Gas Drainage Improvement in Underground Coal Mines

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ABSTRACT

Effective gas management is vital to the success of the longwall mining in the Bulli seam, in the Southern Coalfield, Sydney Basin, NSW, Australia. The evolution of gas drainage methods and practices are discussed with respect to gas type, gas drainage lead time and prevailing geological conditions. Both underground to inseam drilling and surface to inseam drilling techniques are described at both pre and post-drainage conditions. Post-drainage of gas from longwall is discussed for its effectiveness, practicability and efficiency. The long term benefit of the method selected is examined with respect to gas capture efficiency. An alternative method of surface based goaf drainage, using medium radius drilling technology to drill horizontal boreholes above and/or below the production seam into the partial caving zone prior to longwall goaf formation is proposed.

Keywords: Coal mine gas, Gas drainage improvement, Underground drilling, Bulli seam

1. INTRODUCTION

Effective gas management is vital to the success of the longwall mines operating in the Bulli seam, located in the Southern Sydney Basin, Australia. High gas emissions are characteristic of the region with specific gas emissions typically in the order of 30-45 m^3/t. The mines that operate in this area have, since 1980, relied on the use of extensive underground to inseam (UIS) drilling to drain gas both ahead of advancing roadway development (pre-drainage) and following longwall coal extraction (post-drainage). The primary role of pre-drainage is to reduce the gas content of the coal seam to be extracted to less than the prescribed Threshold Limit Value (TLV). Although variable, this typically requires the removal of some 6 m^3/t of gas ahead of roadway development.

Various models exist for estimating the volume of gas liberated during longwall extraction. Flugge is one such Model. Table 1 shows the results of Flugge modeling based on 300m wide longwall panels at a Colliery operating in the Bulli seam. The results indicate that for every tonne of Bulli seam coal extracted by the longwall a combined total volume of 45m^3 of gas will be liberated from the combined gas sources above and below the working seam.

Therefore in this case the gas drainage management system must be capable of effectively managing gas emissions in excess of 50m^3/t.

With the ever increasing production capacity of modern mining machinery the UIS methods are struggling to drain sufficient gas from the coal ahead of mining to avoid gas related production delays.

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Table 1: Flugge longwall gas emission modeling at a Bulli seam longwall mine (Meyer, 2006)

Group	Formation	Thickness	Estimated average pore pressure (kPa)	Potential Gas Emission m3/m2	Potential Gas Emission m3/t	300m Flugge Release %	300m Flugge SGE m3/t
Wianamata	Wianamatta	29					
Hawkesbury	Hawkesbury Sandstone	184					
Narrabeen	Newport Formation	13					
	Garie Member	3					
	Baldhill Claystone	28					
	Bulgo Sandstone	141	3500	48.7	12.9	65	8.4
	Stanwell Park Claystone	7					
	Scarborough Sandstone	58	4300	24.4	6.5	72	4.7
	Wombarra Shale	49					
	Coalcliff Sandstone	22	4750	10.5	2.8	95	2.6
Illawarra Coal Measures	Bulli Coal	2.7					
	Loddon Sandstone	7					
	Balgownie Coal	1	5800	14.4	3.8	89	3.4
	Lawrence Sandstone	8					
	Cape Horn Coal	1	5900	26.1	6.9	75	5.2
	UN2	8					
	Woronora Coal	7					
	Novice Sandstone	4					
	Wongawilli Coal	10	6100	164.3	43.5	45	19.6
	Kembla Sandstone	8					
	American Creek Coal	2	6300	38.5	10.2	13	1.3
	Allans Creek Formation	18					
	Darkes Forest Sandstone	9					
	Bargo Claystone	14					
	Tongarra Coal	2	6700	25.6	6.8	0	0.0
					Total potential emmisions		45.1

2. BACKGROUND

The use of routine drilling programs for gas drainage began in Australia in 1980 and quickly spread among the gassy mines in both New South Wales and Queensland. The early drilling rigs utilised rotary drilling systems that were capable of drilling boreholes of up to 400 to 600 metres with a directional accuracy in the order of ±15^{o} (Kelly 1983, Hebblewhite *et al.*, 1982 and Hebblewhite *et al.*, 1983). The rotary units were later replaced by down-hole motor drilling systems that were capable of achieving much greater drilling distances whilst maintaining survey accuracy in the order of ±0.5^{o} azimuth and ±0.2^{o} pitch (Brunner and Schoebel - Online).

