LONGWALLING AND ITS IMPACTS IN THE SOUTHERN COALFIELD - RECENT BHP EXPERIENCES

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ABSTRACT: Illawarra Coal BHP Minerals currently operate five underground coal mines in the Southern Coalfield of New South Wales in Australia. Each mine operates a retreating longwall extraction system as the primary production process. Economic reserves at several of the mines are nearing exhaustion and a feasibility study is under way to maintain production levels by development of a new mine.
The level of maturity of the current operations and the nature of the remaining coal reserves in the Southern Coalfield present significant challenges for continued viable longwall mining. A general overview of the challenges and recent BHP experiences in relation to a number of more specific issues are presented in this paper.

INTRODUCTON

The Southern Coalfield, in which the Illawarra Coal BHP Minerals underground mines operate, produced almost 11.8 million tonnes in the 1999-00 year of raw coal of which 10.4 million tonnes was saleable. This production rate has been in steady decline over at least the last 10 years (JCB Statistics, 2000). Two Southern Coalfield mines, Brimstone and Avon, ceased production during the 2000 year. This leaves only eight remaining coal mines currently in production.

Illawarra Coal BHP Minerals operate five of the remaining underground coal mines, viz. Appin, Tower, West Cliff, Cordeaux and Elouera. Cordeaux Mine is due to cease production in March 2001 and will be continued only on a care and maintenance basis until its ultimate future is decided. The feasibility for a new mine, Dendrobium, is well under way, with the aim of replacing dwindling Elouera Mine production and reserves by the 2004 year.

The relative age of the remaining mines logically means that the higher quality and easier access reserves have already been mined. As Bulli seam workings progress westward from coastal outcrop escarpments, depth of cover to reserves generally increases and mining conditions become more challenging.

Challenges facing longwall mining in the Southern Coalfield can be broadly slotted into the following categories:

- Safety and Legislation
- Economic viability
- Environment and Community
- Technical issues
- Surface Effects.

SAFETY AND LEGISLATION

Illawarra Coal recognise the imperative of constant improvement in safety performance. We have come a long way but can not afford to relax our efforts.

There has been a general move away from prescriptive legislation to more of an Occupational Health and Safety style legislation, which tends to be organisation and systems based. Risk Assessment principles are now widely used to identify potential risks and hazards, an assessment is made of their consequence and likelihood and appropriate control measures developed. Critical safety risks have been identified and appropriate Management Plans developed to control them to an acceptable risk.

The New South Wales Coal Mines Regulation Act is currently under review and is likely in the near future to change significantly. A greater utilisation of standards, guidelines and management plans is expected.

Illawarra Coal continues to improve our Safety Culture through workforce participation, commitment and involvement. The systems and Management Plans in place must be robust and regularly reviewed to ensure they are appropriate to control hazards and to cope with continual change.

ECONOMIC VIABILITY

When compared to other Australian longwall mines, Illawarra Coal operations productivity is less than half that of a number of our competitors. This is also associated with relatively higher costs of production.

The significant reasons, and hence major challenges to be overcome, include:

- the mines are generally older as is the associated infrastructure,
- mining and coal clearance systems tend to be lower capacity and to some degree outdated,
- the mines are relatively deep with associated higher stress and gas regimes,
- due to reducing throughput to export from the Southern Coalfield, unit costs are increasing, and
- due in part to the age of our workforce, work practices have generally been slow to change.

Export coal prices have been in steady decline over many years. Between the periods 1990-91 and 1999-00 the average FOB price has fallen from $A 64.25/t to $A 51.51/t, a reduction of almost 20% (JCB Statistics, 2000).

Illawarra Coal has seen considerable change in recent years and much effort has been expended in addressing the challenges to our economic viability. Workforce cooperation has allowed greater flexibility, less demarcation and a general acceptance of external labour and contractors where it is efficient and cost effective to do so. To remain viable, Illawarra Coal mines have been forced to shed a significant proportion of its workforce over recent years.

