

LIFE OF MINE VENTILATION REQUIREMENTS FOR BRONZEWING MINE USING VENTSIM

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ABSTRACT

Bronzewing Mine is located in the centre of the Yandal Belt, 360 km north of Kalgoorlie in Western Australia. Discovered in 1992 by Great Central Mines, the Bronzewing Mine is now owned and operated by Normandy Mining Pty Ltd. Mining at Bronzewing is carried out by sublevel open stoping method recovering the ore from the underground operations concentrated in two major zones: Central and Discovery. Future production is expected to include ore zones away from the main orebody, Avocado, Winged Keel, Carrot and others. The future airflow requirement is estimated at approximately 450 m³/s, which falls only slightly short of the current airflow of 412 m³/s. This paper examines the ventilation requirements for the Life of the Bronzewing Mine by using ventilation software, VentSim. The current ventilation conditions are simulated and evaluated in terms of the future ventilation requirements. An optimisation process, based on the proposed mine production plans, is performed to arrive at the most efficient and cost effective use of the current airflow to supply sufficient air to working areas of the future stopes.

KEYWORDS

Mining, ventilation, simulation, VentSim

INTRODUCTION

Bronzewing Gold Operation is located approximately 70 km north-east of Leinster and 360 km north of Kalgoorlie in Western Australia. The operation is situated in the centre of the Yandal Greenstone Belt, an area Archean in age (Figure 1).

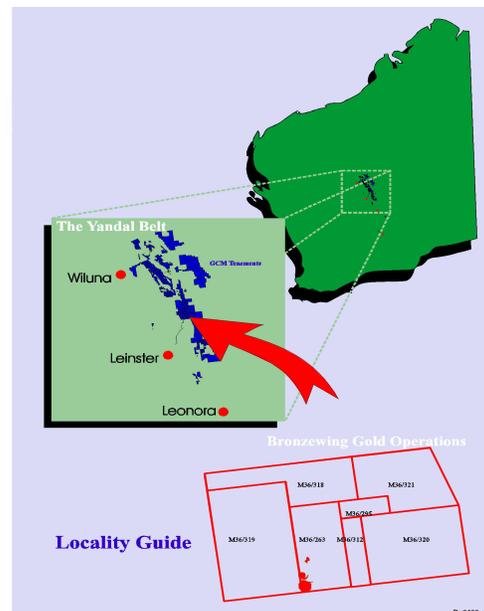
Geology

The Bronzewing area is dominated by a broad alluvial plain of lateritised and indurated sediments overlying a sequence of altered theolitic basalts, some ultramafics and minor sediments. The basalts are locally sheared, having a dominant orientation striking 360 degrees and dipping 70 degrees east.

The gold mineralisation at Bronzewing is associated with quartz veins and stockworks within the sheared zones. The mine is divided into three main mineralised zones: Central, Discovery and Western.

Mining

Open cut mining at Bronzewing commenced in 1994 with the development of the Central Pit and Discovery Pit.



The Central Pit was mined to a depth of 135 metres with underground mining commencing on the Shoot 39 orebody. The Central Pit produced 367,078 tonnes of ore at an average grade of 1.70 g/t. The Discovery Pit, which was mined to a depth of 230 metres, produced 4,953,200 tonnes of ore at an average grade of 2.30 g/t.

Bronzewing Mine can be regarded as a medium sized gold mine since it currently produces 5,000 tonnes of ore per day at an average head grade of 5.0 g/t of gold. Most mining activities are contracted out to Brandrill Ltd. while Normandy employees perform all technical work such as mine design, surveying, geological grade control. Processing of ore is carried out using a carbon-in-pulp/carbon-in-leach gold treatment plant.

The underground operation currently consists of two major mining zones called Central Zone and Discovery Zone. The Western Zone, which was mined during the first stages of underground production, is no longer in production and serves as a connecting ventilation drive between Discovery Zone and Central Zone. Main access to both major mining areas is through two portals located near the base of the Central Pit. A single entry decline branches off into two separate declines, one leading to the Central Zone and the other to the Discovery Zone. The exit portal and exit decline is set up in the same manner (Figure 2).