Following the last fatal Outburst that occurred in Australia in 1994 a directive was issued to all Bulli seam coal mine operators, under the authority of the Coal Mines Regulation Act 1982, prescribing Threshold Limit Values (TLV), and other actions, to be implemented to manage risk and prevent future coal and gas outbursts. In order to comply with the outburst mining guidelines, and meet the TLV, drilling programs became far more intensive and generally the overall drilling effort increased. It is common for mines operating in the Bulli seam to drill well in excess of 100,000 metres annually. An example of a typical drilling program at a Bulli seam operation is shown in Figure 1.

In addition to the inseam drilling for pre-drainage significant attention is also given to post-drainage gas capture methods. The failure of operations to effectively manage longwall gas emissions may result in the volume of gas liberated exceeding the diluting capacity of the mine ventilation system. In such situations the gas concentrations in the mine airways exceeds the prescribed statutory limit resulting in a production delay until such time as the concentration is reduced.

With the increased capability of modern mining machinery to achieve high production rates it is critical to the success of mines operating in these conditions to ensure that both pre-drainage and post-drainage gas management systems are efficient and capable of supporting the planned production targets. For example, a mine producing an average of 10,000 tonnes/day that has a total specific gas emission of 50 m^3/t will liberate 500,000m^3 of gas per day (182.5 million m^3/annum).

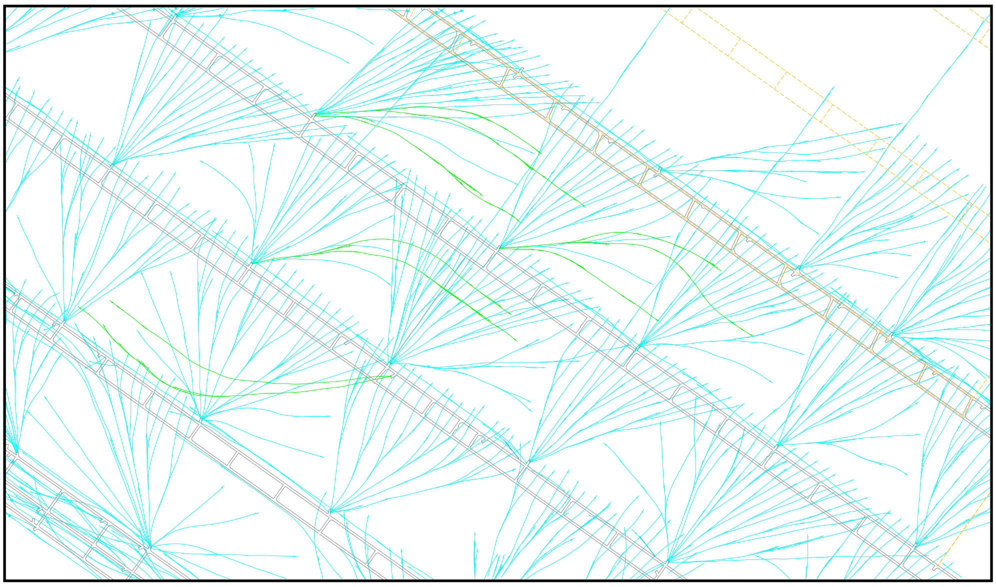

Figure 1: Typical drilling pattern at a Bulli seam operation.

