AN INVESTIGATION INTO A WATER INFLOW AT WONGAWILLI COLLIERY. SOUTHERN COALFIELD, NEW SOUTH WALES

By
J.F. Doyle¹ and G.R. Poole²

ABSTRACT

An unusually high flow of water from an extraction panel in Wongawilli Colliery prompted the investigation of the possible sources of the water.

It is more probable that water is derived from sources adjacent to or within the Wongawilli Coal rather than by direct transmission from any surface source.

INTRODUCTION

Wongawilli Colliery is a bord and pillar mining operation located in the Southern Coalfield of New South Wales, 20 km south west of Wollongong (Fig. 1). The mine works the Wongawilli Coal, this unit being approximately 9 m thick. Only the basal 2.7 m to 3.0 m is mined. The upper section of the unit is composed of uneconomic interbedded shales and coal. Depth of cover to the seam varies between 90 m and 250 m.

The Wongawilli Seam can be described as a "wet" seam with openings in the seam normally allowing water to be emitted from the roof (dripples). In December 1982, a flow of unusual volume was experienced in Blue 2 Panel, Wongawilli Colliery. This paper will detail three possible sources of the water and available techniques of water source evaluation.

EXPERIENCES WITH WATER IN BLUE PANELS

From June 1982, a flow of water was experienced in Blue panels of the Wongawilli seam workings, Wongawilli Colliery (Fig. 2). The flow increased in volume progressively with pillar extraction. In December 1982, the flow rate rose rapidly from about 30 000 to 100 000 1/hr, during pillar extraction in Blue 2 Panel.

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About half of the total water make from the Blue Panel area originates from Blue 2 Panel. Fig. 2 illustrates the mine workings and Wongawilli seam geology.

**HYDROGEOLOGY**

Relative to an understanding of the origin of mine water, the hydrogeological characteristics of the Southern Coalfield become important to the Wongawilli case.

The main factor controlling movement of water into mine workings is fracture-porosity. (Williamson, 1978, Stutlz, 1974) The rocks of the overlying Narrabeen Group (Fig. 3) have extremely low primary permeability, usually less than 0.1 milidarcy equivalent to 8.6 x 10^-15 cm/sec), with the exception of some limited aquifer zones. Water yields from the Narrabeen Group in bores and shafts are also most invariably low. Ground water movement is dominantly horizontal along the stratigraphic bedding. The intervening shale units have this formation virtually impervious in the vertical direction.

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<td>American Creek Coal Mbr.</td>
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Fig. 3 - Representative Geological Section at Wongawilli Colliery

Entry of significant volumes of water into mines originates mostly from the escarpment or portal zones where joint systems open up because of stress relief and effects of weathering. Entry in such cases can vary with the climate. The adjoining Nebo Colliery at a time of prolonged rainfall experienced an entry of 40,000 to 1,000,000 l/hr.

Away from the escarpment or portal zones, entry of water in the form of flows and seepages has mostly been at a rate of up to about 4,000 l/hr. In flat workings, rates of about 350 l/hr, are more common. Rates of flow need to be compared with the location and area of exposed workings.

Dykes and faults do not transmit water.

Goafs have initiated or accelerated flows of water. For example, in Kenitra Colliery the normally dry Bullo seam allowed a flow of 9,000 l/hr. from its caved roof.

Surface water does not enter mine goafs because of the low permeability of the Narrabeen strata above the caved zone. Surface tensile fractures do not provide hydraulic connection to the workings. Over Wongawilli Colliery workings, where both the Bullo and Wongawilli seams had been fully extracted, subsidence was measured at 2.1 m, 277 m above the Bullo seam and substantial tension fractures were evident at the surface. The deepest effective aquiclude was from 113 to 137 m, below which any aquifers present could drain more or less freely into the workings. Thus, in this severe case, strata disruptions sufficient to allow ready drainage into the workings extended for 50% of the strata sequence above the Bullo seam. In the upper 50% low-permeability strata effectively retained the aquifer system (Williamson, 1978).

