

Mine Water and The Environment, Vol 13, No 1, March 1994, pp 27-40

MINE WATER MANAGEMENT AND CONTROLS IN AN ENVIRONMENTALLY SENSITIVE REGION

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ABSTRACT

The paper outlines the Mine Water influx and water quality problems associated with underground coal mining in an environmental sensitive area of the south-east coast of Australia . As the study area has a number of water supply reservoirs, precautions associated with mining under large bodies of water are identified. The treatment and disposal of contaminated mine water in the Illawarra region is crucial to control effluent discharges within the desired limits.

INTRODUCTION

The coal mining industry of the New South Wales south coast exists in an environmental sensitive area around Wollongong, which is situated 80 km south of Sydney. The Wollongong city is heavily industrialised and is located on a narrow coastal plain which rises by an escarpment to a plateau and drains in the north-west direction away from the coast. A part of the plateau acts as a water supply catchment area for Wollongong and Sydney and has restricted access to public. In addition to problems associated with mining in water catchment areas and under stored waters (Reynolds, 1976), mining operations occur next to a National Park and on the escarpment above beaches and recreational areas. It is for these reasons that mining is being carried out with strict environmental controls.

SOUTHERN COALFIELD, ILLAWARRA REGION

Rainfall and Climate

Rainfall over the area is controlled largely by orographic up lift at the escarpment, and is relatively high. The medium annual rainfall is mostly between 1020 and 1270mm. In places, rainfall is up to 1500mm which is high in comparison to Australian annual averages. The wettest months are usually December to April. Maximum monthly air temperature generally ranges from about 14°C in July to about 26°C in January. Annual evaporation averages about 900mm.

Mining and Geology

There are 15 mines currently in operation on the Southern Coalfield producing approximately 18 million tonnes of coal per year. Most of the coal is mined by longwall operations and is used as a high quality coking coal for the steel industry. The Illawarra coalfield lies in the south-eastern part of the Sydney Basin, where the strata consists mainly of sedimentary rocks of Triassic and Permian age. The strata overlying the Illawarra Coal Measures is a series of interbedded sandstones and shales of the Narrabeen Group. These in turn are overlain by a thick massive sandstone unit, the Hawkesbury Sandstone. The Hawkesbury Sandstone outcrops, covering most surface areas, is overlain in some parts by a thin veneer of Wianamatta shale. Talus slopes extend from the base of the Illawarra escarpment onto the coastal plain. Most coal production in the Southern Coalfield comes from the Bulli seam which is the uppermost coal seam of the Illawarra Coal Measures. These coals tend to be low in most trace elements, partly because of the low content of pyrite and other sulphide minerals and also because extensive mineralisation does not occur near the coal seams. Toxic elements such as arsenic, beryllium, cadmium, mercury and selenium are low in comparison with coals from the eastern United States coal regions.

WATER PROBLEMS IN AUSTRALIAN UNDERGROUND COAL MINING IN WATER CATCHMENT AREA

There are two major mine water problems associated with mining under bodies of water in the Sydney basin:

- Environment protection for water courses due to mining
- Mining under stored water

There are several real and apprehended dangers of working below stored water. These are:

- Hazards to dam structure from minor distortion, cracking and increased seepage
- Major distortion, rupture failure, loss of life and property
- Danger to stored water
 - (a) Minor leakage leading to loss of safe yield
 - (b) Major leakages leading to total loss of supply
- Loss of coal reserves in protection barriers

A number of techniques are available to assess the danger of underground mining under stored water and is outlined by Singh (1989). The boundary of economic reserves (Bulli and Wongawilli Seams) in the Sydney Water Board catchment areas are shown in Figure 1.

Cordeaux Colliery

Cordeaux Colliery is one of the most modern underground coal mines in Australia, producing an average daily output of 6200t. The mine is owned by BHP Steel International, Colliery Division, and located within the Sydney Water Board catchment area. The location of the mine itself has imposed a number of environmental restrictions (Fisher, 1991).

Initial proposals were produced to locate the surface facilities at the centroid of the lease area. That location would have been too close to the Cataract Dam which was unacceptable to the Water Board. The alternative, and subsequently constructed surface facilities were moved 2km off the centroid. This distance has resulted in increased travel time to the underground production units and has increased the number of permanent roadways in operation.

