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## MANAGEMENT OF IMPACTS OF LONGWALL MINING UNDER URBAN AREAS

Daryl Kay<sup>1</sup>, Arthur Waddington<sup>1</sup>, Joanne Page<sup>2</sup> and Ben de Somer<sup>3</sup>

**ABSTRACT:** Current and proposed expansions to existing underground coal mines are occurring in closer proximity to and directly beneath urban areas. The density of built infrastructure potentially impacted by longwall mining is substantially increased in urban areas when compared with mining beneath rural areas. Management of the impacts of longwall mining in such areas requires extensive consultation with the affected community, including education and management of communities' expectations regarding what could be expected during and after the mining period.

Approaches undertaken by Tahmoor Colliery to manage the potential impacts of mining under the township of Tahmoor are discussed. A summary of impacts that have occurred as a result of mining the first two longwalls are outlined, which are part of a series of eight longwalls that the Colliery plans to mine beneath this town. The experience gained at Tahmoor illustrates that longwall mining beneath urban areas is sustainable and can be successfully managed to mitigate the impacts on surface developments.

### INTRODUCTION

The main coal seams in the Sydney Basin are deepest at Sydney and are close to the surface in the Newcastle, Southern and Western Coalfields, where the coal can be extracted at relatively shallow depths. However, as coal reserves are extracted, mines are progressively expanding to extract coal from deeper underground. This expansion is generally directed towards Sydney.

Sydney's population is steadily growing. It is estimated that another 1.1 million people will be living in Sydney by 2031 (Department of Planning, 2005). While the State government is trying to accommodate a large proportion of these people through urban renewal and consolidation, approximately 350,000 new dwellings are proposed for the south-west and north-west of Sydney, and the Gosford/Wyong area. Some of these areas lie within proclaimed Mine Subsidence Districts.

The above trends lead to an apparent convergence of the needs of resource recovery and urban development. Proposals for new or expanded coal mines understandably raise concern and resistance within potentially affected communities; while on the other hand, developers experience caution and resistance when they propose to construct developments above untapped coal resources.

However, in reality it is feasible for underground coal mining and urban development to co-exist, particularly when mine subsidence movements are small enough that surface features remain safe, serviceable and repairable.

The challenges presented by mining under urban areas are described. Reference is made to the approach undertaken by Tahmoor Colliery to manage the potential impacts and associated risks of mining under the township of Tahmoor in the Southern Coalfield. It also includes a summary of impacts that have occurred as a result of mining the first two longwalls, which are part of a series of eight longwalls that the Colliery plans to mine beneath this town.

### MINE SUBSIDENCE

Subsidence occurs as a result of underground coal extraction by longwall mining or other mining techniques. In longwall mining, a rectangular panel of coal is totally removed by longwall shearing machinery, which travels back and forth across the coalface. As the longwall steps forward, the rocks immediately above the coal seam fall

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behind it to fill the void left by the extracted coal. The mechanism progresses upwards through the layers of rock as they fall or sag into the void, resulting in subsidence at the surface.

Subsidence usually refers to vertical displacement of a point. The amount of subsidence that occurs at each point on the surface varies across the area, with greatest subsidence occurring towards the centre of the longwall, and progressively smaller amounts of subsidence beyond the edge of the longwall. The subsided area is similar in shape to a rectangular bowl.

Given that the amount of subsidence varies between points on the surface, differential movements occur as a result of subsidence in a number of ways. The first kind of differential movement is ground tilt, which is defined as the change in slope of the ground. The second kind of differential movement is ground curvature, which is defined as the rate of change in tilt and is expressed in terms of hogging curvature or sagging curvature. The third kind of differential movement is ground strain, which is defined as the rate change in horizontal movement between two points. In areas where hogging curvature occurs, the ground strains are typically tensile at the surface and the ground expands. In areas where sagging curvature occurs, the ground strains are typically compressive at the surface and the ground is compressed.

### CHALLENGES PRESENTED BY MINING UNDER URBAN AREAS

Mining under urban areas presents many challenges that must be considered when assessing potential impacts.