3. PRE-DRAINAGE

The preferred method of draining gas ahead of roadway development has been through the use of underground to inseam (UIS) drilling. UIS gas drainage programs typically involve drilling boreholes, of nominal 96 mm diameter, within the coal seam, from one set of development headings (gateroads), across the proposed longwall block extending some 15 to 50 metres beyond the next adjacent development heading. The boreholes are typically drilled in fan patterns to minimise the frequency of drill rig relocations, and the spacing between boreholes varies according to seam permeability and overall drainage effectiveness. The inherent limitation with this method is that it is linked to the mining cycle i.e. drilling cannot commence until the gateroad has been developed, and the drainage lead time is dictated by the rate of advance of the adjacent gateroad. Therefore as the rate of gateroad advance increases the effective gas drainage lead time reduces. For many mines that operate in favorable gas drainage conditions, with permeability greater than 1-5 mD, that require relatively small gas content reduction to achieve TLV, this has not been an issue. However the Bulli seam has quite low permeability, typically less than 1.0 mD, the insitu gas content is relatively high (9-14 m^3/t). A number of mines in the region are also progressing toward zones of increasing CO_2 concentration.

In the areas of increased CO_2 concentration the coal is deeply undersaturated in gas and requires far greater time to remove the water from the cleat and pore structure prior to any reasonable gas drainage occurring. Figure 2 shows a typical example of the relative saturation in both CH_4 and CO_2 zones and the comparative depressurising (dewatering) that is required to reach the critical desorption point on the respective isotherm curves after which gas desorption will occur.

Where such difficult drainage conditions exist, the UIS method of gas drainage does not have sufficient drainage time to effectively remove sufficient gas from the coal. A typical response of mine operator in such cases is to reassign drilling rigs from routine drilling into these areas to further increase the borehole density. This action, although generally effective in removing sufficient gas to enable mining to advance, places additional pressure on future mining areas as available drainage lead time has been lost for the period the drill rig had been relocated.

As mining progresses toward areas of increased drainage difficulty the impact is compounded and in a number of cases production delays have resulted. In the most extreme cases mine plans have been changed to avoid operating in such problematic conditions.

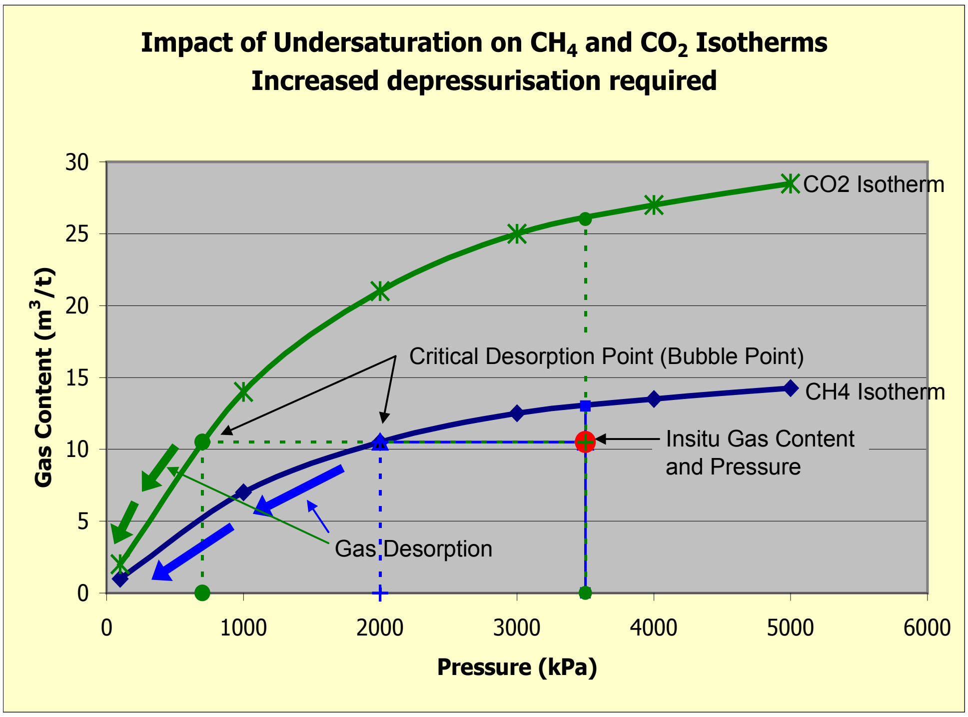

Figure 2: Relative saturation in typical Bulli seam conditions and depressurising (dewatering) required to reach critical desorption point

