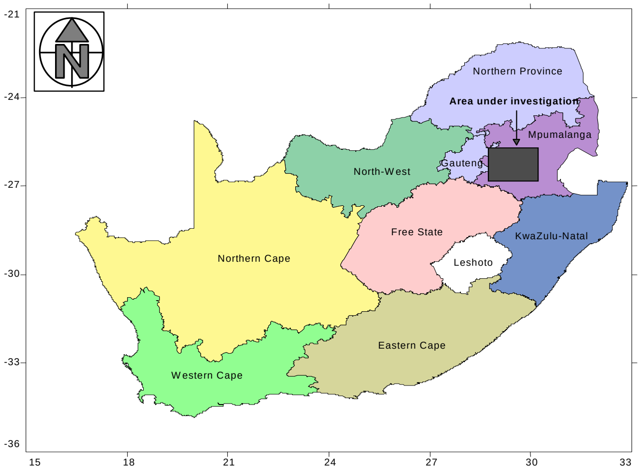

Figure 1 *Map of South Africa, with the position of the Mpumalanga coalfields*

groundwater reservoirs must be investigated and quantified. The Mineral and Petroleum Resources Development Act, Act 28 of 2002 states that no closure certificate may be issued unless the management of potential pollution to water resources has been addressed.

The government has turned down many applications for mine closure, because of the concern of possible uncontrolled pollution of water resources in the vicinity of the mines. The government's reluctance to grant closure certificates has forced the industry to investigate other ways of managing the water pollution problem. To do this, they need to know the rebound rates, water qualities, decant positions and decant volumes.

In this paper seven interlinked deep coal collieries in the Mpumalanga province are discussed (Figure 2). The management of groundwater resources in the vicinity of these mines after closure are important because of the possible acid mine drainage and poor quality decant that can occur once mining operations cease and if the mines decant.

Mining and recharge

The underground workings of the Mining Complex consist of various layouts and configurations. These configurations are a function of mine planning and method, and can broadly be classified under bord-and-pillar and total extraction methods. The different layouts of the mines are expected to have different effects on the quality and quantity of undergroundwater.

The scenario that has been taken into account for this study is what will happen after the mines have closed down and being filled with water; for environmental impacts it is important to understand what will happen after the mines filled up. The time it will take for the drained overburden to saturate again, can be modelled numerically, thus the time till water seeps out on surface, can be predicted; in most cases more than a hundred years.Important in such a study to determine if the mines will decant/seep or not is the interconnectivity between the mines, geology of the overburden, type of mining, topography and depth of mining, and thus the piesometric levels of the mine and the different aquifers.Two sources of influx need to be considered namely groundwater influx and recharge.

The overburden formations consist mainly of sandstone, shale, interbedded siltstone, mudstone and coal of varying thickness. The total thickness of the sediments ranges from 15 160 m. Dolerite intrusions in the form of dykes and sills are present over the entire coalfield. The common characteristic of these mining methods is that the removal of the coal seam results in the caving of the overlying strata into the mined void. This disruption of the overlying rock mass has a significant effect on the geohydrology, especially where total extraction was done, resulting in sub-

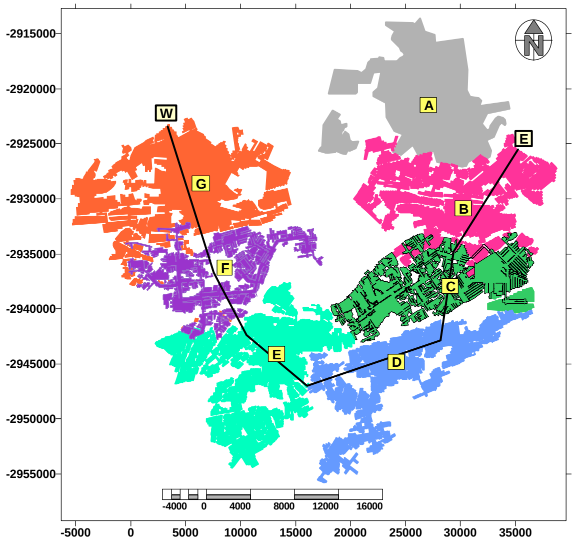

Figure 2 Outline of the collieries complex

sidence. Recharge of between 5 and 7% can be expected at the subsidence areas. Low recharge of between 1 and 3% can be expected where no subsidence occurs, with a tendency towards 1% where the sill is thick (Vermeulen and Usher, 2006). The area is overlain by a dolerite sill, with numerous dolerite dykes. The thickness of the sill plays an important role in recharge into the mining cavities and especially the aquifers above.

Two distinct and superimposed groundwater systems are present in the coalfields, as described by Hodgson and Grobbelaar (1999). They are the upper weathered aquifer and the system in the fractured rock below. Below that the mining voids are also filled with water after mine closure.

Discussion of regional conceptual decant model

Once the mine has filled up with water, the piesometric level of the mine will rise with the storage coefficient value of the mine (and not the specific yield) as conditions have changed from unconfined to confined. The flux from the overlying aquifers into the mine aquifer will decrease as the two water levels approach each other. This has been illustrated in the drawing in Figure 3. This figure is a cross section drawn on the line EW as illustrated in Figure 2.

The lowest point on surface through this particular section is at Colliery F. However, the lowest point in the mining area is on the border of Collieries E and F, at 1560 mamsl. The highest point of the coal seam roof (no. 4 seam) is at 1521.79 mamsl (at Colliery G and at Colliery B). The smallest difference in height between the surface and coal seam is thus nearly 40 m if all the collieries are being interconnected, and act as one colliery. Both these high points are in future mining areas and adjacent to Colliery A. (By moving away from the fringes of these mines, the seam drops to 1495mamsl, which indicates a difference in height of 65m between surface and the coal seam). For polluted water originating from the mining cavities to decant, it will have to overcome four bar of pressure, which is unlikely. As the piesometric level from the mine and the water level above in the weathered zone combines, any excess water will seep out as normal unpolluted springs at the low points.

