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REPORT
on
MINE SUBSIDENCE RISK ASSESSMENT

PROPOSED RESIDENTIAL DEVELOPMENT
MINMI AND LINK ROAD
MINMI

Prepared for

COAL AND ALLIED OPERATIONS PTY LIMITED

Project 39663D

NOVEMBER 2008

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18 November 2008

MINE SUBSIDENCE RISK ASSESSMENT
PROPOSED RESIDENTIAL DEVELOPMENT
MINMI AND LINK ROAD

1. INTRODUCTION

This report presents results of Mine Subsidence investigations at the proposed residential development at Minmi and Link Road. The assessment was carried out at the request of Coal and Allied Operations Pty Limited, in consultation with Catylis Pty Ltd. The work was carried out in conjunction with a geotechnical and contamination assessment, the results of which are presented separately (Ref 3).

The mine subsidence risk assessment included the following:

- Desktop study of available records related to mining, including the following:
  - Record Traces sourced from the Department of Primary Industries – Minerals;
  - Coal & Allied internal records held by the University of Newcastle;
  - Records held by the Newcastle City Library;
  - Historical aerial photographs;
  - Archive search by Mr Kevin Price, former mine surveyor at Gretley Colliery.
- Consultation with the Mine Subsidence Board with respect to likely development restrictions;
- Site walk over by senior geotechnical engineer;
- Discussions with people familiar with the history of mining in the area;

- Subsurface investigations of shallow mine workings to assess the risk of pothole subsidence and deeper workings to assess subsidence risk associated with pillar failure;
- Numerical modelling of pillar stability and potential subsidence;
- Recommendations with respect to the risk of mine subsidence for submission to the Mine Subsidence Board for final consideration of appropriate development restrictions.

2. SITE IDENTIFICATION

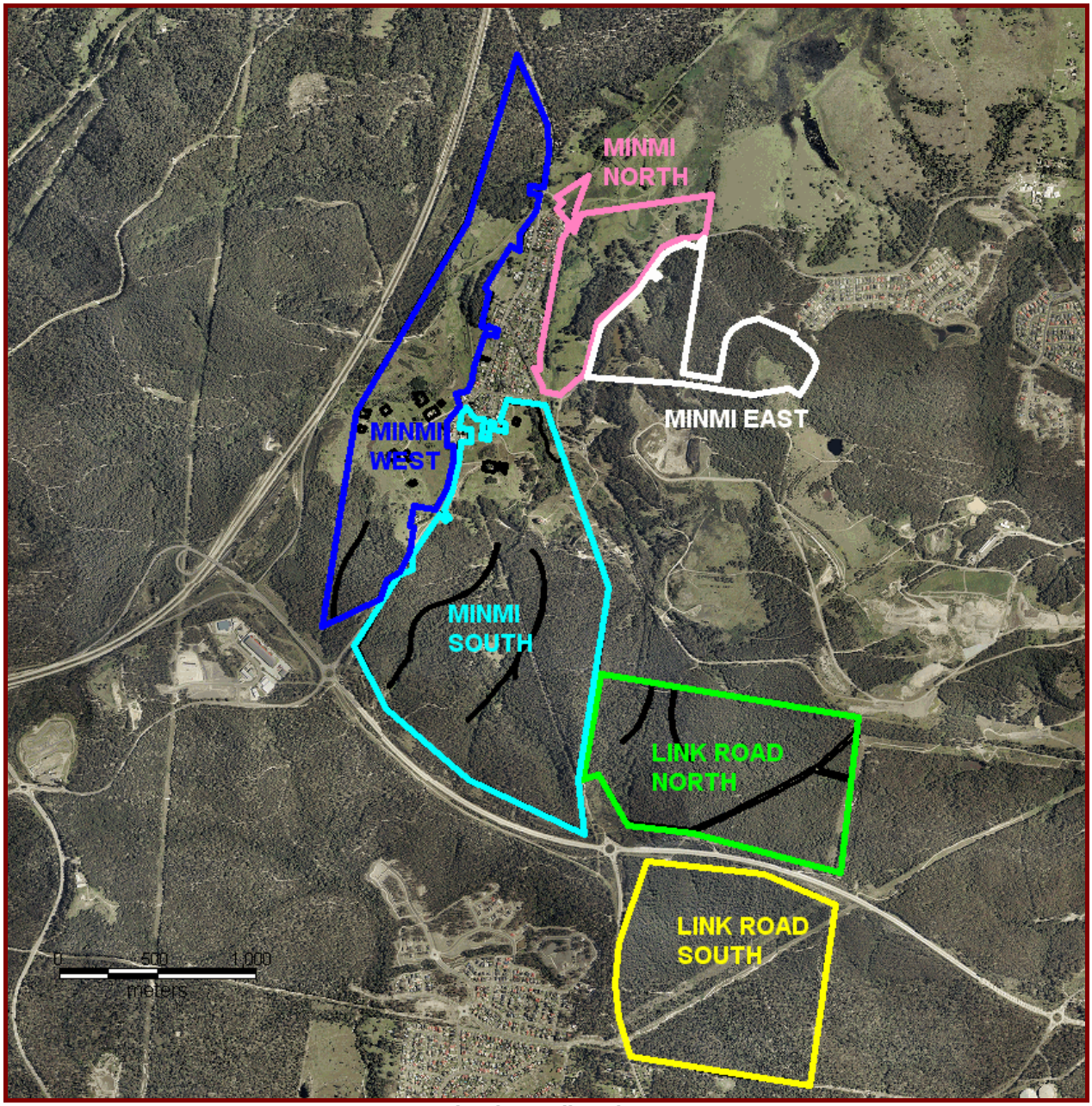
The Minmi site is identified as Lot 71 DP 1065169, Lot 351 DP 1108608 (formerly Lot 35 DP 800036), within the Newcastle City Council (NCC) area Lot 6 DP 1044574, Lots 2 and 3 DP 877349 within the Lake Macquarie City Council (LMCC) area.

Within the NCC area the land is zoned 2(a) Residential in the immediate vicinity of Minmi and south of Fletcher, 7(b) Environmental Protection Zone, and 7(c) Environmental Investigation Zone. Within the LMCC area the land is zoned 7(2) Conservation (Secondary) and the south – west corner zoned 10 Urban Conservation, with a small area between the two, zoned 5 Infrastructure.

For purposes of this assessment, the site has been divided into six areas. The extent of each of the potential development areas is shown on the Locality Plan below. Each area is described as follows:

- ***Minmi West:*** This area is between Woodford Street, which bisects the Minmi village in a north-south direction, and the F3 freeway to the west. The area has an irregular shape and covers about 100 hectares;
- ***Minmi North***: This area is to the east of the Minmi township and to the north/west of Minmi Road. The area is generally low lying and has an area of about 40 ha;
- ***Minmi East***: This area is to the east of Minmi Road and north of the Summerhill Waste Disposal Centre. The area has an irregular shape with two sub areas, one to the west and one to the east. The overall surface area is about 45 ha;
- ***Minmi South***: This area is between the Minmi Township and the Newcastle Link Road to the South, it has an area of about 170 ha;

- ***Link Road South:*** This area is an approximately square area to the south of the Newcastle Link Road and East of Minmi Road with an area of about 100 ha;
- ***Link Road North:*** This area is also approximately rectangular and immediately north of the Link Road. It has an area of about 100 ha.



