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A Water Balance for the Life Time and Beyond of an Opencast Colliery in South Africa

E. Lukas, P.D. Vermeulen
Institute for Groundwater Studies, University of the Free State, Bloemfontein, 9301, South Africa

Abstract The colliery discussed in this paper is situated in the Mpumalanga Coalfield, southwest of eMalahleni, South Africa. Current life of mine projected for this opencast colliery will continue until 2021. Throughout the mine's life it is important to know how much the water-make of the mine will be as well as the storage capacity of the mine, as both change as the mining progresses from year to year. Recharge factors will differ for the virgin land, the active pit, the levelled and unlevelled spoils and the full rehabilitated areas. It is important for future planning of the mining company to assess whether decant will occur at the end of mining to determine if a water treatment plant is necessary and if needed, what the specifications for such a plant would be. The total water make of the virgin ground during the lifetime of the mine is in excess of 870 Ml; a feasibility study into pro-active dewatering of the virgin ground was performed by developing both an analytical and numerical model. After mining ceases, managing the storage capacity of the rehabilitated pit becomes important as a temporary buffer to absorb the recharge in months of high rainfall. The storage capacity of the main pit is, after rehabilitation, only 2 Mm^3 but can be enlarged to 18 Mm^3 by building a wall at the northern boundary of the main pit. With treatment cost at 1$ (USD) per cubic metre, a saving of 16 million dollars is possible.
Keywords dewatering, water balance model, treatment costs

Introduction

According to Morton (2009), dewatering means the removal of water by lowering the water table from a high-wall or underground mine. The low rainfall and low-yielding aquifers means that the control of mine water inflows have been covered in the design of the mine. In the majority of mines, in South Africa, groundwater will generally not be encountered below 50-150 metres. The geology in South Africa is mostly hard rock and water can generally only be found at the contacts with dyke intrusions, at fractures and weathered zones. The amount of groundwater present, the rate at which it will flow through the rock, the effect it may have on stability and the influence it will have on the economic development of the pit, depend on many factors (Connelly and Gibson 1985). Brawne (1982) defines these factors as, the topography of the area, precipitation variation, the permeability of the rock mass and overburdened soil, and the fragmentation and orientation of structural discontinuities in the rock. The colliery currently mined by opencast methods commenced mining in 2003. Production is 3.6 Mt/a. The current life of mine indicates that mining will continue until 2021 (fig. 1) with an average of 60 ha mined each year. Geophysical data suggested definite areas of higher magnetism, although no dolerite dykes could be positively identified. Areas of higher magnetism may be targeted as potential dewatering positions.

Aquifer testing was done on five boreholes that were sited for this study. These boreholes were placed according to accessibility for the drilling rig, and closest to the most favorable positions based on the geophysical data. The main objective for this study was to locate and use boreholes that could strategically be dewatered ahead of the mining activity to produce an up to date water balance model for the Klipspruit Colliery.

Water volumes and decanting points

Although rainfall and recharge contribute to water in the pit, groundwater from the surrounding rock also adds to the equation. As mining continues from the east to the west, backfilling and rehabilitation will also progress at the same speed. Water will only be left in the pit as long as it does not interfere with the mining operations.