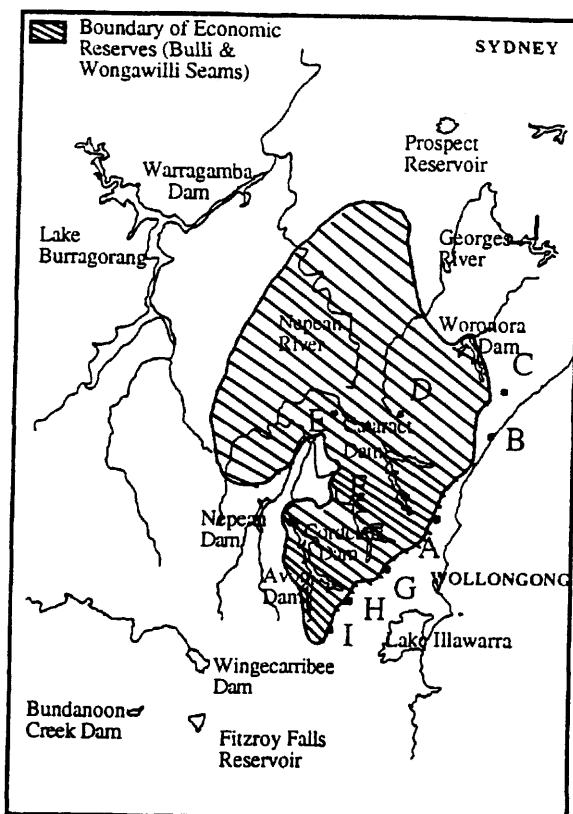


Figure 1 Boundary of Economic Reserves (Bulli and Wongawilli Seams) in the Water Board Water Supply Catchment Areas.

The area of the surface facilities is 16 ha (400m x 400m) which encompasses two shafts (i) men and materials, and (ii) coal clearance. The mined coal is transported by enclosed conveyor to a surface storage bin and trucked away to the company's central southern washery. The other surface facilities included office, pit-head bath, workshop, store, storage areas as well as car park (Loveday et al, 1984, Atkinson, 1991).

The Water Board produced the most stringent requirements prior to development approval and Figure 2 illustrates the water collection and treatment system. Obviously, the major area of interest was the water pollution measures which can be divided into four distinct areas and are outlined briefly as follows:-

- (i) Collection, treatment and disposal off the catchment area of dry weather contaminated water.
- (ii) Collection of mine water, its use and discharge of excess off the catchment area.

- (iii) The collection, treatment and disposal off the catchment area of treated sewerage effluent.
- (iv) The diversion of external run off away from the site.

Fisher (1991) reported that out of the 16 ha used for the surface facilities, only 8 ha has been disturbed by mine development. Further 40% of this disturbed land is dedicated to various aspects of pollution control showing Cordeaux Colliery's commitment to environmental protection.

(i) Contaminated Water

(a) Collection

Contaminated water is generated by the wash down facilities in the workshop, wash down bay, oil storage and diesel filling area. The contaminants are oil and coal. Clean down water from the coal conveyor as well as water from dust control equipment and run off from ancillary areas collects in a holding sump. Water from the sump is pumped to a Corrugated Plate Interceptor adjacent to the Primary Separator Lagoon. Coal spillage at the loading bins is collected in another sump under the bin system.

Car park run off is collected and drained through a flow limiting weir to the primary separator to remove any oil. Rainfall from the electricity substation, men and materials, shaft areas as well as hard standing areas flow by gravity through a flow limiting weir to the primary separator. Rainfall from access roads and roofs are reticulated directly to the natural water courses.

(b) Treatment

All runoff from the contaminated water areas is treated on the basis of a 1 in 3 year return period, 10 min storm. The treatment system has a capacity to deal with 28,000 L/min. Any flows in excess of 28,000 L/min are passed untreated to a natural water course via an underpass/overflow weir. This allows the heavier particles to be treated and the lighter uncontaminated material to flow to the water course.

Oil is initially removed by a Corrugated Plate Interceptor. The remaining water flows onto the primary separator where further oil is separated by a skimmer. The oils are collected in a central sump for subsequent removal. The primary separators' other function is that of settling basin which allows partly clarified water to be drawn off to a filter lagoon.