Under normal geological circumstances in Southern Coalfield mines the only appreciable water entry from exposed strata is from the upper section of the Wongawilli seam, i.e. about 6 m of coal and mudstone beds overlying the mixed basal section of about 3 m. The strata may yield water in small quantities in any one place but the aggregate quantity over a mining district can become significant.

The overlying Bullo seam has been mined in portion of Wongawilli Colliery. It was evident by inspection that the Bullo seam remained dry whereas the underlying Wongawilli seam workings were typically wet.

**WATER SOURCES**

The source of the water inflow into Blue Panel is thought to be derived from one or more of the following alternative sources.

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OLD WORKINGS

Handworkd mining stopped to the south east of the inflow, approximately along the edge of an igneous intrusion. The abandoned workings subsequently became filled with groundwater.

The distance from the point of major inflow (i.e. Blue 2 Panel) to the nearest point in the old workings is 800 m. There is no precedent for water to transit through a constrained seam for this distance. Although the Wongawilli seam can be wet in first workings and upon pillar extraction, as a result of strain relaxation, it would be expected to act as a solid barrier in this case, particularly as the first workings of the nearer Blue 4 Panel stopped 400 m from old workings and did not experience a similar inflow. The general history of water emissions around the edge of the Blue panels workings has been of irregular encounters of magnitudes ranging down to dryness.

In the Wongawilli seam elsewhere, first workings have traditionally encountered seepages, rather than flows, hence an unworked block of coal 400 to 800 m wide would not be expected to yield any greater amount.

Circumstantial evidence of the old workings as a source, based on a huge volume of water estimated to take two years to drain at the present rate, can nevertheless be supported by the knowledge that the magnitude of the flow rate is unprecedented by any alternative source of supply.

The body of water in the old workings is inaccessible, but the mine management inspected water levels near the mine portals, 2 km or so from the western limit of the workings in January 1983. Here recent lowering of water height was observed. Water samples, labelled "old workings" were analysed, the results of which are quoted in Table 1. Since underground monitoring of the level in the main body of old workings is not possible practically, it is necessary to distinguish between the assumption of a direct relationship of the observed workings to the flooded workings and the assumption that the observations are confined to isolated pools. Measurable flows of water into workings that extend back to the escarpment have been experienced in other places. In this case, the long dry climatic period, the effect of the mine ventilation system, the nature of water make in the old workings and entry of surface water through weathered strata or cracked shallow cover, are factors that should contribute to an explanation of fluctuation in levels of mine water near the portals.

GROUNDWATER

The Wongawilli seam would not normally be regarded as an aquifer. Nevertheless, it has always had an ability to exit water into mined places. In various panels of Wongawilli Colliery's current and recent first workings, water has been observed as seepages, drippers from the roof and as flows from some roof bolt holes. On occasions the coal beds above the working roof have been relieved of pressure by release of water through bolt holes. Pillar extraction is often a means of accelerating an emission of water into flows of varying magnitude. The caving of the upper part of the Wongawilli seam allows fracture permeability to be created out of its previous state of low to zero vertical permeability. In some cases special pumping arrangements have been necessary to cater for these inflows, but documentation is seldom made in Wongawilli seam mines of locations or rates of flow, since mining operations are never interrupted for intolerable periods.

Because the Wongawilli seam can be a wet seam and can increasingly transmit water as a result of goaf formation, the groundwater regime within the Wongawilli seam geological section is regarded as having an irregular expression, and is capable of being tapped in

<table>
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<th>Blue Panel</th>
<th>Old Workings</th>
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<td>7.5</td>
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a manner different from the Bulli seam which is usually dry and dusty.

The experience in Blue panels of Wongawallin Colliery is along similar lines. Seepage was first encountered, then inflows commenced and increased with extraction of pillars. However, water continued to flow at a sustained rate that exceeded previous experiences and produced more water than the goaf is capable of yielding from merely the volume of roof caving. Circumstantial evidence for groundwater being the explanation for such excessive flow lies in the nature of the cinder associated with igneous intrusions in this part of the mine. The cindered parts of the Bulli and the underlying American Creek seams are porous and permeable. In addition, SE Headings has shown a higher-than-average, water-bearing capacity in the roof above first workings near Blue 2 Panel's pillar extraction.