ENVIRONMENT AND COMMUNITY

The expectation of the community and the environment in which we operate is of ever reducing impacts resulting from mining activities. The approval process and conditions of approval to extract coal by the longwall process reflect the less tolerant community attitudes. The tendency to wider longwall faces to improve mine productivity is sometimes at odds with a reduction in mining activity-induced impact.

Subsidence impacts and surface effects of longwall mining will be discussed later in more detail. Illawarra Coal has faced and continues to face significant challenges in controlling subsidence impacts on natural features such as watercourses, cliff lines and river valleys as well as man made features such as road bridges, water supply tunnels, canals, aqueducts, dams and pipelines.

Environmental licensing conditions are tending toward the ideal of minimal discharge of pollutants with ever increasing restrictions on pollutant type and quantity limits. Load based licensing, introduced into general industry, will soon become a reality for coal mining operations with no doubt added cost and restriction to the business. Coal mines will need to become even more innovative in such areas as materials reuse and recycling, solid and liquid waste production and disposal, dust, noise and gas emissions.

Illawarra Coal, at a number of sites, is trailing waste water injection into relaxed strata above worked out longwall areas. Injection is via boreholes drilled from the surface to intersect the relaxed strata above the goaf areas. The quality of the waste water that is injected is better than the water already contained within the targeted zones and boreholes are strategically lined and grouted to prevent aquifer mixing from multiple horizons.

Disposal of the refuse from coal washing operations is an issue for longwall mines both from the visual and land use aspect of the waste material as well as the necessary emplacement activities. Waste material transport and emplacement potentially have traffic, noise and dust control implications which must be controlled to community expectations.

Illawarra Coal operates mines in the Bulli Seam which is considered a gassy seam by world standards. To enhance safety three of the mines practice methane drainage via in-seam, cross measure and goaf drainage drilling and collection. The predominant gas present within the coal seam being mined and those coal seams adjacent is methane, although carbon dioxide does become prominent in localised zones. Partial recovery of costs associated with the methane drainage systems is accomplished by utilisation of the drained methane to generate electricity which is subsequently sold to an electricity distributor. In general terms, as the width of longwall blocks increase to improve productivity, the mining influence is expanded and the potential for methane to impact on operations is increased. There is also some evidence that strata above the Bulli seam may contain gas that has the potential to impact mining operations. This aspect is currently being actively investigated.

Methane and carbon dioxide are both considered to be gasses which contribute to the greenhouse effect. The longwall mining process liberates gas that is present in the coal seam being mined as well as a proportion of the gas that is present in adjacent coal seams and strata. The greenhouse effect can be reduced to some degree by collecting gas into a drainage system and using the drained gas as a fuel to generate electricity. Approximately half of the gas emissions from three of the Illawarra Coal Mines is collected and utilised in this manner. Burning the methane to produce electrical energy and carbon dioxide reduces the greenhouse effect. Carbon dioxide has a much lower greenhouse effect than methane, with additional greenhouse gas reduction being achieved by displacing the need to generate a quantity of electricity from alternative fuel sources. The major challenges here are to increase mine gas capture and to improve the energy conversion efficiency of the gas utilised.

Environment and community interests demand improved performance. The BHP Charter states that we are successful when the communities in which we operate value our citizenship and that BHP value an overriding commitment to safety and environmental responsibility. Success will only come with higher levels of community involvement in longwall approval processes and, along with other stakeholders, early input into project definition and planning. Communication with community, councils and statutory authorities needs to be ongoing and at an increased level.

TECHNICAL ISSUES

Exploration

The longwall mining process can be a highly productive coal extraction method. However the system is somewhat inflexible compared to other forms of extraction. For optimum productivity, blocks to be mined by longwall should be as large as practical and free of geological features such as faulting and igneous intrusions. An unplanned relocation of a longwall panel can be both difficult and costly. Exploration is the major tool available to define suitable longwall domains and to reduce the risk of unexpected longwall interruptions due to unpredicted features.