(ii) Mine Water

Excess mine water is pumped from underground sumps to a 2.5ML holding lagoon with a nominal retention time of seven days (Figure 2). There is opportunity for re-use of lagoon water in the areas of fire fighting and underground dust suppression.

The excess lagoon water is piped and used off the catchment area as an irrigation source. During heavy rainfalls, the overflow in the holding lagoon discharges into the primary separator for treatment.

(iii) Sewage Treatment

Sewage from the bath house, office, workshop and coal handling facilities produces approximately 50,000 L/day. The sewage is collected in a holding tank and is then pumped into a Smith and Loveless extended aeration

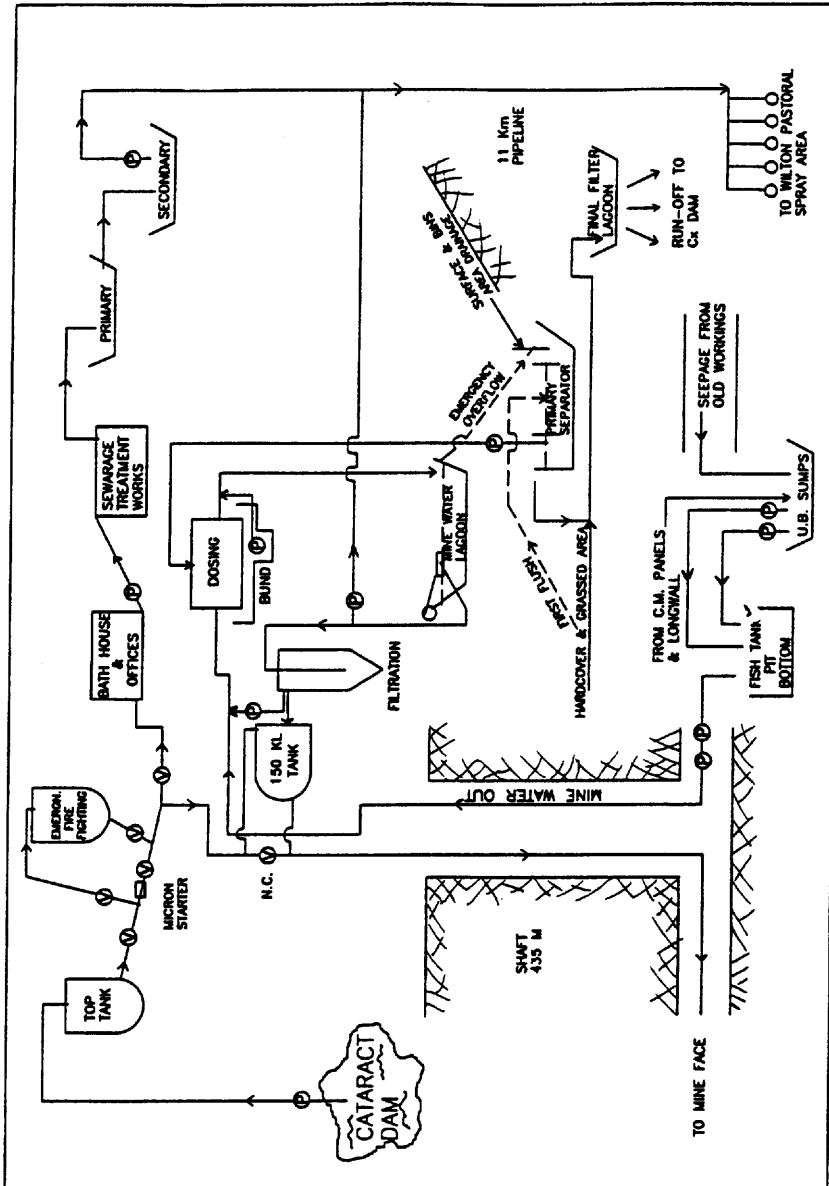


Figure 2. Water Collection and Treatment - Cordeaux Colliery (Adapted from Fischer, 1991)

treatment plant. The sewage treatment plant effluent flows into a chlorinator and onto the primary stabilisation lagoon to be held for 16.5 days. A secondary stabilisation lagoon is used with a retention period of 6.5 days. A spray irrigation system is used to dispose of effluent onto a site of approximately 6 ha which is 11 km off the catchment area.