The mining method adopted at Bronzewing is sublevel long-hole open stoping. Levels are generally 30 metres apart. Most of the stopes are typically 30 m × 30 m × 90 m though future production will consist of smaller and narrower stopes.

Bronzewing is utilising a backfill system where the primary stopes are filled with cemented aggregate fill. The backfill infrastructure is located on the third level in an 800 metre long drive extending from Discovery Zone to Central Zone. This drive is also used as an airway that connects the ventilation system of the two major mining zones.

Underground drilling, which tested lateral extensions to Central, Discovery and Western Zone orebodies continue to intersect additional high-grade deposits. Recent orebody discoveries include Carrot and Winged Keel in Central Zone, Avocado in Discovery Zone and Apple in Western Zone (Normandy Homepage, 2000). The main focus of this study is related to the Carrot and Winged Keel stopes.

CURRENT VENTILATION SYSTEM

The ventilation system at Bronzewing has evolved as needs have dictated ie no strict planning or development structure has been adopted for the mine's total ventilation system. The expansions and modifications

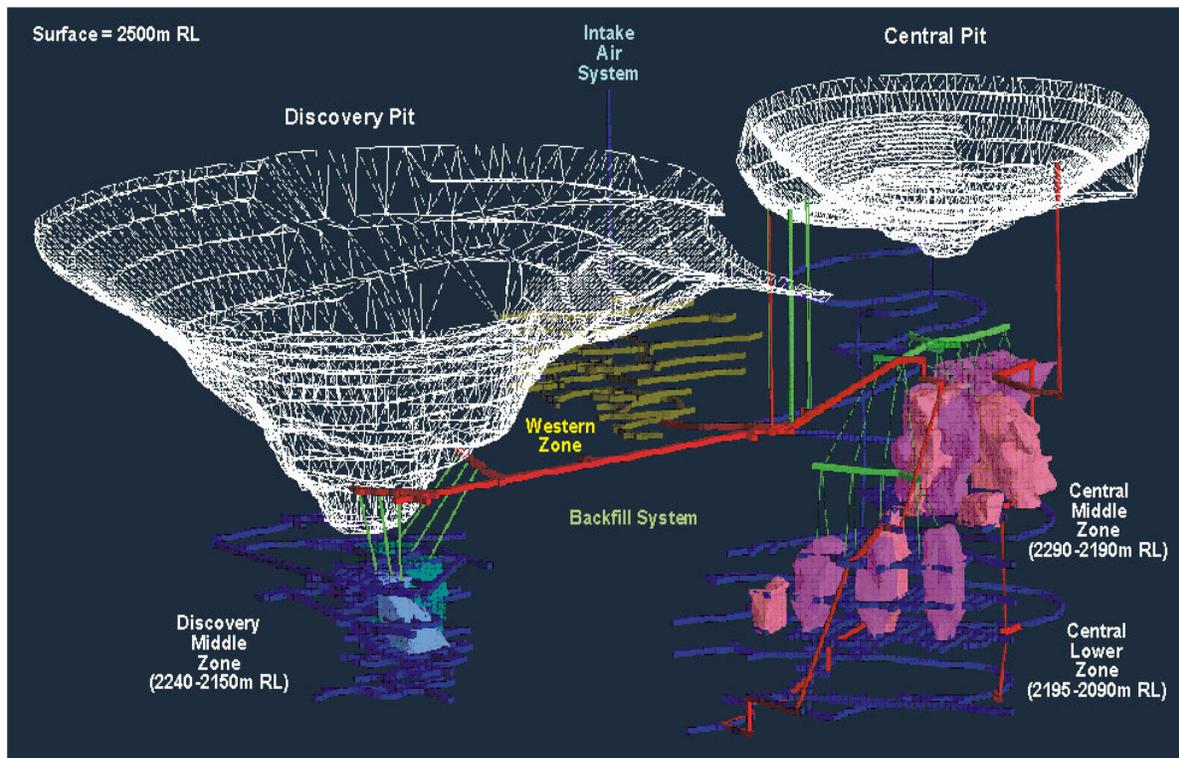


Figure 2. Isometric view of Bronzewing Mine

leading to the current ventilation circuit have been implemented to accommodate the discovery of new ore grade and the improved delineation of existing orebodies.