Minmi Locality Plan

Adjacent land use comprised the following:

- Low lying farm land and sewage treatment works north and downslope of Minmi North area;
- Township of Minmi between Minmi North and Minmi West areas, generally upslope;
- Bushland and F3 freeway to west of Minmi West area, generally upslope of site;
- Bushland and Newcastle Link Road to the south of Minmi South and Link Road North areas;
- Bushland to east of Link Road North and South areas;
- Bushland and residential development west and south of Link Road South, generally downslope of the site;
- Summerhill Waste Facility between Minmi East and Link Road North and east of Minmi South areas;
- Minmi Cemetery immediately east of Minmi South area.

3. DESKTOP REVIEW

3.1 Regional Geology

The 1:100,000 scale Newcastle Coalfield Regional Geology map indicates the site is generally underlain, from north to south, by the Tomago Coal Measures (siltstone, sandstone, claystone, coal, tuff), the Waratah Sandstone, basal unit of the Newcastle Coal Measures, and the Newcastle Coal Measures Lambton Subgroup (sandstone, siltstone, claystone, coal and tuff). The mapping does not indicate the presence of alluvial sediments, however as discussed below, alluvial soils are expected on the northern portions of Minmi West and Minmi North.

3.2 Mining History

3.2.1 General

The brief review of site history comprised the following:

- Review of historical records regarding mining at the site including mine record traces, newspaper articles and historical reference books;
- Interview with local resident and former mine employees;
- Review of historical aerial photos.

The site is underlain by coal mine workings in two seams, the Young Wallsend and the Borehole seams. Mine record traces (RT) have been geo-referenced using survey grid on the record traces where available (on Young Wallsend Seam workings) and available cadastral information on the record traces as well as the location of mapped shafts which have been accurately located on site. The record traces are slightly distorted in places, particularly those for the Borehole Seam workings, however comparison with background cadastre and shafts indicates that this is generally less than 10 m, with the exception of the western parts of RT457 for Browns Colliery/Duckenfield No 1, but this area is outside the site.

3.2.2 Underground Mining

A, B and C Pits – RT 497

Mining in Minmi commenced with the A, B and C pits starting about 1853. The workings were in the Borehole Seam and comprised bord and pillar workings. The locations of shafts for Pits A, B and C are shown on Drawing 1.

A report by Smith & Moore to the provisional directors of the Melbourne and Newcastle Minmi Coal Company, dated 1862, indicated the following:

- Coal measures exceedingly regular;
- Seam was discovered by outcrops;

- The seam dips southward and eastward at 2°;
- The thickness of the seam averages 8'10'' (2.7 m) of which 2' is left in the roof and 1 foot in the floor leaving a net thickness mined of 5'6" (1.68 m);
- Coal worked on the pillar and stall system;
- Trucks drawn by horses;
- C Shaft is 92' (28 m) deep and 14' (4.3 m) diameter lined with sandstone for the upper 20' (6.1 m);
- B Pit is 56' (17 m) deep, 10'7" (3.3 m) diameter and lined with timber;
- An air upcast shaft with fire at its base provided ventilation;
- A water shaft was sunk 39 chains (785 m) from C pit;
- Steam driven winding engines.

The pit infrastructure was mostly on the southern half of the Minmi West area, and included a rail line and Coke Ovens, which appear to have been to the west of Pit B as indicated by the following sketches presented in Figures 1 and 2 below.

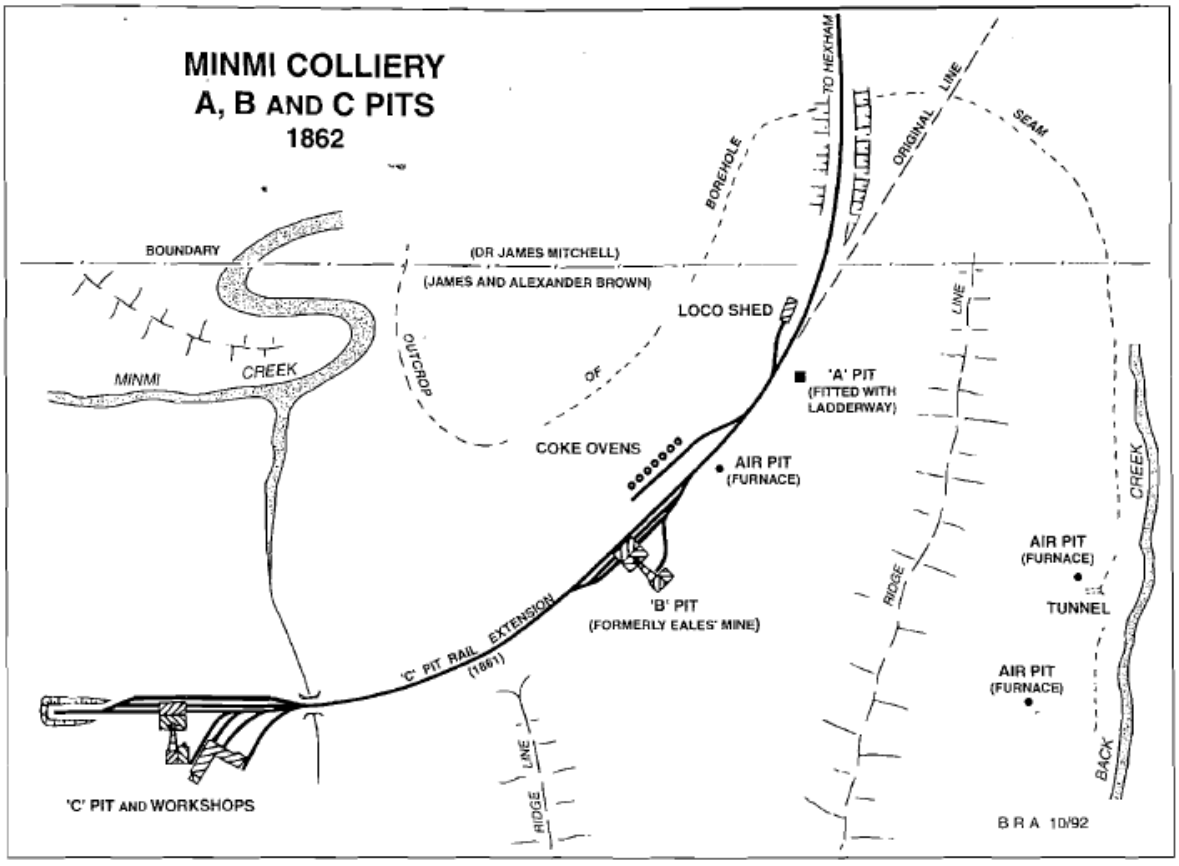


Figure 1 – Layout of Pits A, B and C, 1862 (Andrews, Ref 1)