Exploration in the Southern Coalfield is not without its challenges. Surface access is often difficult due to steep topography and much of the surface is administered by Sydney Catchment Authority (SCA) and National Parks and Wildlife Service (NPWS). The SCA administered area includes water catchment and a number of major water storage reservoirs which are integral to the Sydney water supply system. There are obviously restrictions and tight conditions placed on accessing these areas for exploration. The population growth and expansion to the south and southwest of the Sydney area also presents access issues and restrictions over exploration activities.

The deep reserves over 500 m and presence of significant sandstone elements in the sequence leads to relatively high drilling costs associated with surface drilling.

Geophysical and electromagnetic surface based exploration techniques have limited success on the Southern Coalfield. Sill and dyke material is often non-magnetic and/or weathered. Location of surface power lines and the presence of basalt aggregate along the partially built Maldon Dombarton railway line route can make interpretation difficult.

High resolution surface reflection seismic is relatively successful in locating half to full seam dislocations and indicating coal seam continuity. Gas and water present in strata above the coal seam horizons may reduce integrity of data collection and complicate analysis in some areas.

In the mines employing gas drainage, underground in seam drilling doubles as a valuable exploration tool. The drilling and pre-drainage of a longwall block will normally reveal any anomalies within the block but the timing may not be sufficient to prevent a major production dislocation in all cases. In seam longholes can be used to prove the existence or otherwise of targeted features.

Illawarra Coal holds a number of mining exploration licences in the western portion of the Southern Coalfield. The resource in this area is indicated, in some parts, to have a depth of cover in excess of 700 m. Portion of this licence area contains an overlapping petroleum title which is held by a coal bed methane explorer who is assessing production potential from a number of surface wells drilled and fracced in the Bulli Seam. There will likely be future challenges to be faced during exploration and production in an area occupied by a coal resource company and a gas resource company who are separate entities.

In parts of the Southern Coalfield coal reserves are present in a number of coal seams, with the overlying seam having been mined out, in some cases, many years ago. Exploration of the lower coal seams presents a challenge, particularly when mining records of historical mining are incomplete.

Outburst Risk

The Bulli Seam in the Southern Coalfield is known to have some propensity to outburst. Outburst prevention is currently dependent upon reducing gas content within the seam being mined to below a threshold limit. The limit is based upon history, composition of the seam gas and ultimately the volume of gas calculated to be in a cubic metre of coal.

Until relatively recent times threshold limits have been restricted to development mining. However in the last couple of years evidence of several outburst events has been associated with longwall mining.

A major challenge exists to develop a better understanding of the outburst phenomenon. Significant research has been applied to this issue in the past and is continuing, seeking a fundamental understanding of the mechanism which results in an outburst occurrence.

Depth of Reserves

As indicated above, Illawarra Coal hold mining exploration licences over resources that are indicated to have a depth of cover ranging to over 700 m. Apart from one mine in the Sydney Basin, which had limited operation, this indicated depth to potential reserves will be deeper than any other in Australia.

Longwall mining in these conditions will no doubt present a new set of challenges. Roof support design and ratings, expected stress regimes, and gas characteristics will need to be accurately predicted to ensure longwall mining in this environment is successful.

SURFACE EFFECTS

Almost all of the current coal extraction is under a surface veneer (to 150 m in thickness) of Hawkesbury Sandstone. Minor thin Wianamatta Shale covers parts of hill tops and ridges in the current Appin and Tower Colliery extraction areas. The Wianamatta Shale supports a thick fertile soil profile, while the Hawkesbury Sandstone is usually overlain by a poor, thin sandy soil. The Hawkesbury Sandstone is an interbedded massive to thin bedded unit with crossbedded units, shale beds and lenses. This unit is moderately jointed, with some major joints penetrating a series of individual beds. The surface expression of this unit varies from competent to deeply weathered.