- *High density of surface features*

There are a high proportion of covered areas in urban environments, particularly in high density developments such as flats or units. In addition to the areas covered by building structures, a survey of 120 properties by MSEC at Tahmoor and Thirlmere revealed that only one property did not have an external pavement of some kind. In relation to publicly owned land, a large amount is covered by sealed roads. The high density of surface features in urban environments increases the chances of adverse impacts occurring, when compared to rural areas.
- *Great variety of services infrastructure*

Urban areas are serviced by power and communications systems, potable water networks, sewerage systems, and gas reticulation pipework. Additionally, there are also many transport systems such as rail networks, local roads, footpaths, bridges and culverts. There is great inter-dependence between services. For example, if the electrical network is compromised, sewage pumping stations can lose power, which could then lead to other adverse impacts.
- *More people are potentially affected*

This presents many challenges for the mining industry. These are discussed in more detail later in this paper.
- *Large number of public amenities*

Public amenities provide great support to urban communities. Amenities include schools, churches, shops and shopping centres, child care centres, health services and sporting fields.
- *Large number of business and commercial establishments*

There are many business and commercial establishments within urban areas. Mining companies are exposed to any consequential losses associated with subsidence impacts.
- *Urban areas are dynamic and continually changing*

Studies by Australian Bureau of Statistics indicate that the Wollondilly's population grew at a rate of 2.1 % per annum between 1991 and 2001 (WSC, 2006). A study by MSEC on the net rate of growth of houses in Tahmoor indicated that approximately 2 to 3 additional houses are being constructed in Tahmoor per month. The population growth and development of rural areas is substantially less.
- *Structures are in various conditions*

Urban areas contain dwellings of many ages. Some dwellings are listed as items of heritage significance, while others may be only recently constructed. The existing condition of some older structures may not meet current Australian Standards, before mining occurs. Furthermore, some structures have been built

prior to the proclamation of Mine Subsidence Districts and have not, therefore, been designed to accommodate mine subsidence movements.

- *Impacts are more easily observed*

Given the high density of surface features and the number of people who live and work in urban areas potentially affected by mine subsidence, there are more opportunities to observe any impacts that might occur. In a rural environment, for example, there is a good chance that a crack in the ground will not be noticed. However, in an urban environment, these movements may result in adverse impacts, which can be observed and reported by many people.

### CASE STUDY ON MINING UNDER TAHMOOR

Tahmoor is located approximately 100 kilometres south-west of Sydney, within the Southern Coalfield. The town was first settled in 1820's, initially to house travellers traversing the 'great south road' (Stonequarry, 2005). The town is now the largest in the Wollondilly Shire, with a population greater than 4000 people (ABS, 2001). There are over 1500 dwellings in Tahmoor (ABS, 2001), and approximately 2000 sheds and other small structures. Tahmoor lies within the Bargo Mine Subsidence District, which was proclaimed in 1975.

The town is located on the former Hume Highway and was once part of the main vehicular transport route between Sydney and Melbourne. The Main Southern Railway between Sydney and Melbourne passes through Tahmoor, carrying passengers and freight at approximately half hour intervals.

The town includes two shopping centres, which are joined by a small commercial district. A turkey processing plant is also located at Tahmoor.

Tahmoor Colliery commenced operations in 1979 and holds mining leases that include Tahmoor and some parts of neighbouring Thirlmere and Picton. The mine employs approximately 400 people.

Tahmoor Colliery has previously mined under many houses and other structures. It commenced mining under the urban area of Tahmoor in early 2005 with Longwall 22. It is currently mining Longwall 23 and a further six longwalls are planned to extract coal beneath the extent of the urban area. The extracted coal seam is approximately 400 to 500 metres beneath the surface, with subsidence expected to reach a maximum of 750 mm after the extraction of Longwall 23.