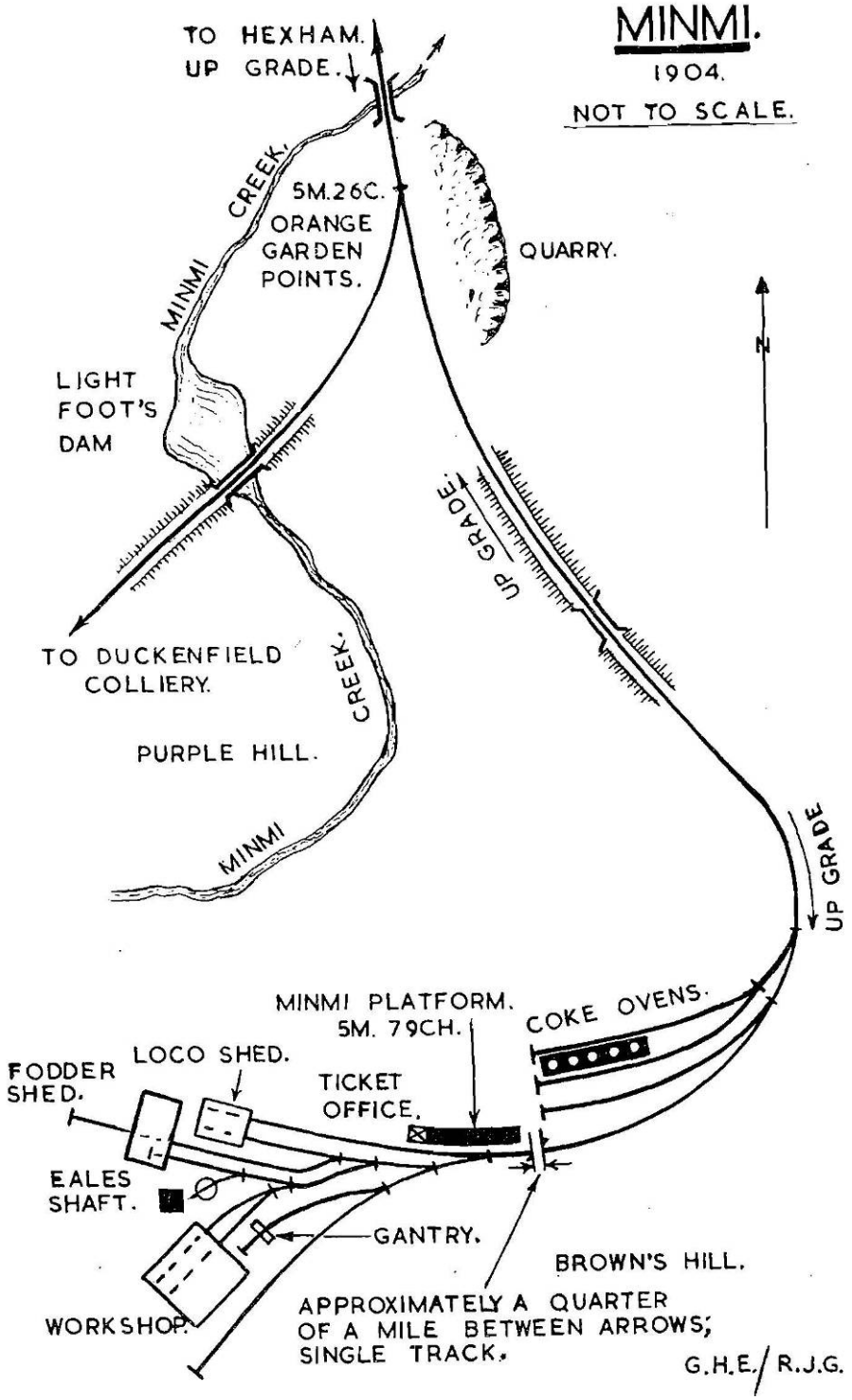


Figure 2 – Layout of Rail Lines, 1905, Showing Line to Duckenfield (Eardley – Ref 2)

In 1859 the coke ovens were expanded to 32 in number and in 1861 a large workshop was also constructed near the C – Pit winding boilers, as shown in Photo 1 below.

Photo 1 – Workshops Near Pit C, 1906 (Andrews – Ref 1)

The workings extended below much of the West Minmi and South Minmi areas. The mining was discontinued in 1871 due to flooding of the workings. The railways and workshops remained in operation servicing the Duckenfield Colliery, located to the west of the site

A typical seam section shown on RT 497 indicated a working section of 5'3" with 10" not worked.

Browns Colliery – RT 257 (Duckenfield No 1)

Browns Colliery was opened in 1876, with the pit top located on the northern parts of Minmi South area. Tunnel entries No 2 and No 4 are shown on Drawing 1. Browns Colliery is also at times referred to as Back Creek and Duckenfield No 1. The arrangement at the pit top is shown on Figures 3 to 5 below (Ref 1) and included the following:

- Stables;
- Cabins;
- Screens;
- Rail lines and sidings;
- Boiler.