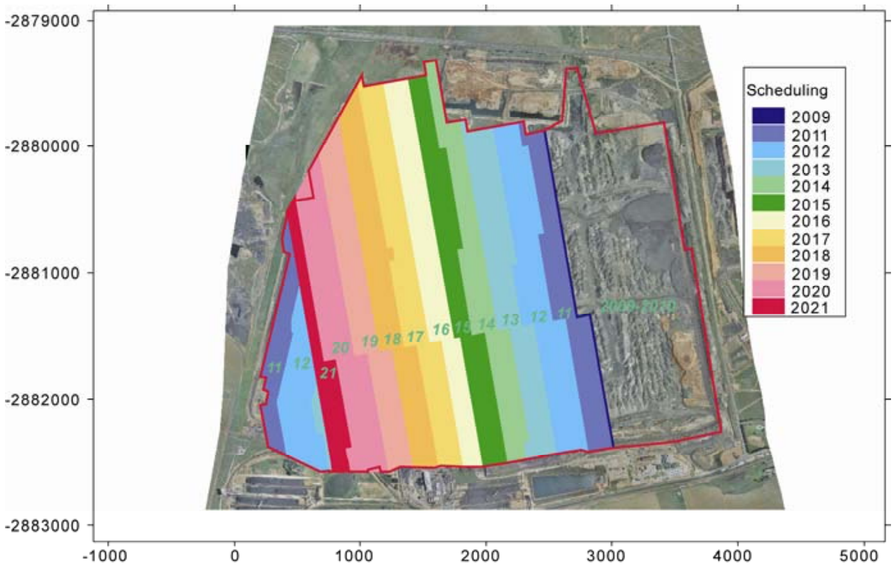

Fig. 1 *Scheduling of mining*

After mining ceases in 2022, the water level inside the pit could rise until it starts to decant at an elevation of 1512.10 mamsl. When the decant elevation is reached, the rehabilitated opencast will have two major pools (fig. 2). The volume of water in the North pool will be 1.23 Mm^3 and 0.77 Mm^3 in the South pool. A watershed on the coal floor contours separates the two pools. The catchment for the North pool is 414 ha and the South pool has a 480 ha catchment. With a 700 mm annual rainfall and a 20% recharge factor, it will take 420 days for the south pool to fill.

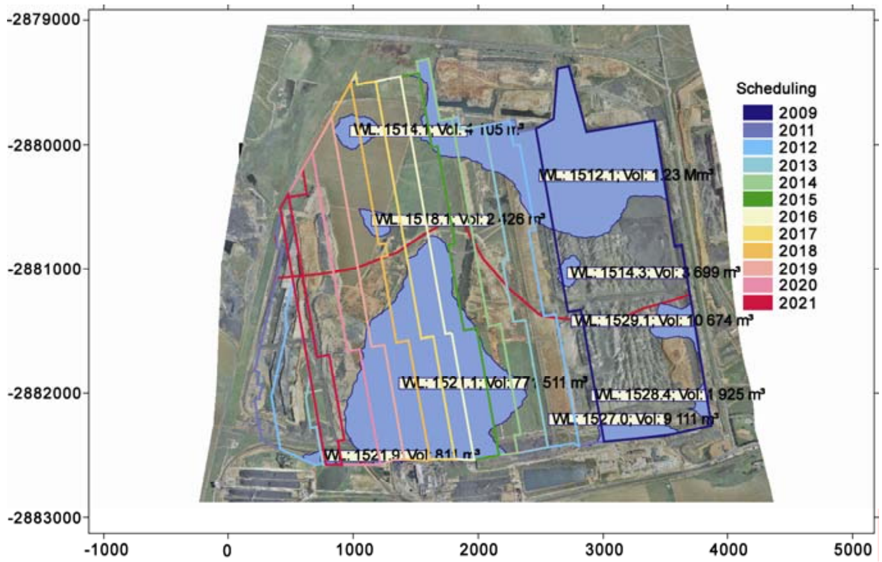

Fig. 2 *Water in the opencast at 1512.10 mamsl (watershed line and scheduling superimposed)*

When full, the water recharging through the southern catchment will spill over into the north pool. The north pool will fill up in 585 days. Rising the decant height will require the building of a dam wall at the northern border of the opencast. Elevating the decant level to

1530 mamsl will allow a volume of 18.5 Mm^3 to be stored on site (table 1 and fig. 3). Recharge of the North pool will already start during the mining operations. It can start filling up after the first cut is finished. To keep the 2012 cut free of water, an expected 170 Ml must be removed from the rehabilitated opencast. The amount of water to be removed in 2013 will be just over 470 Ml.

During the active mining process, the recharge can be divided into two separate entities: recharge of the spoils and recharge of the un-mined (virgin) ground. South Africa legislation requires water pumped from the active mine or spoils to be treated before it may be released into streams and/or canals; water pumped from the virgin ground does not need to be treated. Water that can be stored on site does not need to be treated. In order to enlarge the amount of water that can be stored on site, the decant height must be raised. This implies building a wall (dyke) on the northern border of the opencast. With water treatment prices at 1 USD per cubic metre, the total treatment cost can be reduced by 16 million dollars. (This excludes the cost of the wall construction.)