Geomorphology

The surface is composed of gently rolling plateau area that is deeply dissected by major watercourses. The Cataract and Nepean Rivers are enclosed in gorges with sub vertical cliff lines to 60 metres in height. The rivers follow a zigzag course with major changes in direction aligned sub parallel to the prominent local joint direction. In most cases the cliff lines are steeper on the concave side of the river valley.

Cliff lines are typically sub vertical, or composed of a series of sub vertical steps, and are typically undercut into cavernous zones some five metres in depth. These cavernous zones are typically associated with cross bedded or thinly bedded quartzose sandstones with water seepages from the bedding planes.

Mechanisms

The typical classical maximum subsidence parameters associated with supercritical extraction include some 1.1 metre of vertical subsidence, tilt of less than 8 mm/m and strains of less than 2 mm/m. Superimposed on these classical subsidence parameters is the concept of horizontal movement. This mechanism was recognised and documented as a result of precise surveying while mining under and adjacent to significant surface structures.

Horizontal movements in excess of 5 mm (GPS accuracy) are recorded some 5 km from the extraction. Movements are towards gorges or surface notches. These movements increase with proximity to extraction areas and gorges.

The largest horizontal movements are a direct result of horizontal compression induced by mining in the vicinity of deeply dissected areas. Horizontal compression is concentrated in the base of gorges, mining induced movements promote delamination of strata reducing strength and result in horizontal shearing in the base of the topographic lows. This mechanism results in closure of the walls, and hence crests, of the gorge cliff lines and relative upsidence (when compared with subsidence predicted for flat topography) of both the base of the gorge and, to a lesser extent, the immediate shoulders of the gorge. The major planes of relative horizontal movement are located in the strata immediately below the base of the gorge.

Surface Infrastructure

Economic coal extraction at both Appin and Tower Collieries required mining under, or close to, major surface infrastructure including:

Twin Bridges – SH2 Hume Highway crossing the Nepean River at Douglas Park

Each bridge consists of two carriageways and the decks are 14 m in width, the maximum deck length (Northbound Bridge) is 286 metres and the maximum pier height is 34 m.

Cataract Tunnel

This tunnel connects the weir at Broughtons Pass to the Upper Canal, has a gradient of 0.67m per km (0.067%) and a capacity of 704 megalitres per day.

Upper Canal and Aqueducts

The canal was excavated, where possible from solid rock. Excavated material was used to construct masonry walls in soft earth. In shallow cuttings or bad ground concrete walls or cemented rubble was used. Two aqueducts at Elladale and Simpsons Creek are 8 feet [2.4 m] in diameter wrought iron structures of lengths 655 [199.6 m] and 150 feet [45.7 m] respectively, are multispan structures with spans up to 60 feet [18.3 m].

Broughton's Pass Weir

This weir diverts water from the Nepean Tunnel and the Cataract Reservoir into the Upper Canal System via the Cataract Tunnel. It also supplies water via the low lift and high lift pumping stations to the Macarthur Water Treatment Plant. The weir is a concrete gravity structure, which was built around 1885 as part of the Nepean System. The dam has a nominal storage capacity of some 50 megalitres. The Low Lift Pumping Station, the High Lift Pumping Station and the rising mains were built as part of the Macarthur Water Quality Project during the period 1994 – 1995.

Gas pipelines

The AGL natural gas pipeline, ethane pipeline and Eastern Gas Pipeline traverse the area of Appin Longwalls 403 to 407 and also cross under the Cataract River and Simpsons and Elladale Creeks. The pipelines consist of fully welded steel pipes laid in the ground with a minimum cover of 0.8 m.

Others

- Transmission lines, telephone lines, roads and residential structures
- Numerous residential and utility structures are undermined throughout the area.