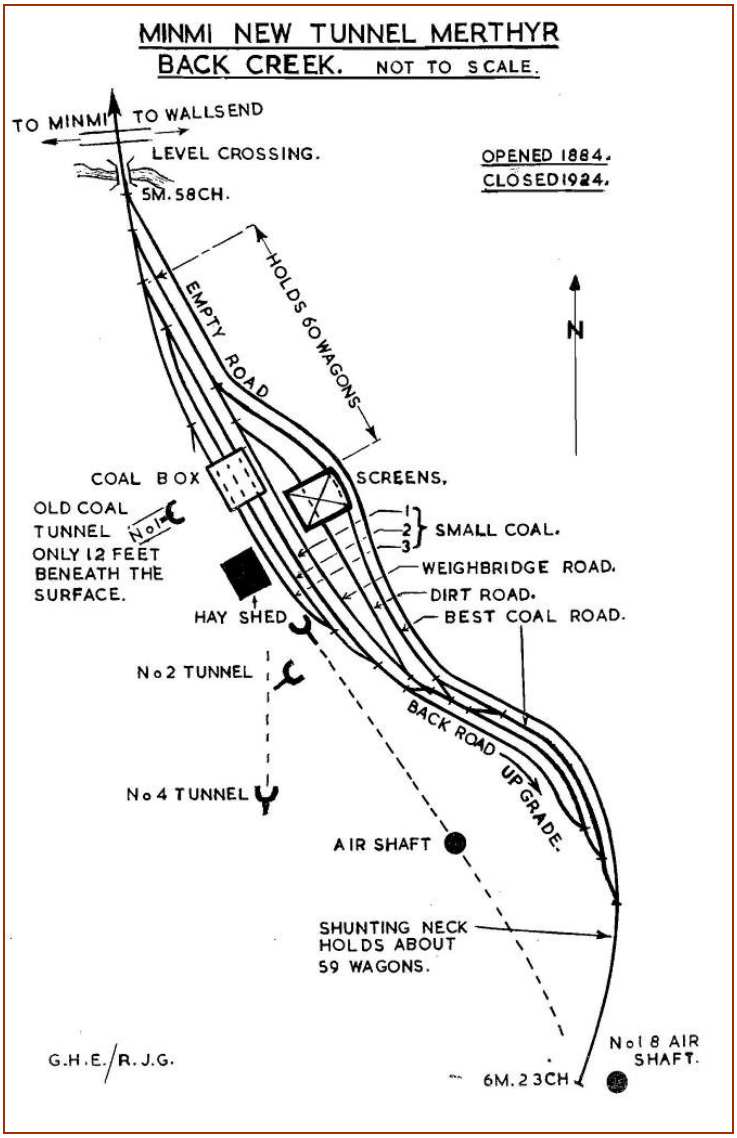
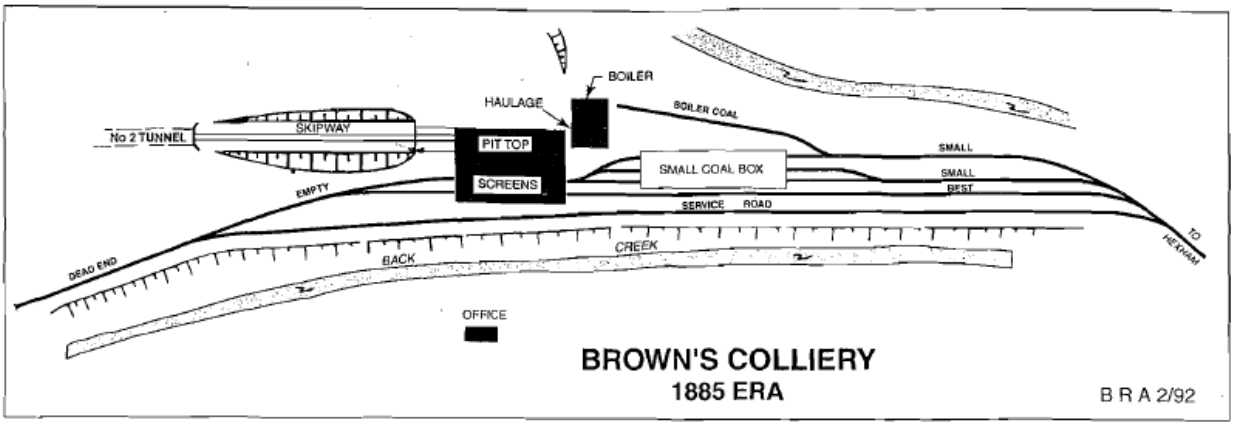
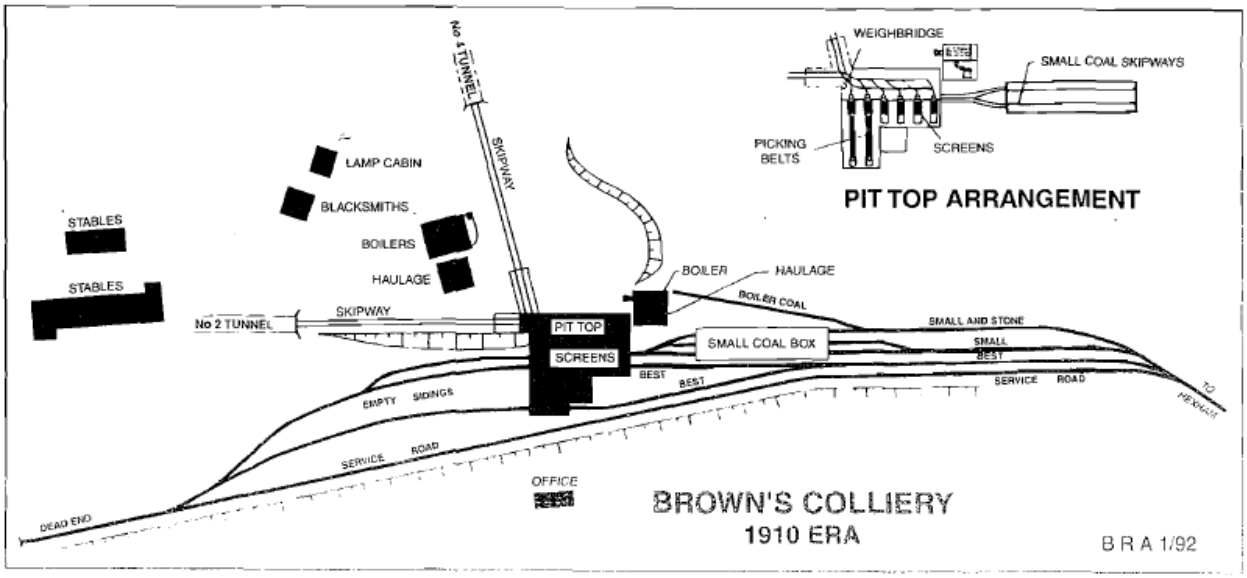


Figure 3 – General Arrangement of Rail Lines Relative to Browns Colliery Tunnel Entries 1924 era (Eardley – Ref 2)





Figures 4 and 5 – Showing Arrangement of Browns Colliery Facilities in 1885 and 1910 (Andrews – Ref 1)

A photo of Browns Colliery from late in the 1800s is shown below (Photo 2), probably taken from the southern end of the Minmi township, looking south west.