Currently, the mine ventilation system supplies 412 m³/s of air to the two main mining areas: Central and Discovery Zones, with primary airflows of 257 m³/s and 155 m³/s, respectively. The entire ventilation system consists of five inlet routes and three outlet routes. Three surface exhaust fans, two located in the Discovery Zone and one in the Central Zone, are used to ventilate Bronzewing Mine. The Central and Discovery Zone share an entry and exit portal, both located at the base of the Central Pit. The nominal cross-sectional area of both declines is 26 m², and with a maximum allowed air velocity of 6 m/s, each decline can accommodate for up to 156 m³/s of intake air. Higher airflow can lead to dust control problems.

Central Zone Ventilation

There are two intake routes located in the Central Zone: the Central decline and the Central Fresh Air Rise (FAR) with air quantities of 157 m³/s and 43 m³/s flowing through the respective intakes. The ventilation circuit on Central sides exhausts 151 m³/s through a Korfmann axial flow AL25-3300 exhaust surface fan.

The Western FAR, which is located halfway between the Discovery and Central Pits, assists the Central intakes to ventilate the Central side of the mine with the extra air quantity provided by the Western FAR of approximately 57 m³/s.

Both the Central FAR and Central exhaust extend down to the 13 level, the current bottom of the mine. The Western intake extends down to the 6.5 level where it joins with the Central decline. Therefore, the Western intake only assists in the ventilation of areas below the 6.5 level.

The lower levels of the Central Zone have two exhausting systems. One is commonly known as the Central Exhaust whilst the other is called the H/W Exhaust system. These two systems, which service two sides of the Central Zone, meet at a common drive on the fourth level. This drive has been fitted with a wall so that the Central exhaust emits its airflow at the Central Exhaust fan on the surface while the H/W Exhaust system is forced to emit its air through the Discovery Exhaust. The Discovery Exhaust is connected through a series of airways that join level four to level three. The third level on Central side has been fitted with a wall since mining here has ceased.

Discovery Zone Ventilation

There are two intake routes and two exhaust routes in the Discovery Zone. The two intake routes, entry portal and Discovery FAR, allow 116 m³/s and 39 m³/s of air into the Discovery Zone, respectively. The Discovery Pit Exhaust and Discovery Exhaust discharge approximately 119 m³/s and 142 m³/s of air, respectively.

The Discovery FAR and Discovery Pit Exhaust extend down to the 10 level, the current bottom of the Discovery Zone. The Western intake, which helps to ventilate the Central side, joins with the Discovery decline near level 2. The Discovery portal and FAR provide adequate ventilation to the Discover side of the mine thus the need for any further ventilation by the Western FAR is eliminated.

The third level is an 800-m long drive serving as a major airway between the Discovery and Central ventilation systems. The underground backfill distribution system is also located on level 3. The entrance to the third level backfill drive is fitted with a twin steel door arrangement.

Secondary Ventilation

The major types of ventilation devices used at Bronzewing to control airflow include brattices, Nixon flaps, steel doors, aquacrete-sealed walls, muck piles and brick bulk heads.

The most common type of brattice used at Bronzewing is the 'mesh and ventbag' brattice. This type of brattice is constructed by standing large sheets of mesh across the drive and fastening them to fixed elements, such as, face plates or eye pins, around the perimeter. Ventilation bag is then used to cover the mesh to complete the brattice.