**SURFACE WATER**

If the mine water resulted from natural fractures between the seam and the surface, there should be some relationship between the area exposed by first workings and water make. Since this is not the case, entry of surface water into the mine must rely upon mining-induced cracks for access.

Evidence tendered to the Judicial Inquiry into Mining Beneath Stored Water (Reynolds, 1977) related to the shallowness of cover that could be tolerated by various degrees of extraction. The area of the goaf and the cover of 130 m above the point of entry of water into Blue 2 Panel are not consistent with cracking at the surface that would act as a conduit for water from Avon Reservoir to Wongawallin Colliery. Measured tensile strains over the area of the inflow are less than 0.27 mm/m. A maximum strain of 1.27 mm/m above Blue 4 Panel and across a dyke was observed. A tensile fracture 80 m long and 80 mm wide was associated with the dyke.

Many dykes have been exposed in Blue panels but none has provided access for water.

Although there are occasional cases of lenticular permeable zones above the coal measures, Narrabeen strata as a whole are classified as impermeable. Transmission of water usually relies upon bed separation as a result of goaf formation. For example, a free flow of water 100 m above a Bulli seam goaf in AIS Kesra No.6 Bore was related to a slumping of the Stanwell Park Claystone from the overlying Bulgo Sandstone. The comparison of this knowledge with the Wongawallin case is that the Stanwell Park Claystone/Bulgo Sandstone contact occurs about 35 m below the surface at the point of shallowest cover, i.e. at the floor of Avon Reservoir, and the Wongawallin seam is 30 m below the unmarked Bulli seam. In this comparison, the Bulgo Sandstone floor of the reservoir would act as a bridge over the separated underlying beds near the seam. A closer comparison may be made with the experience in JS and J6 panels of Wongawallin Colliery's Bulli seam workings. Directly below, at a depth of 30 m, the Wongawallin seam had been previously extracted. The Wongawallin seam goaf had not extended to the Bulli seam, but had had some subsidence of that seam of 300 mm from its roof, which maintained a sound sandstone bridge over the dumped seam and separated beds. The Bulli seam workings were dry, despite subsidence cracks on the surface.

Upward penetration of Blue Panel goaf would be less than that observed in the more extensive pillar extraction area beneath the Bulli seam J panels. Permeability as a result of caving, therefore should be no higher than the Bulli seam.

**METHODS OF INVESTIGATION**

**CHEMICAL ANALYSIS OF WATER SAMPLES**

Water samples were collected where possible from available sources of water that were entering Wongawallin Colliery regularly since December 1982. Samples were collected from:

1. Roof drippers in the Wongawallin seam away from the major water inflow.
2. Major inflow, Blue 2 Panel.
3. Avon Reservoir.
4. "Old Workings" to the south east.

The chemical analysis of inflowing water collected in Blue Panel has depicted little change over two years. They indicate that Blue Panel water originates neither from the "old workings" nor from Avon Reservoir. The results are consistent with a natural groundwater source. However, caution must always be exercised when applying mine water analysis to explain the source of the water. Mine water must enter workings via the coal seam or surrounding strata. Irrespective of its source, its passage will have a bearing upon its composition, according to the solubility and chemical composition of the rock minerals and the time spent by the water in passing through the rock strata. The analysis of mine water may not be uniform and may not be similar to the analysis of that water at its inferred source.
Future chemical analyses are expected to show that saline contents of the water entering the mine is fairly constant thus confirming groundwater as at least the dominant source.

BLUE PANEL INFLOW/AVON RESERVOIR WATER BALANCE

A "mathematical" approach to test the validity of Avon Reservoir being the source for the water inflow to Blue Panel was considered. If all the water which flows into Blue panels is derived from Avon Reservoir the reduction in the storage is not detectable. The level of the reservoir would drop only 6.8 mm per month given a 100,000 l/hr. outflow from the storage. The loss by evaporation alone from the storage is 70 mm per month.