There are many factors, both controllable and non-controllable, that impact the ability of mine operators to remove gas from the coal seam prior to mining. A detailed study undertaken by the first author at an Illawarra mine, operating in the Bulli seam, concluded that a variety of actions can be taken by operators to optimise UIS gas drainage programs (Black and Aziz, 2008). Such actions include:

1. Borehole monitoring and management to identify holes that may be blocked by a buildup of water or coal fines and to take action to remove that blockages;
2. Optimise the trajectory of the UIS boreholes being drilled that they are favorably oriented relative to the Cleat, Stress and Dip of the coal seam;
3. Maximise available drainage time; and
4. Maintain suction at the collar of the borehole to assist in gas removal and the prevention of back pressure that would impede gas drainage.

Surface-based gas drainage has significant potential to assist in the drainage of gas ahead of mining. Techniques such as vertical hydraulically fractured wells and medium-radius drilling (MRD) are becoming more common, particularly in the coalbed methane (CBM) industry. Figure 3 shows the components of an MRD gas drainage system.

The benefit of such methods is that the drilling and production of the wells are independent of the mine workings and therefore can be installed many years in advance of the planned mine working therefore providing far greater pre-drainage lead times.

Such techniques have been trialed in the Southern Sydney Basin however they have not to date become common place. Two of the main reasons for the lack of uptake are the relatively high cost of such wells compared to UIS, given the drilling depth to reach the Bulli seam is typically in the order of 500 metres, and the significant constraints and limitations relating to gaining surface access to undertake such programs. Many of the mines in the Southern Sydney Basin are located below a variety of significant surface features that impact their ability to undertake certain activities, including coal extraction, such as dams and water catchment, state forest, urban development, creeks/rivers and road and rail networks.

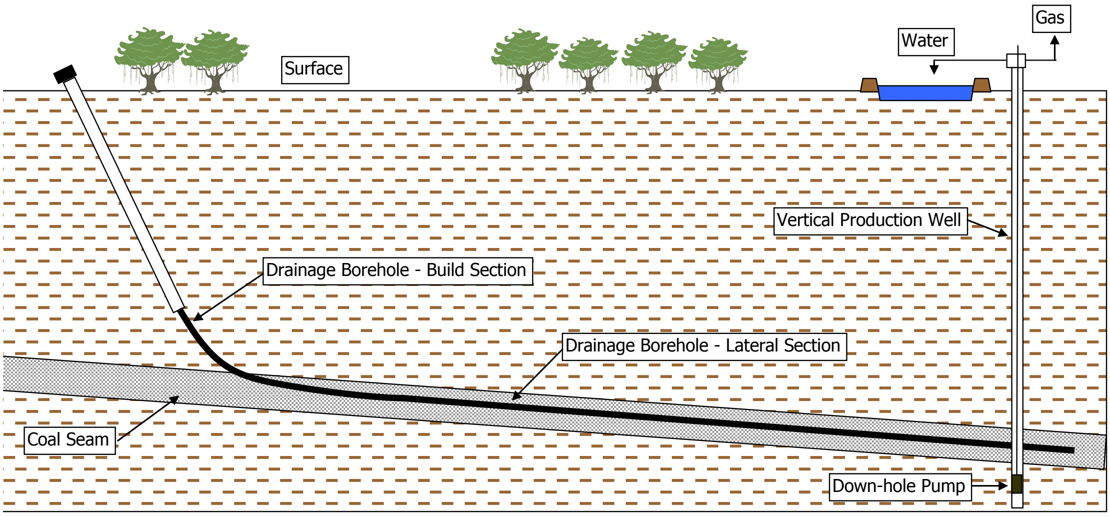

Figure 3: Components of an MRD borehole and vertical gas drainage production well.