The Nixon Flap is a ventilation device invented at Mount Isa Mines, Australia to control stope short circuiting problems, which cause the reduction of decline airflow and lead to dusty air blowing over bogger operators during mucking operation at stope drawpoints. The use of Nixon Flaps is considered to be an effective method in controlling short-circuiting since they are robust, relatively easy to install and generally inexpensive to establish and maintain. The flaps are rolled up during blasting to prevent airblast damage.

Steel doors are used at Bronzewing to create an airlock, preventing airflow into the third level of the Discovery Zone. The airlock is achieved by allowing only one set of doors to open at any one time. The ventilation doors must be able to open to a large enough cross-sectional area to allow for the largest piece of mobile equipment used in the mine to pass through at a practicable speed without any undue damage to the doors or the mobile equipment. In the case of Bronzewing Mine, the largest piece of machinery going through the doors would be an Integrated Tool Carrier (IT) and the doors can easily allow for its passing. When the doors are closed, major air leaks are reduced and short-circuiting is eliminated.

The Aquacrete wall serves as a stopping or seal that is normally intended for permanent control of ventilation. Aquacrete can be sprayed onto many surfaces including hessian, plasterboard, mudstone and even existing stops and seals (AquaCrete Company Profile Book, 2000). Although Aquacrete is extremely effective in serving as ventilation control device and is easy to apply, it is very costly.

Muck piles can be regarded as the easiest and cheapest method of controlling airflow in a mine; however, it is not the most effective method since the leakages over the top of the pile can often be quite significant. Therefore, muck piles are essentially a short-term measures used to control ventilation. This type of ventilation control requires mullock rock fill and the use of a loader for pushing up the mullock into a suitable size stockpile. The effectiveness of the muck pile can be improved when used in conjunction with the ventilation bag to reduce leakages over the top of the muck pile.

Brick Bulk Head (BBH) is installed at Bronzewing as and when stoping is completed. Prior to backfilling of stopes, the BBH act as a ventilation device at stope brows to stop the fresh air from flowing through the stopes down to lower levels. With BBH, less air is contaminated by the blast fumes and dust and more fresh air is provided to lower levels of the mine, making the system more efficient. Once backfilling commences, the BBH acts as a barrier, which keeps the backfill in the stope.

SIMULATION OF THE CURRENT VENTILATION SYSTEM

The Bronzewing ventilation network was modelled in the VentSim package to assist engineers with mine planning and everyday airflow problems.

The VentSim model of the Bronzewing ventilation network consists only of the primary airways. Generally, the network is updated every time a major change is made to the ventilation circuit. The results attained from primary ventilation survey, performed every three months, are used to compare the airflows of the mine against the simulation and regulations (WA Mine Safety and Inspection Regulations, 1995). This process is used to verify the validity of the VentSim model and to update the model with current information. If the values from the simulation and real ventilation circuit do not agree yet the simulation is deemed to be acceptable by engineers, then the discrepancy indicates major leakages and short-circuits occurring somewhere in the mine, which warrants the need for a detailed analysis of the ventilation network.

Construction of the Bronzewing Ventilation Model

The current Bronzewing ventilation model was created using files imported from the Vulcan 3D mine design package. VentSim imports all line and linestring data from the DXF files and creates a 3D network. The airway attributes of the network are defined manually by the user using the 'airway edit' function. More details regarding VentSim software can be found in VentSim User Manual 3.0 (CMS Software, 1999).

Simulation Results

The VentSim program produces a summary of the ventilation network being simulated. The simulation summary of the current ventilation network at Bronzewing is given in Table 1.

Table 1. Current ventilation network simulation summary.