- (iv) **Diversion**
A series of intercept drains were used to reduce the amount of run-off from surrounding areas from entering the surface operational site. A simple system of creeks and drains achieved this particular system of water control.

THE LIMITATIONS OF MINING UNDER STORED WATER

In New South Wales there are number of examples whereby dams and reservoirs are underlain by coal seams of economic importance (Table 1). There are a numbers of hazards that are possible in the extraction of minerals from beneath stored water or the retaining structures.

Table 1. In-situ coal reserves under storage reserves, southern coalfield (Mt)

SEAM		AVON	CATARACT	CORDEAUX	NEPEAN	WORONORA	TOTAL
Bulli	a	21.65	20.67	6.89	0.79	9.84	59.84
	b	51.18	50.19	14.76	2.46	46.25	164.85
Balgownie	a	-	5.91	7.38	-	6.89	20.18
	b	-	19.68	16.73	-	30.51	66.92
Wongawilli	a	19.68	23.62	30.51	3.44	-	77.25
	b	47.24	69.88	75.78	9.84	-	202.74
Tongara	a	0.89	-	-	-	-	0.89
	b	2.95	-	-	-	-	2.95

a : *under stored water*; b : *under stored water plus 35° angle of draw*

As a result of the Reynolds Inquiry (Reynolds, 1976), the following mining limitations were set down:

- (i) No mining whatsoever in areas of 60m or less cover.
- (ii) Bord and pillar mining is allowed at depths of greater than 60m. The boards have a maximum width of 5.5m and pillars the minimum width of 15 times the extraction height (or 1/10 the depth of cover, whichever is greater).
- (iii) Panel and pillar mining is allowed at depths above 120m. The panel sizes are to be no greater than the third the depth of cover; the pillar sizes are to be of a length co-extensive with that of the panel extracted and a width not less than one-fifth of the depth of cover, or 15 times the height of extraction, whichever is the greater.
- (iv) The marginal zone around stored waters should be determined by an angle of draw of 26.5° taken down from the boundary of the stored water at full storage level as indicated by Figure 3.

- (v) There should be no mining or driving of access roads beneath a dam structure within a coal pillar at a point 200 metres away from the edge of the structure and an angle of draw of 35°.

Some changes have been made to the criteria since the Reynolds Inquiry. These changes include the following: (Williamson et al 1987)

- (a) Panel and pillar mining are allowed with widely spaced cross-cuts to allow underground development.
- (b) The depth used in the panel width calculation is taken as the least solid cover. For the pillar width calculation, the greatest solid cover is used. The result of this amendment is a reduction in recovery rates.
- (c) The marginal zones were increased to 35° from the top water level. At the intercept of that angle with the seam, a further distance of half the depth from the bottom of the seam to the top water level is used as a restricted zone.