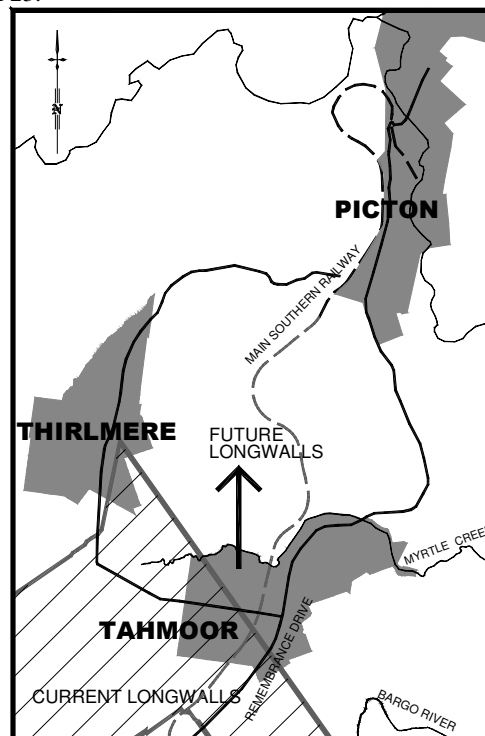


Fig. 1 - Location of Tahmoor and previous and future mining

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## METHODS EMPLOYED TO MANAGE IMPACTS AND RISKS AT TAHMOOR COLLIERY

A number of measures are being employed by Tahmoor Colliery to manage the impacts and risks associated with mining under the urban areas.

- *Identification and characterisation all surface features that may potentially be affected*

As part of its assessment, studies of all surface features have been undertaken. This included identification of all houses and other structures, public amenities and commercial and business establishments. Letters are sent to residents requesting them to check on the accuracy of the surveys and advise of any changes.

Information on all services has been collected from infrastructure owners and meetings were held to understand how each service operates.

It is also recognised that Tahmoor is growing in population and size and all information collected only represents a snapshot in time.

- *Assessment of likely impacts*

Greater confidence in predicting likely impacts can be achieved by undertaking detailed impact assessments. This has been a complex task given the density of features above the longwalls. For example, there are over 39 kilometres of sewer pipes in Tahmoor and predictions of subsidence were conducted along every length of sewer in Tahmoor, to determine whether the grades of any lengths of sewer were likely fall below self-cleansing grade.

Impact assessments are then made based on increased subsidence predictions, so that the sensitivity of each surface feature could be understood.

- *Consultation with the community*

The Colliery continues to consult with the community on many levels. It has been found that this consultation has greatly assisted the Colliery in identifying and characterising surface features, understanding how sensitive they might be to mine subsidence, and monitoring and reporting impacts that occur.

- *Identification of potentially unstable structures*

It is difficult to identify potentially unstable structures without entering private properties. Tahmoor Colliery has addressed this risk in two ways. Firstly, it invites residents who live in older homes, particularly those that were constructed prior to the declaration of the Bargo Mine Subsidence District, to an inspection by the Colliery prior to mining. Secondly, it has sent letters asking all residents to advise them of any concerns that they may have in relation to the stability of their structures. Thirdly, the colliery conducts home visits to residents prior to mining, to generally look around the property, take photographs of any potential issues and arrange for additional monitoring during mining, if required.

- *Monitoring ground movements and impacts*

Tahmoor Colliery has installed an extensive network of ground survey marks within the urban area. The design of the network was discussed and developed through consultation with the Department of Primary Industries Minerals, the Tahmoor Colliery Community Consultative Committee, the Mine Subsidence Board and the general public through open days. The ground survey network allows the Colliery to periodically check whether subsidence is developing as predicted and identify any areas where irregular and potentially damaging movements might be occurring. If adverse impacts occur, the survey network allows the Colliery to quantify the subsidence movements and check whether these movements are irregular.

The Colliery also conducts routine visual inspections of surface features for impacts. These are mainly conducted within the 'active subsidence zone', which is over an area that is defined by a distance of 150 metres in front and 450 metres behind the longwall face, within the predicted limit of subsidence. In relation to services infrastructure, the colliery and infrastructure owners have engaged in a number of monitoring programs that are specific to the needs of each type of infrastructure. There are also automated monitoring systems that are already operated by infrastructure owners that can detect whether impacts are occurring.