Natural Features

Cliff Line Stability

A total of nine rock falls were identified during extraction at Appin and Tower Collieries during undermining of the Cataract and Nepean Rivers. The observed rock falls were small in size (some 50t average) and were all associated with significant chemical weathering, erosion and overhangs. The majority occurred in the middle third of cliff height.

Because of the natural instability of cliff lines that are moderately well jointed and contain significant chemical weathering, the prediction of areas with the potential to fall during the mining process is difficult. It is significant that only a small proportion of potentially unstable cliff line has exhibited failure.

No evidence of massive slope failure (tension cracking behind the slope of slip planes for the full height of the cliff line) was observed.

Water Loss and Cracking of the River Bed

Localised water loss was recorded from the Cataract River during the extraction of Tower Colliery Longwalls 8 – 14. This water loss was restricted to pools behind rock bars. Horizontal fracturing consistent with failure due to horizontal stress accumulations was observed in rock bars. Water lost from the pools surfaced further downstream at the extremity of cracking or where the river gradient flattened. No water loss was recorded when undermining areas of permanent water.

A shallow grout curtain was installed from vertical holes in one rock shelf. This curtain proved successful in reducing the rate of leakage from the pool located immediately upstream.

No water ingress was recorded in the underground workings. This agreed with the conclusions of numerical modelling.

There is evidence that natural siltation processes will successfully reduce leakage with time.

Gas Emission

Areas of gas emission into water were recorded from the Cataract and Nepean Rivers subsequent to longwall extraction. This emission was typically observed as a number of bubble streams in localised areas within the main stream or from under rock ledges. Two significant gas emissions, with sufficient gas flow to ignite, were recorded. These more substantial gas emissions persisted for some 6 months after undermining.

The gas chemistry confirmed that the major component was methane. Higher hydrocarbons were detected while the gas had a petroliferous odour similar to that of the Bulgo Sandstone gas. Atmospheric gas measurements indicated a total gas emission for the Cataract River to Longwall 14 of some 20 L/s.

Vegetation Effects

Four localised areas of vegetation stress were identified during the extraction of Tower longwalls 10, 14 and 15. These areas were located in relatively deep sandy soils between the main river channel and the cliff line.

Field investigations concluded that the temperature of the soil increased to excess of 40^{o}C and that the temperature peaked at a carbonaceous clay horizon some 40 cm from the soil surface. Laboratory analysis indicated that the temperature increase was due to bacterial degradation of hydrocarbon gas migrating through the soil profile. A combination of anoxic conditions, high temperature and dehydration resulted in the death of deeply rooted vegetation in the very localised areas associated with this gas emission. When gas migration subsided, self revegetation of the areas was soon evident. No vegetation effects were recorded from the lower reaches of the Cataract River or the Nepean River.

CONCLUSIONS

Many of the issues discussed above are complex and interact with each other. To manage effectively we need to understand their causes, mechanisms and characteristics. Management needs to be able to predict outcomes more accurately and this can only be achieved by higher level of understanding.

Communication and interaction with potential stakeholders who may be affected by mining operations is of paramount importance. It needs to be proactive and ongoing. Stakeholders include outside bodies and entities and include surface infrastructure owners, landholders, community interest bodies and government regulatory bodies.

Management Plans are an effective way of managing and controlling specific issues associated with the mining effects. They provide the rigour and discipline in the components of planning, observation, measurement, reaction and review. Management Plans are developed with significant stakeholder input and knowledge and provide a transparency to the process and control of an issue.

The Southern Coalfield in general and Illawarra Coal in particular face a challenging future. Longwall mining will likely continue to be the extraction method of choice, with widths increasing in an effort to address economic viability demands. Control of the environment in which we operate and of the impacts of underground longwall mining is essential to maintain acceptable productivity levels and the licence to operate.

REFERENCE

Joint Coal Board Statistics, 2000. *Joint Coal Board New South Wales Coal Statistics 1999-00,* Joint Coal Board ISSN 1441-4546.