Description	Quantity
Total Airflow, [m ³ /s]	412
Total Air Power, [kW]	557
Network Input Power, [kW]	922
Network Efficiency, [%]	60
Mine Resistance, [Ns ² /m ⁸]	0.00806
Annual Power Cost, [AUS \$]	646,331
Number of Airways	611
Length of Airways, [m]	20,872
Number of Fans	3

Based on the simulation results, the mine is currently supplied with 412 m³/s of fresh air. The total length of the 611 primary airways is approximately 21,000 meters with large proportion of this length attributed to the large size of Central Zone. The operating cost of three exhaust fans in the ventilation system is approximately \$650,000 per year ie \$1,780 per day. The VentSim package uses a value of \$0.08 per kWhr to determine the power cost, a value also adopted by Bronzewing's engineers. The default air power efficiency factor used was 68% and the ventilation network efficiency was 60%, calculated by dividing the total power of the airflow by the input power of the network (Table 1).

FUTURE AIRFLOW REQUIREMENTS

General Approach

A general estimate of primary airflow can be obtained by referring to Figure 3. The current production rate is about 1.5 Mtpa, while a future production rate of 1.2 Mtpa is being considered. The amount of fresh air needed to accommodate mining at this rate at a greater depth is approximately 440 m³/sec. Thus, if no modifications are made to the ventilation network to increase its capacity, the current primary flow rate may be inadequate by about 30 m³/sec.

Detailed Approach

The ventilation requirements at Bronzewing have been dictated by the use of diesel equipment and other rules defined in the Western Australian Mine Safety and Inspection Regulations (1995).

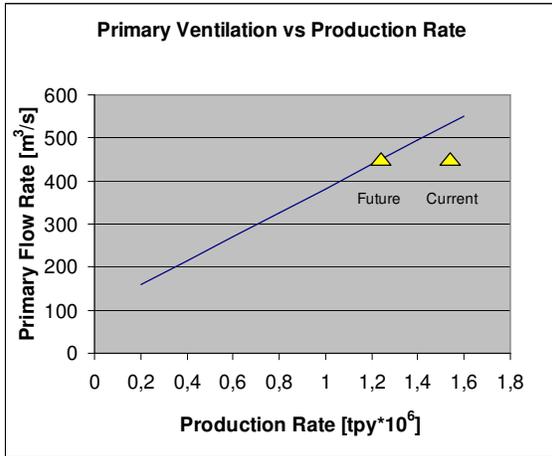


Figure 3. Required airflow based on annual production rate (After Australian Mining Consultants AMC, 1999¹)

The Mines Safety and Inspection Regulations 1995 state that the following regulations must be adhered to:

- Section 10.52 (6)... an underground diesel unit must have a ventilation volume rate of not less than 0.05 m³/s per kilowatt of the maximum rated engine output specified by the manufacturer, for the fuelling and timing configuration at which the engine has been set.
- Section 10.52 (3)... the airflow in any workplace in which a diesel unit is operated must not be less than 2.5 m³/s.

In addition, Bronzewing engineers have used the values shown in Table 2 in the ventilation design procedures. These values serve as design guidelines that must be used to ensure the airflow in significant parts of the mine are not contaminated by dust or diesel fumes. The minimum required primary airflow for an underground mine is based on the number of diesel equipment operating intermittently in the major working area (Table 3).

Table 2. Airflow velocity design guidelines

Design Guidelines	Air Velocity (m/s)
Maximum airflow in main decline	6.0
Minimum development airflow	0.5
Minimum production airflow	0.7-1.0

¹ Based on the analysis of 28 different Australian mines. Mines that used sub-level caving and block caving mining methods were left out of the analysis.

Table 3. Minimum airflow requirements for individual diesel equipment at Bronzewing

Equipment Type	Diesel Power [kW]	Airflow required [m ³ /s]
Bogger (development)	242	12.1
Bogger (production)	292	14.6
Truck	320	16
Jumbo (self-contained)	328	16.4

The minimum airflow required for different phases of mining at Bronzewing, based on the figures from Table 3, is as follows:

- Development - Load & Haul:
2 x trucks => 32.0 m³/s
1 x bogger => 12.1 m³/s
Total => 44.1 m³/s.
- Production - Load & Haul:
2 x trucks => 32.0 m³/s
2 x bidders => 29.2 m³/s
Total => 61.2 m³/s.
- Drilling:
1 x Jumbo => **16.4 m³/s.**

The various mining activities, which are expected to occur simultaneously together with required airflow, are summarised in Table 4.