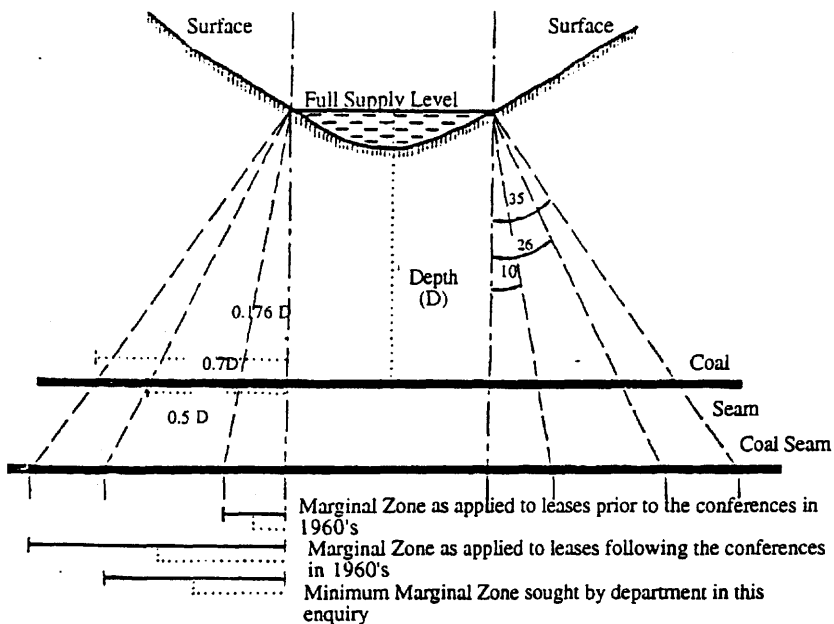


Figure 3 Effect of Draw Angle on the Width of Marginal Zone

PROCEDURES FOR MINING UNDER STORED WATER

In order to regulate the potential hazards, the New South Wales Government produced the Dam Safety Act, 1978. The Act set down a procedure for collieries to adopt when there is a possibility that mining operations, either for extraction or access roadway, would lie in Restricted Area in the Southern Coalfield beneath stored water. (Ramsland and Holla, 1986). As the amount of water inflow to mine workings may depend upon surface subsidence caused by coal extraction, a local knowledge subsidence pattern of the New South Wales coalfield is necessary.

The individual members of the Dam Safety Committee are drawn from both the regulating authorities as well as mining group. The jurisdiction of the Dam Safety

committee is shown in Figure 4 which shows the boundary of the surface areas the mine operators were interested in effecting mining in an underground seam or seams. In order to clarify this situation the restriction zones were established as determined by an angle of draw of 35° together with an additional seam sterilisation of 0.5 depth. Any proposed mining activity within the restricted zone needs to be submitted to the Dam Safety Committee for assessment together with the supportive materials. The Dam Safety Committee considers the application together with the supportive material and makes its recommendations to the NSW Minister of Minerals and Resources for approval, conditional approval or rejection.

Typical conditions which could be imposed are as follows:-

- Submission of mine plan identifying progress made and geological features encountered.
- Observation of the water inflows including seepage and their sediment content.
- Measurement of surface subsidence and stains.
- Measurement of water entering and leaving the mine covered by the restriction zone.
- Possible results of borehole logs showing the fluctuations of ground water levels.

Cost of annual monitoring could be as high as A\$100,000.

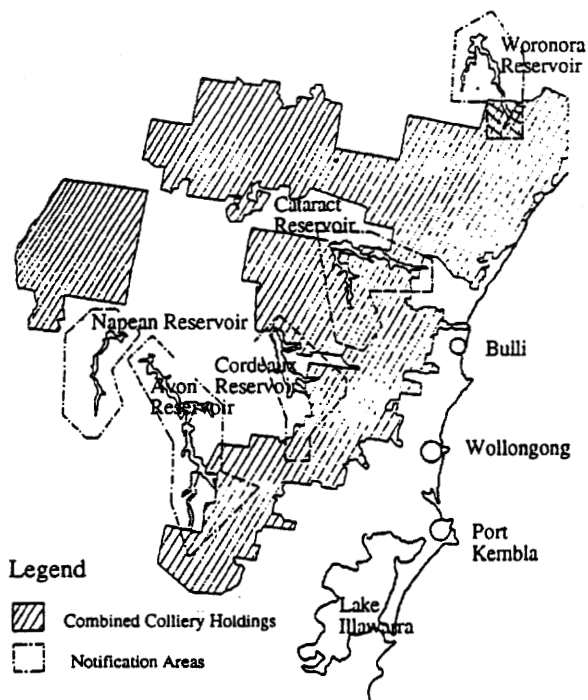


Figure 4 Notification Area of the Southern Coalfields

WATER CLASSIFICATIONS

NSW Environment Protection Authority

The classification of waters given by the Clean Waters Act 1970 and subsequent amendments currently provides the main legislative framework for water discharges in New South Wales. These are:

Class "S": Specially Protected Water - into which 1) no wastes are to be discharged; and
2) only Class P waters flow.

Class "P": Protected Water - discharges of effluents into Class "P" water are limited to those with a quality similar to that required as a "raw" source of potable water.

Class "C": Controlled Water - discharges are permitted subject to approved treatment for the removal of contaminants and to adequate dilution of the discharge being available in the receiving waters.