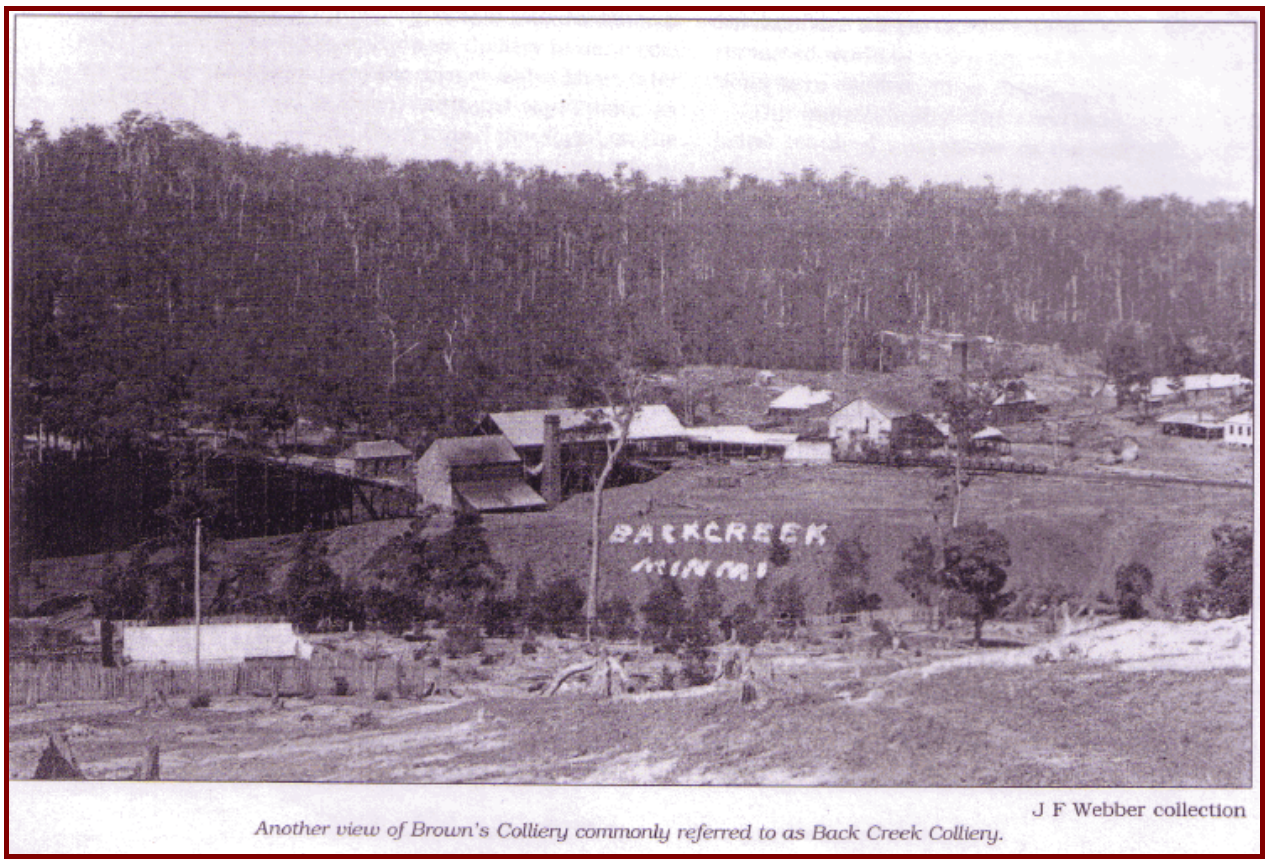


Photo 2 – Browns Colliery in Back Creek (Andrews – Ref 1)

A second tunnel (Tunnel 4) was driven in 1888. Workings of the Browns Colliery, as shown on RT 257 extended under most of Minmi South as well as Link Road North. The workings were bord and pillar with some pillar extraction on the southern parts of the site.

RT 257, sheet 5 indicates a workings seam thickness of 1.9 m, with 0.25 m left in the floor and a working section of 1.65 m (Refer Kevin Price Data Summary, Appendix B).

Minmi East

The eastern section of the Minmi East area is underlain by the following workings in the Borehole Seam:

- Co-Operative Colliery – RT 527;
- Cramp Colliery – RT 282;
- Wentworth Colliery – RT 305.

The workings were undertaken in the late 1800s and comprised bord and pillar workings. Numerous shafts and entries are shown on the RTs, as mapped on Drawing 3 in Appendix D.

The RTs indicate seam thicknesses in the order of 6'. The working sections are not shown.

Young Wallsend Seam – RT 701 and 574

Workings in the Young Wallsend seam were undertaken by the Wallsend Borehole Colliery (RT 701) under the southern parts of Minmi West and most of Minmi South. The Link Road South and North are underlain by workings of the Gretley Colliery (RT574). Record traces indicated workings on the northern parts of the site in the 1970s. The workings comprised bord and pillar workings, typically with 5 m wide bords, and pillar extraction in some areas.

An entry to the Young Wallsend Seam was located in Minmi South in a former open cut pit as shown on Drawing 3. A wash plant was located to the east, partly encroaching onto Blue Gum National Park.

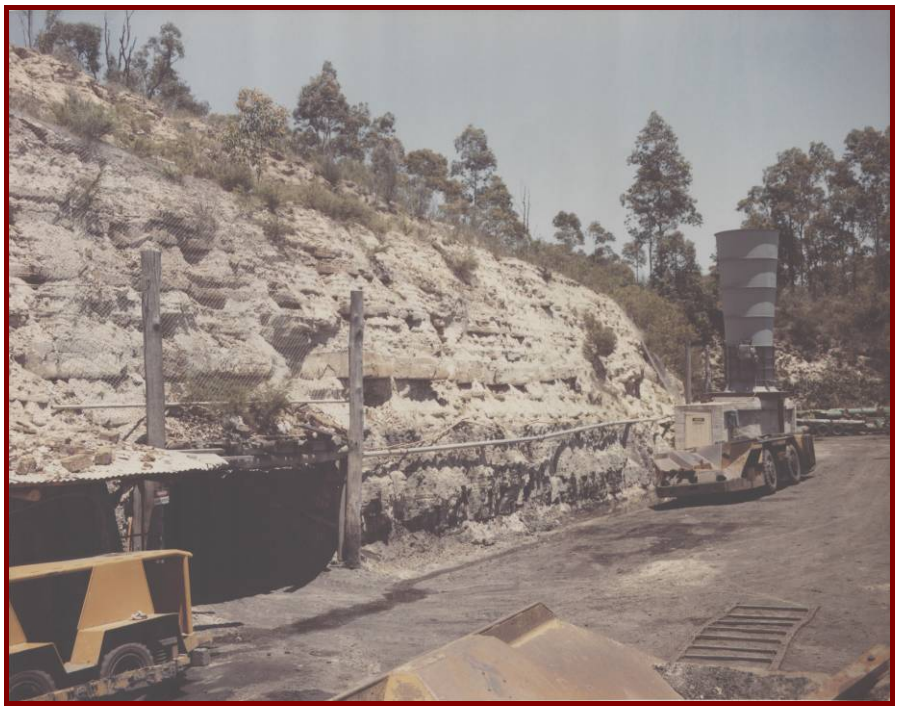


Photo 2a – Wallsend Borehole Colliery Entry No 2

3.2.3 Open Cut Pits – RT 621

Four open cut pits have been identified on the site as follows:

Purple Hill Open Cut. Located on the central western parts of the Minmi West area and continues to the west of the site. The cut was in the Borehole Seam, with the mining undertaken in the period 1948 to 1954. Underground workings were broken into on the south side of the cut.

Back Creek Open Cut. This is located on the north eastern boundary of Minmi South. The cut was in the Borehole Seam and was undertaken in 1949. The open cut continues to the south and east of the site. The thickness of coal on the RTs ranges from 5' to 7'6" (1.52 m to 2.28 m).

Old Workings in Young Wallsend Seam: There are two smaller open cuts shown on the central parts of the Minmi South area, where there were workings of the Young Wallsend Seam. The workings were undertaken in 1953. No details of the seam or working depth are shown.

Browns Colliery: A continuation of the Back Creek open cut extended to encroach onto the south western part of Minmi East. The workings were in the Borehole Seam and were undertaken in 1950 and 1951. The workings broke into the Browns Colliery underground workings.

Wallsend Borehole Colliery (Young Wallsend Seam) : Open cut workings of the Wallsend Borehole Colliery extended onto the eastern part of the Minmi East area. The workings were undertaken in 1984 and did not extend to the outcrop.

A Newcastle Herald article from 1950 and an article in Australian Coal, Shipping, Steel and The Harbour, 1-8-1949, indicated the following regarding the Purple Hill and Back Creek mining operations:

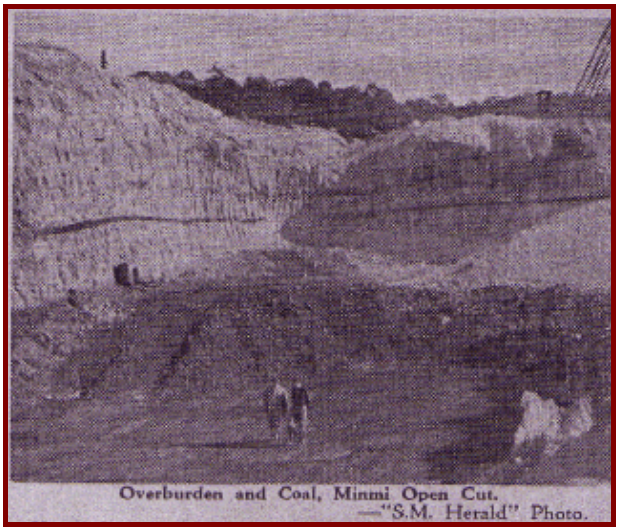
- Cuts in the order of 30 ' to 45' (about 9 m to 14 m);
- Cuts fringed with 'peaks of earth';
- 14' of water in open cut (about 4 m);
- Diesel shovel used in places (see Photo 3 below);

- Blasting used, as well as bulldozers and drag lines;
- Coal seams 7'6'' thick (2.28 m);
- Overburden taken with scrapers to surrounding land which is not coal bearing;
- Old workings broken into : "although in old mines very accurate maps of workings were not made, and the layout was not set down with such mathematic precision of today, the present operators have a general idea of the size, direction and depth of the workings".