Table 4. Airflow requirements for mining activities occurring simultaneously

Activities	Discovery Zone [No]	Central Zone [No]	Required Airflow [m ³ /s]
Development	1	3	176.4
Production	1	2	183.6
Drilling	1	2	49.2
Airflow Required [m ³ /s]	121.7	287.5	409.2
Leakage (10%)	12.17	28.75	40.92
Total Airflow Required			450.12

The leakage factor used in the calculation was assumed to be 10%. However, ventilation survey conducted at the mine shown leakage to be in the order of 25%. This can be attributed to the ineffectiveness of many ventilation devices used throughout the mine. When the effectiveness of these devices is improved, the leakage factor should decrease and the value of 10% could be considered acceptable.

The calculated airflow requirement of 450 m³/s from the above assessment corresponds with the AMC (Australian Mining Consultants, 2000) approximate

value of 440 m³/s. The shortfall of 40 m³/s of airflow required for future mine ventilation does not warrant significant expansion of the ventilation system. Since the mine is considering reducing its production rate in the future, it is best to consider the utilisation of the current available airflow in the most effective way to meet the future ventilation requirements. Also, the calculated airflow is an 'overdesigned' value ie calculated for the worst case scenario. Therefore, unless the mine operates in a worst case situation everyday, the shortfall of 40 m³/s can be dealt with using the existing ventilation system.

VENTSIM SIMULATIONS OF FUTURE VENTILATION SYSTEMS

Proposed Removal of Western Intake Wall

Due to the simultaneous extraction of CN1 and CN3 stopes, which result in a breakthrough in the Discovery Pit, the primary ventilation of the mine will be adversely affected once the stope brows open. Therefore, a simulation of the removal of the Western Intake Wall was carried out to ensure that adequate airflow is provided in the decline to accommodate haulage trucks and other equipment.

The cross-sectional area of CN1 stope at the pit breakthrough is approximately 1,372 m², calculated using Vulcan. The 'closed brow' simulation is with the stope brow fully closed with no air leakages. In reality, however, there is some leakage through broken ground. The 'open brow' simulation is with the stope brow fully opened allowing maximum airflow through. Once the CN1 brows at 7 and 8 LD open, the airflow above 7 LD will up-cast the decline to the Discovery Junction and into the Central Zone. However, the airflow is reduced to approximately 11 m³/s by the time it reaches the Western Junction, which is not sufficient for haulage equipment. The proposed method of increasing the airflow above 7 LD would be to remove the Western Intake Ventilation Wall. This would increase the flow from 7 LD to the Western Junction as well as from the Discovery Junction to the Western Junction. The result is increased airflow traversing the Western Decline into the Central Zone, supplementing its primary airflow. However, removing the ventilation wall when both brows are not open will not have a desirable effect on the decline airflow.

The removal of the Western Intake Ventilation wall will have a negligible effect on the Central Zone primary circuit irrespective of whether CN1 or CN3 stope brows are open or not. However, the removal of the ventilation wall poses another problem as the extra airflow supplementing the Central Zone from the Discovery Zone via the Western Decline is essentially return (contaminated) air and the fresh airbase that exists between the ventilation wall and 6.5 LC access would be compromised.

Therefore, the removal of the Western Intake Ventilation Wall could only be carried out when CN1 brows at 7 and 8 LD are open. Once the stope has been mined out, the ventilation wall needs to be erected when back-fill walls are erected. The same methodology is to be applied for CN3 extraction, whereas the ventilation wall has to be removed when brows at 8 and 9 LD open. It may be prudent to construct a Drop Board Regulator (DBR) in place of the ventilation wall once it has been knocked down for the CN1 scenario in order to save time and resources for re-erecting the ventilation wall for CN3.