4. POST DRAINAGE

The major source of gas emission within a mine occurs in the longwall goaf. Typically a mine will aim to maintain in the order of 150 m^3/s of mine ventilation air to the longwall ventilation circuit for the purpose of diluting gas and maintaining a safe working environment. If not removed from the system by some form of post-drainage gas capture, the gas liberated during longwall extraction will be released into the mine ventilation network. In the case of a mine that maintains 150m^3/s of mine ventilation air to the longwall, with a specific gas emission (SGE) of 40 m^3/t and has an average daily production target of 10,000 tonnes it will be necessary for the mine to capture and remove at least 14 m^3/t (35%) in order to maintain the general body gas concentrations to less than the 2% statutory limit. The percentage of the total gas emission that is captured by the mine gas drainage system and prevented from entering the mine ventilation network is known as the post drainage capture efficiency (PDCE).

There have been many methods of longwall goaf gas capture used by mines in the Southern Sydney Basin. These methods include cross-measure drilling, back-of-block drainage, goaf seal drainage and directional boreholes.

Cross-measure drilling involves the drilling of boreholes from the maingate travel road at an angle into the floor to intersect the lower coal seams in the sequence.

Back-of-block boreholes involve the drilling of a series of boreholes up into the roof above the longwall from the behind the longwall installation face prior to the commencement of extraction in the panel. Following the commencement of extraction and goaf formation these boreholes become exposed to the fractured goaf and extract high purity gas.

Goaf seal drainage involves the drawing of gas from the goaf through existing goaf seals.

Directional boreholes involve the use of down-hole motors to drill long boreholes approximately perpendicular to the longwall face located in the caving zone above and/or below the Bulli seam.

With increasing longwall production these methods have struggled to drained sufficient gas to prevent production gas delays and alternative drainage methods were pursued. In 2006, goaf drainage was trialed at West Cliff Colliery as reported by Meyer, 2006. This method involves the drilling of a series of vertical boreholes from the surface that, following the passing of the longwall face, created a connection to the goaf, through which gas is drawn from the goaf to the surface using a vacuum pump to overcome the mine ventilation pressure. Figure 4 provides an indication of the location and effect of goaf drainage boreholes in removing gas from the longwall goaf.

The West Cliff Colliery experience with surface-based goaf gas drainage has demonstrated an ability to drain goaf gas at an average rate of approximately 400 lps (peak 800-1,000 lps). The production data from three separate goaf drainage wells, SGW#1, SGW#2 and SGW#3 (Figure 5), show the characteristic production profile of such wells. Following the initial connection to the goaf the production rate rapidly increases to the maximum which is sustained for several weeks followed by a rapid decline to a steady state production rate that is maintained until the well is removed from service.