With respect to the old underground workings the article indicated the following:

> "an experienced eye can gain a very good idea on the points from the depressions left when the old abandoned workings caved in. The fall ins are plainly discernable in many places where new workings will be over old. The bords and pillars of half a century ago were much smaller than those of today. An old miner at Minmi informed me that his father had often told him he had driven a cut through in a day. The main headings were kept fairly even but driving was done by sound and it was left to the deputies to preserve some semblance of a line and to tell the miners where to put the bords and cut throughs".

Typical photos of the open cuts from 1949 are shown below.



Photos 3 and 4 – Photos of Typical Open Cut Mines - 1949

For the Purple Hill and Back Creek open cuts a screening plant was constructed on the Minmi West area, near the base of a ridge. An access road was constructed to the west of the rail line to service the Purple Hill Mine and a loop road was constructed off Woodford Road, presumably to accept trucks from the Back Creek Mine via Minmi Road. The general arrangement is shown on Figure 6 below and a photo of the screening plant is shown on Photo 5.

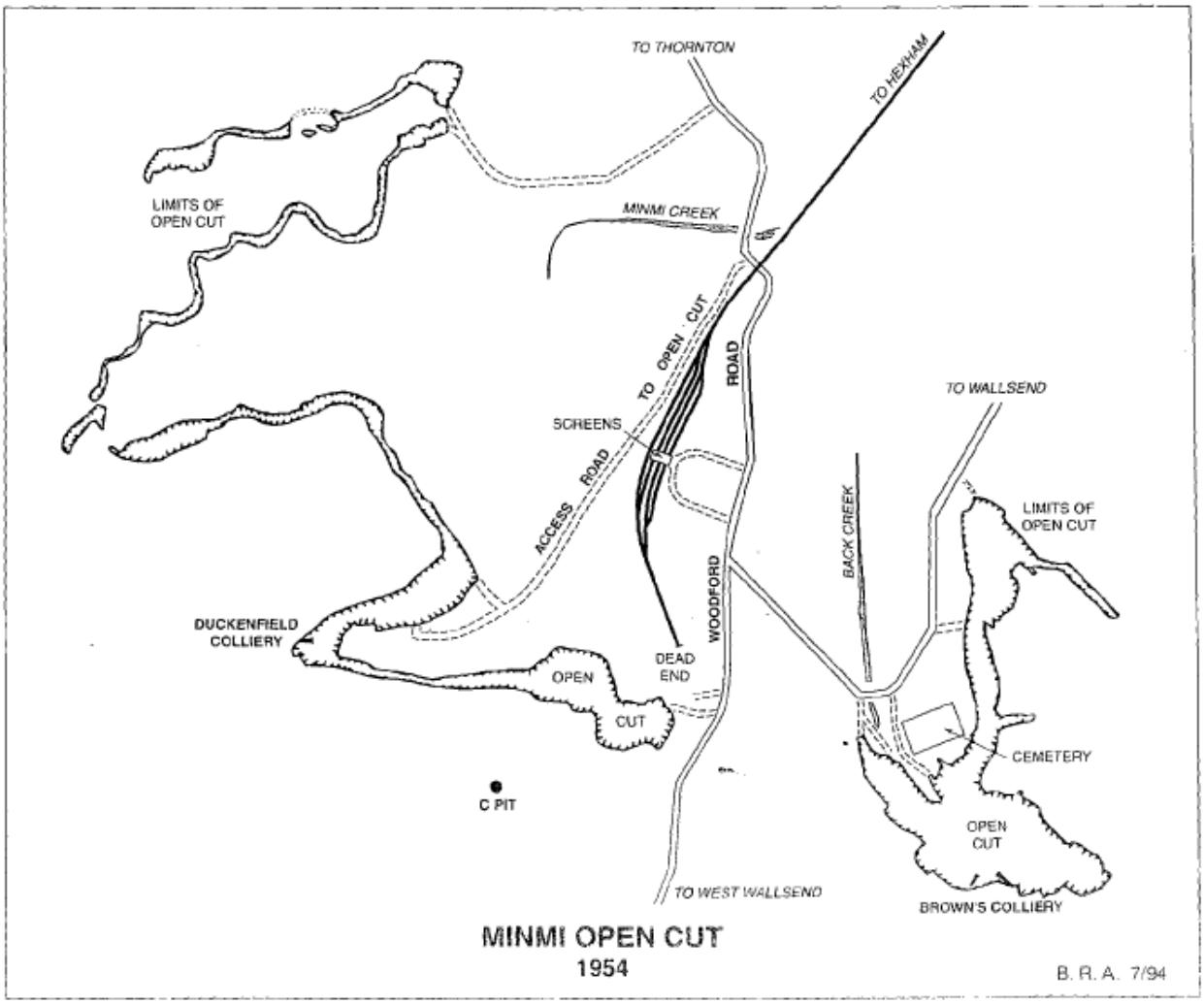


Figure 6 – Arrangement of Rail Lines and Road Loops Relative to Open Cuts (Andrews – Ref 1)

Photo 5 – Rail Siding Screening Plant for Open Cuts, on East Side of Minmi West (Eardley – Ref 2)

3.3 Interviews with Personnel Familiar with the Site

As most of the mining related activities at the site occurred over 50 years ago, it is difficult to find people who have direct knowledge of operations on site.

Discussions were undertaken with the following:

Ron Perry, Local Resident

Ron is a local history buff who indicated the following:

- John Eales commenced mining;
- J & A Brown bought out Eales in the mid 1850s;

- There was a furnace shaft for ventilation;
- A railway was constructed to Hexham initially using horses and then steam locomotives;
- Underground workings near Minmi closed in 1923;
- Useful information to be found in publications of railways of J A Browns by Gifford Eardley (Ref 2) and Andrews (Ref 1);
- Open cut mines started in 1949 during a 7 week strike, army started open cut operations.

Bob Stanton

Bob Stanton is a long term resident of the old school house on the western side of Woodford Street. His house is located at the southern end of the areas of pasture within Minmi East and he leases the pastures between his house and Railway Street. Bob indicated the following:

- A large pothole had formed in a northerly trending gully to the north of his house. This had been previously filled by Coal & Allied;
- A shaft had been filled on the western side of the gully to the west of his house;
- He was aware of no other potholes being filled on the paddocks he leased;
- Significant volumes of filling had been placed in the former mine entry to Wallsend Borehole Seam colliery near Jack Dodd's house;
- Significant subsidence has previously occurred on Woodford St immediately to the east of his house.