New Intake from Western Zone to Lower Central Zone

A new circular 3-m in diameter fresh air rise that supplements the current airflow in lower Central Zone was simulated. This airway will divert the airflow going from Western Zone down the Central decline, straight down the rise to Winged Keel mining areas. The airway starts in the Western Zone at 6 level, goes down to the 11 level, continues on and finishes at 14 level. It was deemed unfeasible to go straight from 6 level to 14 level because the airway would run into old stopes and old drill holes. Therefore, using the 11 level allows the overall rise to run down at a shallower angle and ensures it doesn't run into old workings. The entire length of the new rise is 100+ metres and the quantity of air flowing down rise from the Western Zone is approximately 50 m³/s, which can accommodate approx. 2 boggers and two trucks.

In addition to aiding in the air supply to the lower Central Zone, the rise can be open in the 11 level to increase airflow when production occurs at 11 level and below. However, the feasibility of the air rise development will depend on the cost of the rise from 6 level to 14 level. The length of the rise is quite significant and thus more detailed cost analysis needs to be carried out.

The simulation results showed that the rise construction would have no significant effect on the overall ventilation system.

Mining Scenarios

The mining scenarios likely to take place in the future at Bronzewing Mine are outlined in Table 5. The 10 mining scenarios, modelled in VentSim, are characterised by type of mining process occurring, mining level and mining zone. For example, Scenario 1 is characterised by the stoping operation on levels 11 and 13 and the development on levels 10, 12 and 14 in the Central Zone.

The new intake air rise is used in various mining scenarios to increase airflow in the lower levels of Central Zone, in particular, the Winged Keel mining areas. It has not been used to increase airflow at 11 level and below.

The following discussion summarises the findings from the optimisation of the ventilation simulation for selected mining scenarios.

Table 5. Mining scenarios

Case	Production		Development	
	Central	Winged Keel	Central	Winged Keel
1	11,13		10,12,14	
2	13,14		12,15	15
3	13,15		10,12	14
4	13,15	15	10,12,7	
5	13,7		10,15	15
6	13	15	10,15	
7	15,7		10,14	14
8	15	15	10,14	
9	7	14	10,2	
10	7	15	10,2	

Scenario 2: This scenario is characterised by stoping on levels 13 and 14, development on levels 12 and 15 of Central and level 15 of Winged Keel orebodies.

The initial simulation of the system indicates that the stope extracted from 14 level will updraft air, whilst the stope extracted from 13 level will downdraft. Therefore, if the quantity of air flowing down the stope at 13 level becomes too excessive, dust problems may arise and ventilation control measures may need to be implemented. For stoping on the 14 level to occur, assuming the new intake (or another method) is in operation, a restriction on the number of diesel equipment entering the level may be required ie only the production bogger and one truck will be allowed in the level when loading and hauling because only 40 m³/s is going into the level from the new rise. The remaining air supplied by the rise flows the main decline and then down to the 15 level. Other trucks would wait at the entrance to the 14 level or in the main decline before loading, where the air supply is adequate.

The simulation of the stope extracted from the 13 level shows that it acts as a large airway, allowing approximately 30 m³/s of air to flow from the 12 level into the 13 level. Although this air may be dusty, it is sufficient to dilute diesel fumes emitted by the equipment used in the production process. Trucks can be loaded past the stope drawpoint, further into the level, because there is an existing fresh air rise, which has the capacity to dilute the fumes emitted by the trucks.

Ventilation in the 12 level is adequate for development purposes since there is approximately 40 m³/s of airflow entering from the main decline. The use of secondary fans may be necessary to get more airflow to the development headings, depending on their location in relation to the primary ventilation circuit.

The quantity of air flowing down the main decline is approximately 70 m³/s, which should accommodate ventilation requirements for development processes in the 15 level. Bogger or truck will be sufficiently ventilated with 25 m³/s during the development of Winged Keel stopes.

Scenario 3: This scenario is characterised by stoping on 13 and 15 level and development on 10, 12 and 14 level.