TRACERS

As a purely mathematical balance between Avon Reservoir and Blue Panel water inflow was not possible, several tracers were suggested as possible means of determining the water origin. Radiotopes and dyes were not permissible tracers to be liberated into a water supply reservoir.

Algae was sought as "natural" tracer, with numerous algal species known to pre-exist in Avon Reservoir. Comprehensive sampling of underground and surface waters was conducted with species type and number of species in individuals being determined. Cheng (pers. comm.), suggested that results of his work supported that the water inflow to Blue Panel was derived from Avon Reservoir. His studies found nearly all algal bodies in the mine water were dead, while some cells such as Cryptomonas may be probably live cells. The interpretation taken by Cheng (1994) was that this evidence suggested a passage of water through minute cracks and fissures in the rock strata between the reservoir and colliery workings.

Jones (pers. comm.) supports an alternative explanation for the detection of algae in the mine, suggesting that the algal bodies may be derived from surface water but dispersed in the mine by-

(i) air-borne (algae spores),
(ii) via supplies brought into a mine (e.g. timber props),
(iii) water supply from dams on the surface for dust suppression in the pit.

Further support to this hypothesis is given by the unknown period of time that algal bodies can live with only limited light, such as in a mine environment. Some algae have been stored dry in total darkness for 70 years but have been able to be revived with water. (Jones, pers. comm.)

Results from algal tracing is ambiguous. Though algae has been detected in a mine environment its mode of entry cannot be established.

EVALUATION

Although analysis of the water flowing into Blue Panel is inconsistent with analyses of water from the old workings and from Avon Reservoir, thereby favoring a natural groundwater origin, there is no diagnostic characteristic of mine water to identify its origin positively. The existence of a natural groundwater regime as a source of supply is, however, consistent with previous experiences in Wongawilli seam and with observations on the type and timing of the Blue Panel inflow.

The flow rate experienced by Blue Panel is unprecedented under normal conditions. In Blue Panel, however, the geology is not normal. Igneous intrusions, with associated conversion of coal to cinder, form a widespread environment that has been encountered by the mine workings.

Blue 1 and 4 Panels encountered cinder that was derived from a sill in the floor. 1 SE Headings and Blue 2 and 3 Panels encountered cinder derived from a sill in the roof. A sill within the working section itself appeared intermittently in all these panels.

In the old workings to the south east, cinder was derived from a sill in the roof. The change of character in the sill around Blue 1 and 4 Panels has uncertain significance, particularly as Blue 4 Panel represents the closest projection to the old workings. It is significant however, that the projection of a dyke between known points in Wongawilli and Avon Collieries is close to and parallel to a prominent surface lineament and would occur very close to the extremity of Blue 4 Panel.

The occurrence of widespread cinder, which is porous and permeable, is sufficient to explain the exceptional experience of large sustained water flows. Because dykes do not allow transmission of water from one side to the other, water discharge from beds of cinder would be expected to be confined to that part of their area north west of the dyke that is believed to occur between Blue panels and the
old workings.

The constant high flow of water since workings were abandoned infers an aquifer, such as a cinder bed, with a water-bearing capacity well in excess of those tapped in other parts of the mine where geological conditions were normal. Otherwise the phenomena are consistent with previous experiences in the Wongawilli seam, whereby flow was comparatively slight in first workings and showed only slight increases as first workings developed. Flow increased rapidly upon commencement of pillar extraction and progressively increased with further pillar extraction, then finally stabilised when extraction stopped. Since 1983, the flow has been decreasing steadily. The effect of bed separation in the roof strata over first workings is consistent with the appearance of water in the form of roof drippers and individual minor flows. An unusual feature is that the exposed cinder in places gave no direct indication of excessive water flows above floor level. The major inflow in Blue 2 Panel is observed as running from the goaf at floor level at one place only although its actual origin is obscured from observation by goaf fall. The visible roof of the goaf margin shows no water flows or drippers.