Paul Griffith

Paul Griffith is employed by Coal & Allied to maintain the leased paddocks. We met with Paul in June 2007 when a pothole had been found in Minmi Creek. The pothole had formed shortly after storm activity in June 2007 and the majority of the creek flow was entering the pothole as shown in Section 5.

Paul indicated that several potholes had been filled in the area including the following:

- Northerly trending gully to north of Bob Stanton's house;
- Pothole on road to Jack Dodd's House.

He also indicated that one of his employees, Lenny Grant has significant knowledge of the history of the site.

Lenny Grant

Lenny has lived in the Minmi area for most of his life and was a long term employee of Coal & Allied. Lenny indicated the following:

- He had filled a pothole in the gully to the north of Bob Stanton's house as well as the one which formed in the creek in June 2007;
- A pothole had been encountered during removal of a dam to the south west of the courthouse restaurant near the end of Neal Close. He reported that he thought he could see a tunnel at about 10 m depth heading in the WSW – ENE direction. (Subsequent intensive line drilling in the vicinity of the pothole failed to find any tunnels – See Section 5 for details);
- Significant volumes of filling had been placed in the former western entry to the Wallsend Borehole Colliery and had repeatedly washed out. The filling had been stable for over ten years now;
- He recalled filling two potholes in a paddock to the west of Minmi Pub in the 1960s. He physically located both, and both showed signs of surface slumping. (Both possible potholes were subsequently excavated and were found to actually be brick lined cisterns which had been filled with soil , bricks and sheet metal. Both were water filled. (See Section 5 for details).

Bill Freeman

Bill Freeman lives on the northern side of Railway Street, and backs onto Minmi Creek. Bill indicated the following:

- A pothole had formed in the creek behind his house in June 2007;
- There was a possible old mine entry to the east of his house;
- He also showed the location of a possible old shaft to the north of the creek;
- He was aware of no other potholes in the area.

Phil Alexander

Phil Alexander of the Mine Subsidence Board indicated that numerous potholes had formed in the Minmi area, however could not indicate the locations as such records had not been kept in the past. Phil indicated that potholes had formed in locations where no mine workings were expected and that potholes could be possible as far north as the outcrop of the Borehole Seam.

Phil indicated that a shaft had been filled and capped near 52 Railway Street (Shaft No. 40). The depth of cover at the shaft was about 22 m. He had no records of potholes in this area.

Ian McLeod

Ian was a former employee at Wallsend Borehole Colliery and had been involved in location and capping of shafts at the site. He indicted the following:

- Tailings were pumped into the Borehole Seam workings;
- Most shafts on site has been filled and capped, however some could not be found as follows:
  - No 4 Entry (B4 on Drawing 3) was never found and assumed to have been filled over;
  - No 2 entry (B4) and the nearby unlabelled entry (B10) were removed by open cut operations;
  - The Purple Hill shaft and ABC entry were never found;

- There were three entries into the Wallsend Borehole Colliery, the westernmost one was a ventilation shaft and had limited cover. A number of roof falls occurred. The middle entry was the travelling road and the eastern one was the belt road;
- The entry was in the base of an old open cut and was paved with concrete in places;
- The wash plant was located to the south of the entries.

3.4 Review of Historical Aerial Photos

The following historical aerial photos were reviewed:

Table 1 – Aerial Photo Review

Year	Approximate Scale	Black and White/Colour
1954	1:40000	Black and White
1966	1:38000	Black and White
1975	1:40000	Black and White
1984	1:40000	Black and White
1996	1:50000	Colour
2006	1:25000	Colour

1954 Aerial Photograph

- Purple Hill Open Cut;
- No obvious infrastructure near C Pit;
- Haul road and rail lines evident in Minmi East;
- Road loop to open cut rail siding screens evident, screen not clearly visible;
- Back Creek workings;
- Various cleared areas and tracks on Minmi South;
- Most existing homes in Minmi present;
- Surface disturbance around former Browns Colliery (Back Creek) pit head.

1966 Aerial Photograph

- Open cut rail siding screens evident;
- Possible dam at north end of Minmi North;
- Browns Open Cut mine, including present surface water feature;
- Heavy disturbance around Browns Colliery (Back Creek) pit head;
- Some additional clearing in Minmi South;
- Disturbance near shaft at south end of Minmi South;
- Transmission line on Link Road South.

1975 Aerial Photograph

- Dam on northern part of Minmi South evident with surrounding surface disturbance;
- Track to dam and shaft at south end of Minmi South;
- Open cut rail siding screens still present;
- Additional clearing on northern end of Minmi West;
- Surface infrastructure associated with Wallsend Borehole Colliery underground operations is evident.

1984 Aerial Photograph

- Wallsend Borehole Colliery open cut present on western part of Minmi East;
- Open cut rail siding screens removed.

1996 Aerial Photograph

- F3 Freeway to west of site;
- Link Road present;
- Surface disturbance in former Purple Hill Open cut area on Minmi West;
- Surface disturbance on Minmi South around Young Wallsend open cuts;
- Surface disturbance around shaft at south end of Minmi South.

Information obtained from aerial photos was limited by the relatively small scale and poor resolutions.

3.5 Consultations

Consultations have been undertaken with Mr Greg Cole-Clark of the Mine Subsidence Board. Greg indicated the following:

- The risk of pothole subsidence should be based on the history of potholes in the area as well as subsurface investigations and empirical methods. Where there is a high risk of pothole subsidence, typically for less than about 20 m cover, surface development in such areas would probably only be possible if grouting of the workings was undertaken. The MSB also indicated that there is a history of potholes occurring in areas with no mapped workings and therefore it would be necessary to confirm the absence of workings in any areas with less than about 20 m cover by subsurface investigation. In such areas, provided that it can be established that there is an absence of extensive workings, development is acceptable, however should comprise pier and beam construction with underfloor space and no raft slabs. This is to allow easy repair of potholes, if they occur;
- For remaining areas subject to undermining, an assessment of the risk of mine subsidence would be required. If there was a moderate to high risk of mine subsidence, then it would be necessary to predict worst case subsidence parameters to allow assessment of appropriate development types.

3.6 General Extent and Depth of Mine Workings

3.6.1 Extent

As outlined above, available records show that much of the site has been undermined. No workings are mapped on the northern potions of the Minmi West, Minmi North and Minmi East areas, as shown on Drawing 1. There are also some localised areas of no workings on the western side of the Minmi West area, where a dyke is shown on the record traces.

It is understood that mine subsidence potholes have been identified and repaired by the MSB in areas where records show no mapped mining. These areas are generally in the township of Minmi, north of the mapped workings in areas where there is typically less than 10 m depth of cover to the workings in the Borehole Seam. Based on this information as well as accounts of the poor mapping of the A, B and C pit workings as described by the newspaper article of 1949, there is a possibility of unmapped workings, particularly in the Borehole Seam, in the northern parts of the site. It is possible that such unmapped workings extend to the outcrop of the coal seams (where the coal seams meet the surface).