- *Risk assessments and management plans*  
Risk assessments and management plans have been developed for all surface features that may be potentially affected by mine subsidence. Where possible, the risk assessments and management plans have been produced in consultation with stakeholders, such as infrastructure owners.
- *Close liaison with Mine Subsidence Board*  
The Mine Subsidence Board (MSB) is charged with the responsibility of repairing any damage to properties as a result of mine subsidence. The community often reports impacts to the Colliery or the MSB and it is important that the colliery and the MSB maintain a close working relationship so that both parties are knowledgeable on all the impacts that occur during mining.

### MANAGING COMMUNITY EXPECTATIONS AT TAHMOOR COLLIERY

The concept of mining under houses can understandably create fear and concern for some residents, particularly if they have no experience of mine subsidence. Several approaches have been adopted by Tahmoor Colliery to explain to the community how mine subsidence develops, what impacts might occur, and how these impacts will be managed. This is a very time-consuming but important process.

The initial community consultation commenced when the Colliery applied for development consent to mine. A commission of inquiry was undertaken as part of this process. Following approval to mine beneath the town, Tahmoor Colliery continued to develop their mine plans. These plans were discussed with the Tahmoor Colliery Community Consultative Committee (TCCCC), which was set up in accordance with the conditions of development consent. Prior to mining the first longwall beneath Tahmoor, the Colliery increased the level of communication with the community.

The approaches adopted by Tahmoor Colliery are listed below.

- *Undertake conservative predictions and impact assessments*  
Tahmoor Colliery and MSEC have adopted a conservative approach to predicting subsidence and assessing impacts. This reduces the likelihood of under-stating the predicted impacts. For example, predictions for each structure have been made by predicting the maximum subsidence, tilt and strain within a 20 metre radius around each structure.
- *Undertake detailed predictions and impact assessments*  
By undertaking detailed subsidence predictions, the Colliery is able to provide residents with predictions for their own structures. Individual assessments provide some comfort to concerned residents. This is particularly helpful for residents that live beyond the extent of mining and are expected to experience only small movements.
- *Community Open Days*  
A number of advertised open days are held by the Colliery through the year. The Open Days allow members of the community to directly meet Colliery representatives and its consultants. The Mine Subsidence Board is also present on Open Days to answer questions. The information exchanged at Open Days also assist the Colliery, as members of the community sometimes provide information about particular surface features or impacts that the Colliery might not have been aware of.
- *Tahmoor Colliery Community Consultative Committee*  
This committee meets at regular (bi-monthly to quarterly) intervals. It allows the Colliery to present information to the committee and receive feedback. The committee is committed to ensuring that the concerns of the community are well understood by the Colliery. Many of the members have been part of the committee for several years, and this allows for informed discussion to take place.

- *Letters to residents*

The Colliery sends many letters to community advising of imminent longwall mining in their area. These letters invite residents to contact the colliery about any concerns that they might have and to remind them to organise a pre-mining inspection if they wish to do so. Some letters may be specifically targeted to residents if the Colliery wishes to conduct its own inspection of the property, which include all public amenities, old houses and houses that have been assessed at a higher level of risk of impact. Letters are also sent to residents just before the longwalls mine directly beneath their homes. These letters again invite residents to arrange a pre-mining inspection and includes a fridge magnet with key phone numbers in the event of an emergency or impact occurring.

By continuing to engage with residents at each stage of mining, the Colliery is able to find new residents who might not have been aware that mining was taking place.

- *Individual meetings with residents*

Many members of the community prefer to meet with Colliery representatives face to face. The Colliery has held many individual meetings with concerned residents to explain how mine subsidence develops and what the impacts might be. This is a time consuming but rewarding process for residents and the Colliery.

- *Newspaper advertisements*

The Colliery places advertisements in the newspaper from time to time to advise the community at large about recent mining applications.

- *Weekly reporting*

The Colliery provides regular updates on the progress of mining in the area. This is conducted mainly by group email to any member of the community who wishes to be regularly informed. The updates advise the current position of the longwall and what impacts have been observed during the past week.

- *Prompt response to reported impacts*

While this is traditionally the role of the MSB, the Colliery also responds quickly to impacts that are reported by the community. Once an impact is reported, the Colliery also checks neighbouring properties to see whether the incident is localised or part of a larger potential issue.