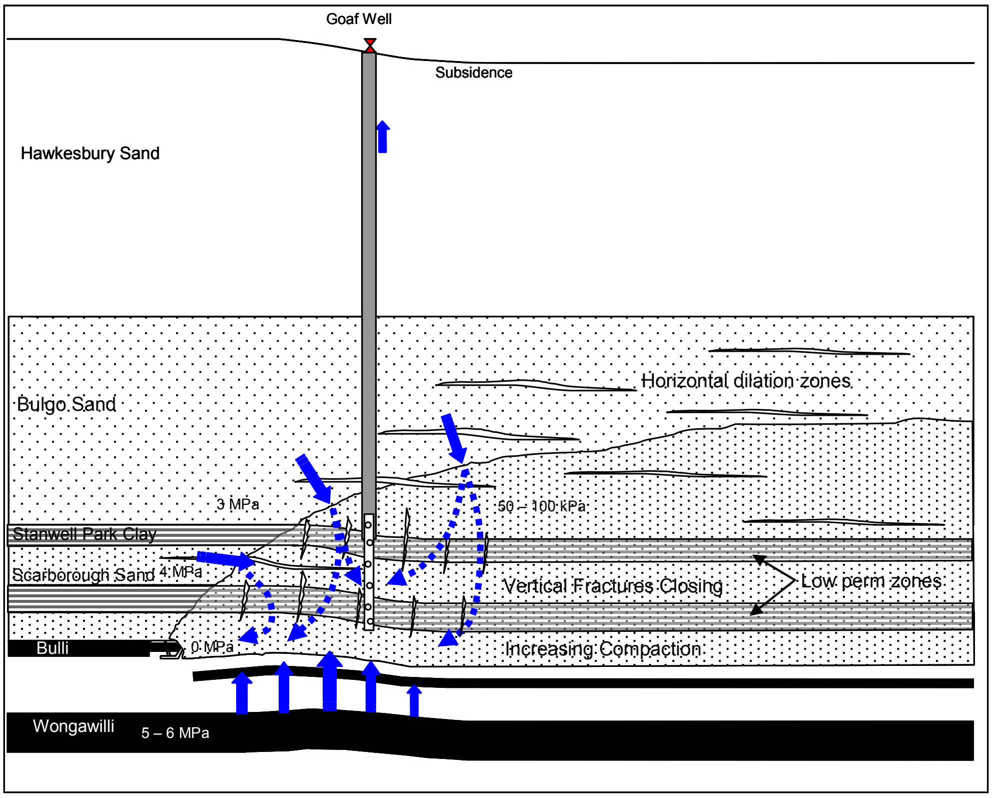

Figure 4: Illustration of the effect of surface gas drainage boreholes in draining longwall goaf gas emissions (Meyer, 2006).

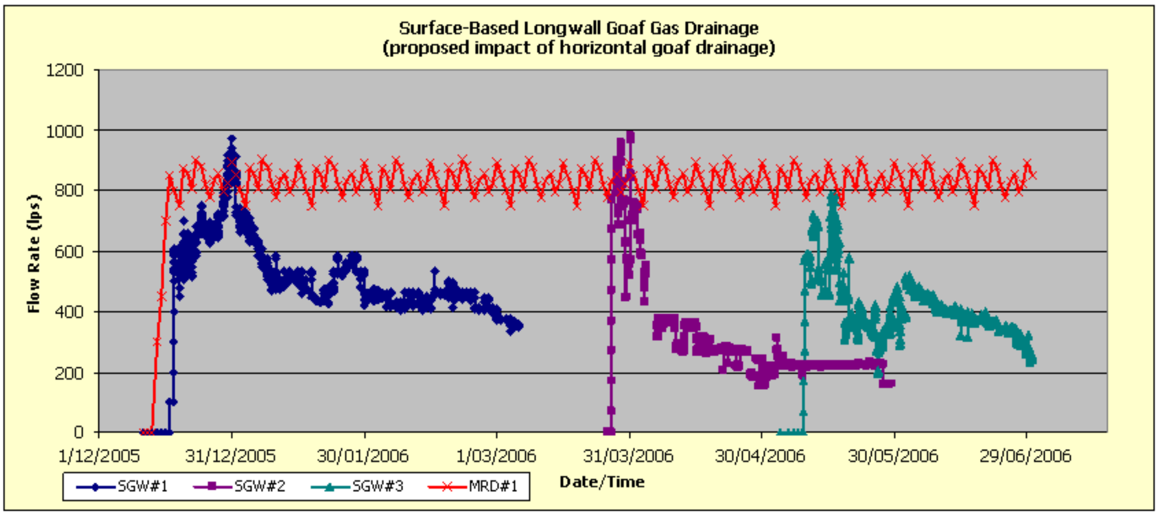

Figure 5: Surface-based longwall goaf drainage production data and estimated MRD well gas production rate.