Table 1 *Capacity in relation to projected decant*

Decant Elev mamsl	Capacity Mm^3	Length of Dam m^3
1512.10	2.00	0
1515.00	3.00	300
1518.00	4.40	1000
1525.00	10.85	2000
1530.00	18.50	2500

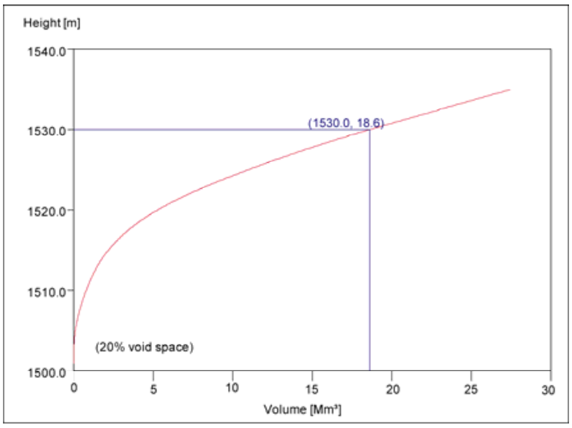

Fig. 3 *Storage capacity vs volume*

The total water make on the virgin ground during the lifetime of the mine is in an excess of 870 Ml. To minimize the water treatment, dewatering of the un-mined part of the mine must be considered. The area has no major geological structures; most of the water moves through the weathered zone. Running the THEIS (Lukas 1999) program suggests that a borehole placing on a 25x25m grid is needed to dewater the pit. The program uses the THEIS equation to calculate the drawdown for each borehole and uses superposition to add the different drawdowns together. This is completely analytical. This method was the first method to be used in an un-steady state flow situation that introduces the time factor and storativity (Kruseman and de Ridder 1970). The method assumes a confined aquifer of (seemingly) infinite extent which is homogenous, isotropic and of uniform thickness and a borehole that penetrates the entire thickness of the aquifer and is pumped at a constant rate. The following parameters values are used (the values are typical for the Mpumalanga coalfields and confirmed by our pumping tests):

- Storativity: 0.05 (or 5%)
- Transmissivity: 2 m^2/d
- Borehole yield: 0.2 L/s

Contours from surface and coal floor indicate an average floor depth of 30 m. Using the suggested borehole yield from above, table 2 is generated displaying the number of boreholes for each cut. Table 2 also implies a placing of one borehole per 4100 m^2 (area/number of bh), resulting in a 65×65 grid. This is much larger that the grid from the THEIS method. The difference can be attributed to the (vertical) heterogeneity.

Table 2 *Watermake from recharge during life of mine*

Active life yyyy-yyyy	Dewatering area (m^2)	Formation water (m^3)	Recharge (m^3/a)	Remove in one year(l/s)	# bh needed at 0.2(l/s)
2009-2010	714 364	1 071 546	21 431	34.66	173
2011-2011	934 020	1 401 030	28 021	45.31	227
2012-2012	621 834	932 751	18 655	30.17	151
2013-2013	549 448	824 172	16 483	26.66	133
2014-2014	561 015	841 523	16 830	27.22	136
2015-2015	572 023	858 035	17 161	27.75	139
2016-2016	613 921	920 882	18 418	29.78	149
2017-2017	596 309	894 464	17 889	28.93	145
2018-2018	537 039	805 559	16 111	26.05	130
2019-2019	608 886	913 329	18 267	29.54	148
2020-2020	251 449	377 174	7 543	12.20	61
2021-2021	0	0	0	0.00	0

Pumping of all the groundwater is not advisable. Only removal of the free flowing water from the weathered zone is needed (fig. 4), this water is allowed to drain into the pit and will flow under gravity into a sump from where it will be pumped. Water captured inside the rock (matrix) must be allowed to stay there. It will automatically be removed when it is trucked out and it lowers the need for dust suppression water.

Fig. 4 *Seepage from the high wall*

Conclusions

The following conclusions were made from this study:

- The amount of water to be stored in the pit after rehabilitation is only 2 Mm^3 and the pit will start decanting as early as 2017.
- Lifting the decant height will result in an increase in storage capacity, which will reduce the amount of water needed to be treated and ultimately saves money.

- The sustainable yield is very low (0.1 – 0.3 l/s) and the transmissivity of the aquifer is in the order of 1 - 2 m^2/d. The placement and number of boreholes will depend on the transmissivity of the rock, the average yield of pump tested boreholes and the inflow into the pit.
- Dewatering is only feasible in higher yielding formations. In our example, the yield is so low that an unrealistic number of boreholes would be needed to dewater the area.

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