Stoping in the 13 level can occur using the 31 m³/s of air that flows from the 12 level. This will bring the total airflow in the level to 40 m³/s, which means that an equipment restriction must be applied because the ventilation system cannot accommodate for two trucks and two boggers to be in the 13 level at the same time. Also, ventilation control devices will need to be utilised to direct the airflow to the intended working areas. Secondary ventilation can be used to supplement the airflow coming in from the main decline.

Stoping on the 15 level will require the same ventilation measures as for 13 level.

The quantity of air flowing into the 10 level is approx. 17 m³/s, which is sufficient for one Jumbo but control devices will need to be constructed to increase airflow if trucks and boggers are going into the level.

Both the 12 and 14 levels have sufficient airflow for development to take place, but the development on 14 level should preferably take place before or after the production on 15 level. This will ensure that the contaminated air from 14 level does not flow into the 15 level.

Scenario 6: This scenario is characterised by stoping on 13 level in Central Zone and 15 level in Winged Keel as well as the development on 10 and 15 level in Central Zone.

The stope simulated between 14 and 15 levels allows approximately 20 m³/s of air to flow into the 15 level. With the intake at 14 level closed off, this amount can be increased to 30 m³/s. Stoping can take place at 15 level Winged Keel with only one truck and one bogger in the level. Trucks waiting to be loaded will have to do so in the main decline. However, these restrictions can be avoided by increasing airflow at the loading point by placing a ventilation control device at the exhaust, located at the end of the main decline. This will increase airflow significantly by 50 m³/s. Alternatively, secondary ventilation can be used at the 14 level to direct more air through the 14 level to the 15 level Winged Keel area.

The airflow in the 13 level is approximately 30 m³/s, adequate for one truck and one bogger. Secondary ventilation can be utilised so that more air from the decline can enter the level.

The airflow in the 15 level is adequate for development purposes. The 10 level, on the other hand, requires ventilation control in certain areas, depending on the location of development, to direct airflow to the working major working areas. Secondary ventilation can be used at the 10 level to increase the airflow coming in from the main decline.

Scenarios 9 and 10: Scenario 9 is characterised by stoping on 7 and 14 levels in Central Zone and Winged Keel, respectively, and development on 2 and 10 levels.

Scenario 10 is characterised by stoping on 7 and 15 levels in Central Zone and Winged Keel, respectively, and development on 2 and 10 levels.

The fresh air rise on level 2 can be used to supplement the airflow from the main decline going into level 2. Although there is sufficient air going into the level for Jumbo development, the use of trucks and boggers will require additional airflow from the rise. The type of ventilation device used in the level will depend on the length of time the development process is expected to take. The effect of level 2 development on ventilation in the lower levels of Central Zone is minimal.

A total of 63 m³/s enters the 7 level from the main decline. This meets the 61 m³/s requirement for the diesel equipment used in the production process. The airflow in the 10 level needs to be controlled by placing ventilation devices in drives that lead to old stopes. This will result in more air being directed to current working areas rather than old mined out areas. The 10 level will be supplied with 20 m³/sec of air, however, it can be increased with secondary ventilation.

Stoping on 15 level can take place if the ventilation recommendations discussed for Scenario 6 are followed.

CONCLUSION

In general, VentSim was found to be an effective tool when modelling and simulating the ventilation network at Bronzewing Gold Mine. Its main advantages was the ability to simulate scenarios 'realistically', ie the simulation results were comparable with those obtained via ventilation surveys conducted at Bronzewing in most cases. In addition, the VentSim program allows for easy file import from mine planning softwares, provides accurate 3D schematic of ventilation systems and allows for detailed network analysis.

Main disadvantage is the difficulty of fixing airflow directions for more complex systems. In addition, the contaminant simulation produces inaccurate results and the secondary ventilation cannot be simulated effectively or realistically. VentSim does not model refrigeration and temperature conditions at the mine.

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