The increased appearance of water from the Blue 2 Panel goaf did not affect the rates of flow from the remainder of Blue Panels. Although the goaf may have tapped an extensive area of separated beds in the upper part of the Wongawilli seam and although fluctuation in water flow from cinder would be relative to the volume of cinder tapped, some draw-down would have been expected from such a large flow rate. A further explanation is that there is yet another cinder zone available, say in the American Creek seam, as a source of supply. Development of a small area of goaf is sufficient to cause floor heave and fracture-permeability downward to the American Creek seam, which is separated by only 9 m of strata from the Wongawilli seam. The American Creek seam consists of cindered coal over a wide area, a significant proportion of which lies north west of the dyke referred to earlier. Cinder is known to occur in ALS Wongawilli Nos. 12 and 15 Bores. Extension to the American Creek cinder of floor heave below the Wongawilli seam provides a flow path from this aquifer. A modifying effect, however, is the existence of a sill, which created the cinder, immediately overlying the seam. The sill is 2.5 m thick and has been described as dolerite. For the cinder bed to be tapped by floor heave, the effect of proximity of the seams must be allowed to dominate over the reinforcing effect of a sill in the stratigraphic sequence.

Postulation that the old workings provide water entering Blue panels is inconsistent with the experiences around the periphery of the workings, particularly in Blue 4 Panel where cinder is derived from the floor, and with the coincidence of increased water emission and goaf formation. Such coincidence has also been experienced in other Wongawilli seam workings where abandoned water-filled workings are sufficiently remote to have no influence. In addition, there is no record of any significant flush of water from the cinder upon exposure by first workings, yet such a flush would have been expected if water from the old workings, although not established, has been indicated with confidence. Any dyke would be a barrier to the transmission of water in the seam.

Postulation that the water inflow may have gravitated from the surface is not supported. No goaf in Blue panels is sufficiently large to generate a high caved zone above the workings, yet water inflow is related to goaf formation. A crack 80 m average width at its maximum development has been noted on the surface above Blue 4 Panel, associated with a dyke 2 m wide at the edge of the goaf. Such a crack is associated with tension in the surface strata. Mining subsidence principles and past experiences with surface cracks as a result of subsidence shows that individual cracks are not continuous down to the coal seam and do not initiate access for surface water into mine workings. Blue panel goaf is less extensive than that below the Bulli seam J Panel workings, hence caving would not be expected to be any higher than the J Panel experience which showed that the subsided Bulli seam roof had not caved. The transmission of water from the surface to the mine due to fracture-permeability is discounted also because of the lack of relationship between the area of first workings and water make. Chemical data distinguishes water from the old workings, Blue Panels and the surface (Avon Reservoir). Algae evidence is ambiguous.

CONCLUSION

The water inflow being experienced by Blue 2 Panel in particular and all the Blue panels in general is derived from natural groundwater in the Wongawilli seam and surrounding strata. Except for the high rate of flow, all circumstances concerning the nature and timing of encounters with water by these panels are consistent with experiences when the mine workings have penetrated the groundwater regime.

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The magnitude of the rate of flow of 80,000 l/hr for ten months, falling to 36,000 l/hr. in due principally to unusual geological circumstances relating to igneous intrusions in the area of Blue panels. The reduction in the flow rates of water in Blue 2 Panel is supportive of a static source such as water-bearing strata in or about the Wongawilli seam. Avon Reservoir is a permanent source at constant head, consequently if water into the mine were to be derived from there then flow rate should remain unchanged. The water is being topped from any or all of the following sources:

(a) Above the working roof, i.e. beds in the upper part of the Wongawilli seam, where first workings have caused them to separate to result in fracture-permeability.

(b) The goaf, where pillar extraction has caused caving of the beds in the upper part of the seam, resulting in fracture-permeability.

(c) An extensive zone of cinder within the working section of the Wongawilli seam, as has been exposed by the workings.

(d) Cinder in the American Creek seam, 6 m below the Wongawilli seam. Strain relaxation below the floor of the Wongawilli seam workings, resulting in puncturing of the inter-seam strata, has allowed the cinder to yield its water under hydrostatic pressure.

ACKNOWLEDGMENTS

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REFERENCES