The average thickness of the overburden at the total mining complex is more than 100 meters, with only the western part of Colliery F where the coal seam is between 90m and 100m.

Numerical modelling

A numerical model (using Modflow) was developed for the study area which was specifically designed to assess the potential dewatering requirements, determine the zone of depression and area of influence as a result of dewatering, determine if the mines will decant after closure and assess any potential groundwater contamination related to the power station. The calibration process was done by changing the model parameters for transmissivity and recharge.

Three layers were initially included in the model, including the weathered upper aquifer, the dolerite silland the fractured deeper aquifer.

The numerical model was then used to simulate the flooding of the aquifers above the collieries. It is therefore assumed that the mine voids are flooded for this simulation.

Due to the flatness of the terrain and the depth of mining, it is unlikely that the collieries will decant. Once the mines has filled up with water, the piezometric level of the mines will rise with

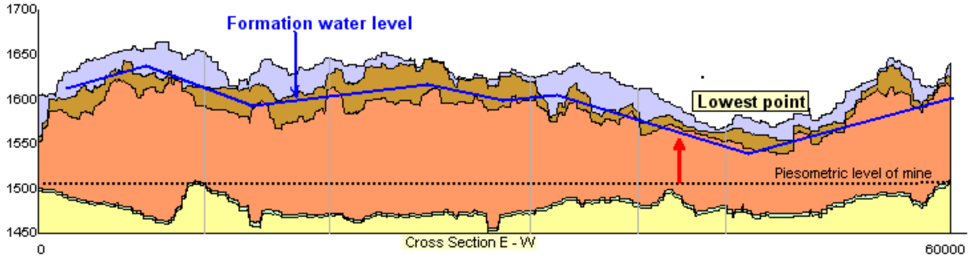

Figure 3 *East-West cross-section of the conceptualisation of the different water levels (the thin green layer between 1450 and 1500 mamsl is the mining void, and the brown layer between 1550 and 1650 mamsl the B4 sill)*

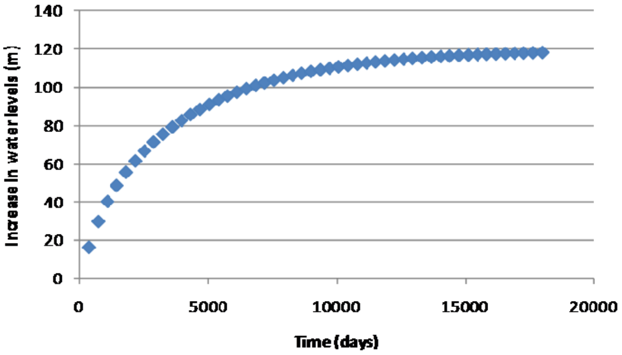

Figure 4 *Increase in water levels in Mine B*

the storage coefficient value of the mine (and not the specific yield) as conditions have changed from unconfined to confined. The flux from the overlying aquifers into the mine aquifer will decrease as the two water levels approach each other (Figure 4). Eventually the aquifers will return back to pre-mining conditions, and normal aquifer water will seep out as springs in lower-lying areas from the shallow weathered aquifer. This will occur after approximately 50—85 years for the different collieries after they have flooded.

Discussion and Conclusions

Mining is relatively deep at all of the Collieries, except Colliery A. Decant is thus very unlikely to occur in the area as a whole. Barriers exist between the different collieries, with many dolerite structures which would prevent the flow of water over large areas laterally in the aquifers. After the mines have filled up, the aquifers should return to the pristine conditions what it was before mining commenced. Chemical profiling in numerous boreholes into the mining voids in coal mines in Mpumalanga indicate a sharp contrast in the water quality in the mining void and a couple of meters above the void; in the void the water is acidic, with initial sulphate generation, and a few meters above the void it is uncontaminated (due to the lack of pressure head to force the polluted water upwards). Sulphate generation is dependent on pyrite oxidation. Oxidation is not possible in flooded areas, as long as that the mine water remains alkaline and thereby limits ferric iron as oxidant due to its insolubility. The exclusion of oxygen due to flooding retards sulphate generation. When flooding of collieries after mining has been completed, the remaining neutralising potential in the coal is usually sufficient to neutralise the acidity in the mine. An investigation by Vermeulen and Usher (2006) has found the daily sulphate generation rate for underground mining to be in the range of 2,7 kg/ha initially, and decrease to less than 0.4 kg/ha after the void has flooded totally.

After the water that filled up above the mine and the water of the weathered aquifer meets, water will move laterally on the contact between the weathered and fractured aquifers, and daylight on the lowest points on surface as springs.

References

Erasmus BJ, Hodgson FDI, Kirstein FE, Roper CB, Smit JS, Steyn PPA and Whittaker RRLG (1981) Geological, hydrological and ecological factors affecting increased underground extraction of coal. SAIMM Vacation School, Johannesburg.

Funke JW (1983) The environmental impact of coal mining and combustion. SA Water, Science and Technology 15, p 115—144.

Hodgson FDI Grobbelaar R (1999) Investigation into long-term water quantity and quality trends at Ermelo Colliery. Confidential Report to Ingwe S.A.

Vermeulen PD, Usher BH (2006) Sulphate generation in South African Underground and Opencast Collieries Environmental Geology 49 (4): 552—569, February 2006

Vermeulen PD, Usher BH (2006). Recharge in South African underground collieries – Journal of Institute for Mining and Metallurgy 106 : 771—788, November 2006.