Class "R": Restricted Water - this classification recognises that certain (generally small) waterways are affected by extreme variations in flows and exhibit marked changes in water quality between periods of dry weather and wet weather. Limitations imposed on discharges are similar, though less restrictive than those imposed on discharges to Class "C" waters.

Class "O": Ocean Outfall Water - waters classified as Class "O" waters must be treated to ensure that:

- 1) the waters are visually free of oil, grease and other floatable matter;
- 2) the waters retain diverse, though not necessarily unchanged communities of marine life;
- 3) the aesthetic qualities of adjacent beaches are not adversely effected.

Class "U": Underground Protected Waters - underground water may be used for several purposes including

- 1) human and animal consumption
- 2) industrial processes
- 3) agriculture
- 4) mineral processing.

Mine water effluents in the Illawarra region are discharging in general into "S", "P" and "C" Classes of water. However, most effluents though are discharging into Class "P" Protected Waters.

In recent years, water quality guidelines and criteria have been made more stringent in many countries by State and Federal agencies, including Australia, in their efforts to assess water quality problems and to manage competing uses of water resources. If the new guidelines (ANZECC, 1992) are to be met, significant changes will need to be made in the management of coal mine effluent waters in the Illawarra region.

MINE EFFLUENT WATER QUALITY IN THE ILLAWARRA REGION

Mine effluents from nine mines in the Illawarra Region were sampled and preliminary results have been reported elsewhere (Sivakumar *et al*, 1992). It was shown that mine effluent water quality varied significantly throughout the nine mines sampled. Several mine discharges were over the respective licence conditions as can be seen from Table 2. Several mine effluents were also slightly to moderately saline. Acidity was not found to be a problem for any mine effluents. On the contrary, the problem

was with Total Alkalinity. The reason for this is that all the coals of the Illawarra region have a very low sulphur content and any acids created are subsequently neutralised by the natural alkaline surface and ground water formed by the varying amounts of carbonaceous rocks. Judell and Anderson (1988) have shown further evidence to this effect in minewaters from the Sydney Basin. However, an extreme case of the rise in alkalinity was seen for the discharge at E.

Table 2. Illawarra mines effluent water quality parameters

M I N E S									
	A	B	C	D	E	F	G	H	I
PARAMETER (Average)	S3	S2	S2	S2	S2	S2	S2	S3	S2
Temperature (°C)	13	21	10	14	12	13	14	16	18
Flowrate (Ls ⁻¹)	7.6	-	0.31	3.1	0.09	0.68	3.75	7.60	-
pH	8.65	6.99	8.06	8.64	9.05	7.76	8.28	8.05	7.60
Conductivity (µScm ⁻¹)	1,802	14,445	992	1,254	1,039	669	2,040	605	771
NFR (mg/L)	12	32	2	82	73	4	5	2	3
COD (mg/L)	33	58	14	61	106	17	13	9	10
Apparent Colour	247	43	30	548	640	48	48	45	1
Turbidity (NTU)	25	18	5	30	49	8	10	5	1
Total Alkalinity (mg/L CaCO ₃)	1,110	628	449	481	1720	176	1,136	272	355
Sulphate (mg/L)	7.13	32.4	6.55	17.51	29.03	30.7	41.9	5.3	3.6
Iron (mg/L)	1.30	2.59	0.54	5.65	2.54	2.32	1.33	0.92	0.8
Manganese (mg/L)	0.24	0.31	0.16	0.20	0.30	0.50	0.47	0.35	0.5
Potassium (mg/L)	4.54	28.27	4.01	3.16	6.71	3.58	5.70	3.53	4.21
Aluminium (mg/L)	3.28	5.32	5.0	9.22	10.88	5.4	9.64	6.98	7.37
Calcium (mg/L)	20.03	87.05	39.88	18.72	25.75	45.25	29.61	36.57	82.0
Magnesium (mg/L)	18.53	935	24.32	11.16	9.47	0.54	37.84	33.25	61.6
Sodium (mg/L)	151.2	148	141.8	151.18	146.3	08.2	52.3	83.2	61.7
Total Hardness (mg/L CaCO ₃)	126	5,203	200	93	104	56	230	336	458
TDS (mg/L)	1115	8939	614	776	643	414	1250	375	477
TSS (mg/L)	1172	9389	645	815	675	435	1436	394	501

CASE STUDY ON MINE “E” WASTE WATER PROBLEM OF INCREASING pH

“E” Colliery is situated on the Illawarra plateau approximately 50 kilometres west of Wollongong. The area is predominantly rural but is adjacent to several areas of low density rural housing.