- *Ongoing monitoring if impacts occur*

Where impacts have been reported, the Colliery offers to continue monitoring the property for further impacts. This offer is in addition to those provided by the Mine Subsidence Board, who also monitors the property as mining continues.

The Mine Subsidence Board also plays a very important role in managing the expectations of the community. The MSB's concerted efforts to quickly respond to residents' concerns, particularly where they relate to emergency repairs to doors, gates or service pipes, have greatly assisted the community in coping with any inconvenience that may have occurred as a result of mine subsidence.

### **IMPACTS OBSERVED TO DATE AT TAHMOOR COLLIERY**

A comparison between predicted and observed impacts to surface features, following completion of Longwall 23A, is summarised in Table 1. It can be seen that the impacts to surface features have been relatively minor. The predicted and observed impacts to surface features compare reasonably well, with the exception of locations where non-systematic movements have occurred.

Table 1 - Summary of Predicted and Observed Impacts

<b>SURFACE FEATURE</b>	<b>PREDICTED IMPACTS</b>	<b>OBSERVED IMPACTS</b>
<b>NATURAL FEATURES</b>		
Myrtle Creek	Potential cracking in creek bed. Potential surface flow diversion. Potential reduction in water quality during times of low flow. Potential increase in ponding.	No impacts observed.
Aquifers or Known Groundwater Resources	See Farmland and Facilities - Wells and Bores	No impacts observed.
Natural Vegetation	No impacts anticipated.	No impacts observed.
<b>PUBLIC UTILITIES</b>		
Railways	Ground movements unlikely to impact operation of railway.	No impacts observed. Track was de-stressed as a precaution.
Roads (All Types)	Minor cracking and buckling may occur in isolated locations.	Impacts observed on road pavements in 3 locations. Impacts observed on concrete kerbs and gutters in 8 locations. Impacts have been minor and include cracking and buckling.
Water Pipelines	Minor impact to pipelines, particularly older cast iron pipes with lead joints.	Two leakages observed at connection to consumer lines during LW 22. Observed frequency of incidences similar to those in areas not affected by mine subsidence.
Gas Pipelines	Ground movements unlikely to adversely impact pipelines.	No impacts observed.
Sewerage Pipelines	Mining induced tilt may reduce gradient of some pipes to less than that required for self-cleansing.	Changes in tilt have occurred within predicted range. Observed frequency of incidences similar to those in areas not affected by mine subsidence.
Electricity Transmission Lines or Associated Plants	Ground movements unlikely to adversely impact electrical infrastructure.	One local feed line was loosened.
Telecommunication Lines or Associated Plants	Ground movements unlikely to adversely impact telecommunications infrastructure.	Air leaks observed in old lead cables in one location during LW 22 and two locations during LW 23A.
<b>PUBLIC AMENITIES</b>	Negligible impacts predicted for all public amenities.	Category 0 (hairline) crack to plasterboard ceiling of a child care centre.



Table 1 - Summary of Predicted and Observed Impacts (continued)

SURFACE FEATURE	PREDICTED IMPACTS	OBSERVED IMPACTS
<b>FARMLAND AND FACILITIES</b>		
Farm Buildings or Sheds	Negligible impacts predicted for all farm buildings and sheds.	No impacts observed.
Fences	No impact assessment was provided.	Impacts to fences or gates observed on 17 properties (1 rural, 16 urban).
Farm Dams	Potential cracking and leakage. Ground movements unlikely to result in overflowing or reduction in dam capacity.	No impacts observed.
Wells or Bores	Potential differential horizontal movements.	No impacts observed.
<b>INDUSTRIAL, COMMERCIAL &amp; BUSINESS ESTABLISHMENTS</b>		
	Negligible impacts predicted for all business and commercial establishments.	No impacts observed.
<b>PERMANENT SURVEY CONTROL MARKS</b>	Ground movement predicted at identified survey marks.	Ground movement occurred.
<b>RESIDENTIAL ESTABLISHMENTS</b>		
Houses	Tilt Impact Category B for 8 houses due to systematic mine subsidence movements. Strain Impact Category 1 for 152 houses and Category 2 for 2 houses due to systematic mine subsidence movements. Potential for non-systematic movement to occur. All structures expected to remain safe, serviceable and repairable during and following mining.	Some impacts observed for 33 houses, although most are negligible to very slight (sticky doors, minor cracks to internal finishes) 2 houses require adjustment to some roof gutters (Tilt Impact Cat B). 2 houses with Category 1 crack, 4 houses with Category 2 crack, and 3 houses with Category 3 crack. Houses with greater impacts had experienced non-systematic mvmts. All structures were safe, serviceable and repairable during and following mining.
Retirement or Aged Care Villages	Negligible impacts predicted for Macquarie Grove Retirement Village.	No impacts observed.
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	Potential impact to pipes connected to in-ground septic tanks. Negligible impacts predicted for non-residential domestic structures, including swimming pools and tanks.	No impacts observed to in-ground septic tanks or other tanks. Tilt impact observed at 1 pool. Tilt impact observed at 1 clothesline. Crack to 1 masonry retaining wall.
External Residential Pavements	No impact assessment was provided.	Impacts to pavements observed on 16 urban properties.