An alternative method of surface-based goaf drainage, proposed by the first author for trial in Australia, is the use of MRD drilling technology to drill horizontal boreholes above and/or below the production seam into the partial caving zone prior to goaf formation. As the longwall retreats the MRD drainage boreholes connects to the goaf and is used to draw gas to the surface using a suction plant, similar to that used with the vertical system. The significant potential advantages of the MRD method include:

1. The point of connection between the drainage borehole and the longwall face remains relatively consistent therefore the gas production rate is expected to be less variable than the vertical well alternative (Figure 5);
2. The effect on reducing gas emissions close to the longwall face will be maintained for the life of the borehole; and
3. Significantly less surface disturbance will be necessary as a single MRD surface installation has the potential to service two adjacent longwall panels and replace at least three vertical surface goaf wells (SGWs) per panel.

Figure 6 provides an illustration of the lateral section of an MRD borehole relative to the operating longwall face and the proposed flow paths of goaf gas entering the drainage borehole(s).

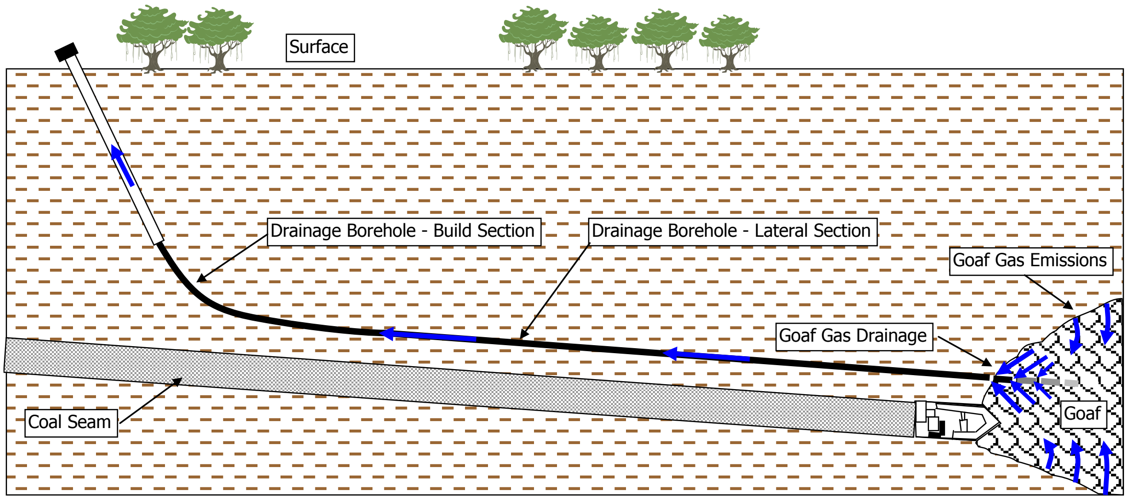

Figure 6: Illustration of the goaf gas capture into a lateral section of an MRD goaf drainage borehole.

5. CONCLUSIONS

The continued use of underground gas drainage methods alone will not be capable of draining sufficient gas in the relatively short lead time available to support high production rates by longwall mines operating in gassy conditions.

The use of surface based gas drainage methods has the ability to enable drainage to be conducted independent of mine operations and enable far greater drainage lead times to be achieved. Although surface-based drilling is generally more expensive than UIS drilling and has an obvious environmental and community impact these methods should be given serious consideration due to the improvement in gas drainage effectiveness and the potential to adequately reduce gas concentrations ahead of mining to avoid production delays and loss of coal reserves.

The use of drilling technologies such a MRD has the added benefit of being able to drill and drain gas from long distances which is very attractive from an environmental and community impact perspective as there is an overall reduction in the total number of surface installations required.

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