The site is drained by two surface drainage networks with catchment areas approximately 200 and 250 hectares. This drainage system meets down at the bottom of the site above a Filter Lagoon. The water is discharged from the Filter Lagoon, which forms a creek. Approximately 150m downstream, the creek joins up with the natural water course which during dry weather conditions does not flow. The creek

winds its way through a rural setting and finally enters a major inland and environmentally sensitive river. The creek and the river downstream is classified as class "P" - Protected Waters.

The sources of water pollution at E arises from mine operations (where water is pumped to the surface after being used at the Longwall face for dust suppression, drilling etc), coal handling and storage areas and surface run-off from areas including the workshop and transport facilities. Most of the waste water generated is derived from the pit and it is this water which is of prime concern.

Mine E buys an average of 1026 kL/d of water from a local water authority and uses this water underground for its mining operations. The water then drains or is pumped to a common pit sump underground where it is pumped to the surface. At this stage the water has a high alkalinity, high conductivity and a pH of 8.0. The water is acid dosed with concentrated sulfuric acid to a pH of 6.9 prior to being held in a Mine Water Holding Lagoon for 7 days. The mine water then flows over a weir (2m deep) and it is from here that the pH has been observed to increase. The water drains down approximately 500m of concrete piping to where it enters one of two Filter Lagoons which consist of blast furnace slag, granulated slag, perforated pipes and sand. The pH of water prior to entering the Filter Lagoon is 8.2 and as it leaves and discharges into the creek, the pH increases to 9.1.

The pH of water in this system is controlled by $\text{CO}_2/\text{HCO}_3/\text{CO}_3$ equilibrium and E mine water is high in both Total Alkalinity and Conductivity. When such complex waters are agitated or aerated, CO_2 is released to the atmosphere and increases the pH content of water. Additional pH increases across the Filter Lagoon may be due to the basic constituents of the filter media.

In accordance with the new discharge conditions which will be granted by the end of this year to Mine E, the waste water discharged shall not be of a pH value of less than 6.5 or greater than 8.5. It is for this reason that E Colliery waste water treatment system will need to be improved to meet the new Environment Protection Authority's requirements. Possible improvements include the relocation of the acid dosing plant to the bottom of the treatment system and/or replacing the Filter Lagoon with sand.

Other discharge limit conditions of Mine E include the following:

- the average flow-rate shall not exceed 400 kL/d
- the peak flow-rate of wastes shall not exceed 25 kL/minute
- the wastewater discharged shall not: cause more than 20 mg/L of BOD.; contain more than 50mg/L of NFR and; contain any visible grease and oil nor contain more than 10 mg/L of grease and oil.

CONCLUSIONS

Mine water presents a range of problems in different mining conditions. There is no hard and fast rule to combat local water problems in underground mining. Mining under large bodies of water has three major implications such as loss of water, safety of mine workings, financial implications due to sterilisation of coal reserves in mine barriers and pillars.

Mine effluent water quality in the Illawarra region varies significantly, from water that is close to creek water quality to water similar in standard to industrial effluents. The non-acidic mine effluent waters are considered to be caused by reactions of the varying amounts of carbonaceous rocks with the natural surface and ground water prior to their entries into the mines. These alkaline waters neutralise any acids formed by the reaction of water with pyrite. Some mine effluent waters had exceptionally high alkalinity levels. This became common for waters derived from particular types of sandstones, eg Scarborough Sandstone.

In addition some mine discharges were well in excess of their new EPA licence conditions for pH and non-filterable residues. Consequently with the implementation of these new conditions, some mines will need to significantly improve their mine effluent management practises. To achieve this considerable economic challenges will be placed on all mining companies.

ACKNOWLEDGMENTS

The authors would like to thank the various Mine Managers, Geologists and Surface Foremen, for allowing access to the mine sites and permitting to take water samples.

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