A total of 547 houses and public amenities are located within the predicted limit of subsidence for Longwalls 22 and 23A. It was predicted that 154 houses might experience impacts. Impacts have been observed for 33 houses and one public amenity at this stage. This represents a ratio of 6 %. All houses have remained safe, serviceable and repairable throughout the mining period.

Figure 2 shows the location of all properties that have experienced impacts to their houses or other structures such as sheds, fences and gates. It can be seen that the majority of impacts have occurred to properties that lie directly above extracted longwalls, although some of these properties first reported impacts before the longwall passed directly beneath them.

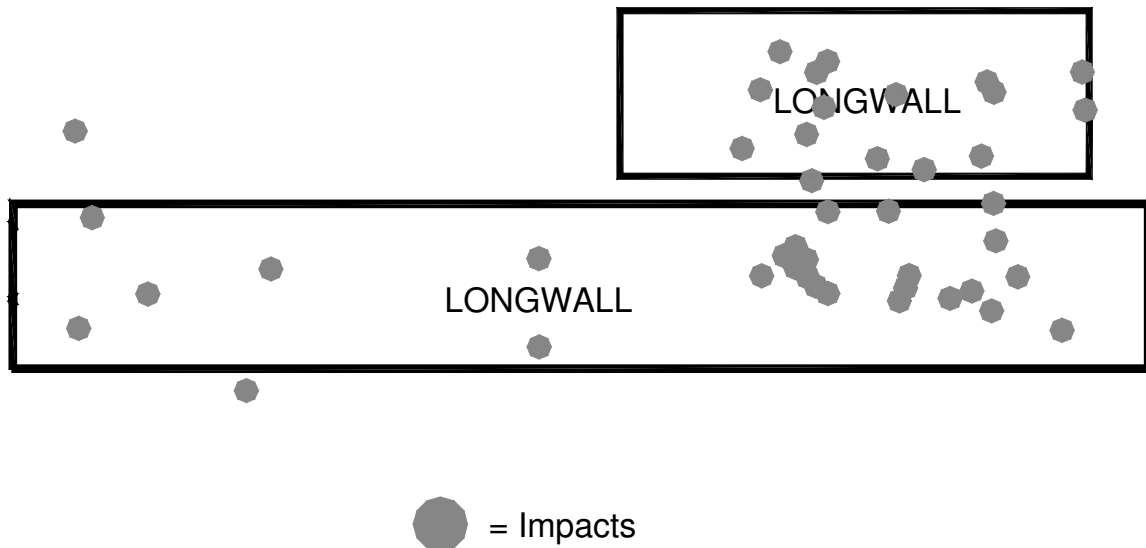


Fig. 2 - Location of properties that have experienced impacts after Longwall 23A at Tahmoor Colliery

### CONCLUSION

Mining beneath urban areas is a challenging exercise and has the potential to inconvenience many people. It requires careful planning and management. However, as shown by the approach undertaken at Tahmoor, it is feasible for underground coal mining and urban development to co-exist, particularly when mine subsidence movements are small enough to result in few impacts on the surface. It is important that the mining industry learn from the experience at Tahmoor, as it is likely that mining will occur under other urban areas in the future.

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