3.6.2 Shallow Depths of Cover

General

The depth of cover was initially estimated from the base of seam contours provided on RT 701 for the Wallsend Borehole Colliery workings in the Young Wallsend Seam and surface elevation contours provided by the client. The depth of cover to the Borehole Seam was initially based on an inter-burden thickness of around 17 to 20 m as well as limited information regarding depth of coal in shafts. The depth of cover was refined by the results of drilling as described in Section 7 and the mapping shown on Drawings 2 and 4 in Appendix D reflect the results of drilling.

Borehole Seam

The depth of cover to the Borehole Seam is generally shallow, less than about 20 m cover, on the northern parts of Minmi West and Minmi South as well as parts of Minmi East. These areas are shown as red on Drawing 1. As the mapping of these workings is expected to be of poor quality and unmapped workings may be present, the zone has been continued to the north to the estimated location of the outcrop. Areas where workings are not shown within this zone include the following:

- Area below creek on south western part of Minmi West;
- Small area south of Back Creek Open Cut in Minmi South.

Intensive subsurface investigation would be required to confirm whether workings are actually present in these areas.

Young Wallsend Seam

Most of the mapped Young Wallsend Seam workings at the site are at greater than 20 m cover, however as outlined in the sections above, unmapped workings are possible at Minmi, although the risk of unmapped workings in the Young Wallsend Seam is considerably less than for the Borehole Seam.
Areas of the site where the depth of cover to the Young Wallsend Seam is less than 20 m are mapped on Drawing 1 as follows:

- Orange where no workings are mapped. This area comprises a winding strip running across the southern part of Minmi West onto the northern parts of Minmi South;
- Red where workings are mapped. These areas comprise narrow strips just to the south of the orange zones described above.

3.6.3 Greater Cover Depths

Both coal seams dip to the south. Ground surface levels also increase to the south with a high point approximately along the Link Road and then falling slightly to the south in Link Road South. Depths of cover to the Young Wallsend seam range up to about 130 m with cover to the Borehole Seam ranging up to 150 m.

3.7 Shaft and Tunnels

Several shafts and tunnel entrances have been identified from the various record traces. The nature and location of these shafts and tunnels has been confirmed as part of the field work as described in Section 6.

3.8 Open Cuts

The location of the various open cuts, as shown on the RTs, are shown on Drawing 1 in grey as follows:

- Purple Hill: central western side of Minmi West;
- Back Creek: north eastern part of Minmi South;
- Browns Colliery: south western part of Minmi East;
- Young Wallsend Cuts (2 no) Minmi South;
- Wallsend Borehole Colliery: eastern part of Minmi East.

The pits are generally expected to be less than about 10 m to 15 m deep, with the spoil stockpiled in the surrounding areas. The pits have generally been partially backfilled and the results of the walk-over assessment suggest significant piles of mine spoil in the surrounding areas. Surface water was observed ponding in three of the pits.

3.8.1 Typical Sections

Sections of the mine workings in the Minmi West area (Section BB) and the Minmi South area (Section AA) are presented on Figures 7 and 8 below. The section shows the following general features:

- Slopes generally falling to the north;
- The Young Wallsend Seam, dipping to the south with workings terminating, generally with about 20 m cover or more, and the seam outcropping at about the 20 m cover contour for the underlying Borehole Seam workings;
- Borehole Seam dipping to the south, with the workings typically continuing to the open cut mines, located near the outcrop;
- Open cut mines, which typically broke into the Borehole Seam workings. The pits have been backfilled to varying degrees.

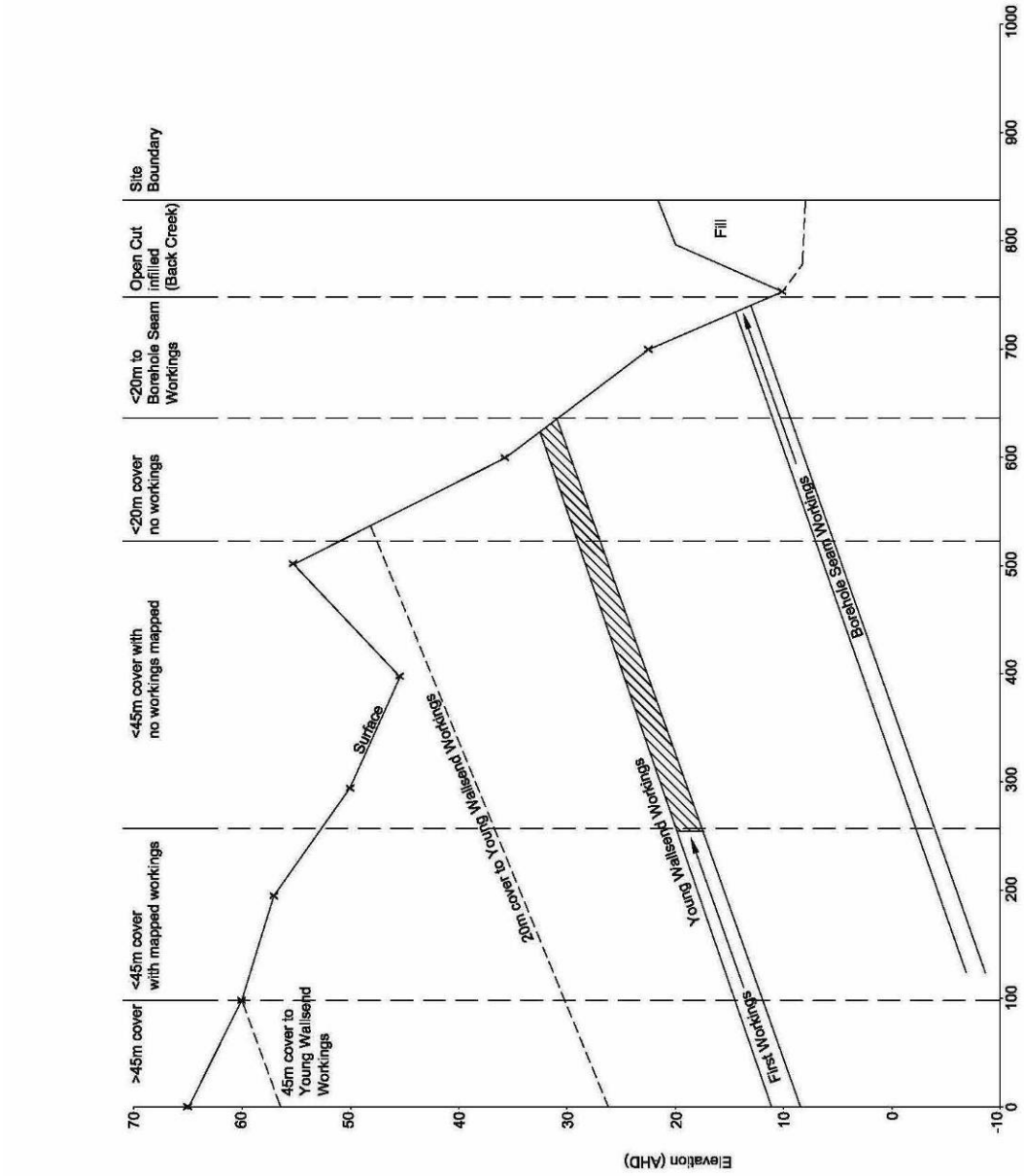


Figure 7 – Section AA of Mine Workings, refer to Drawing 1 for section location - Minmi South

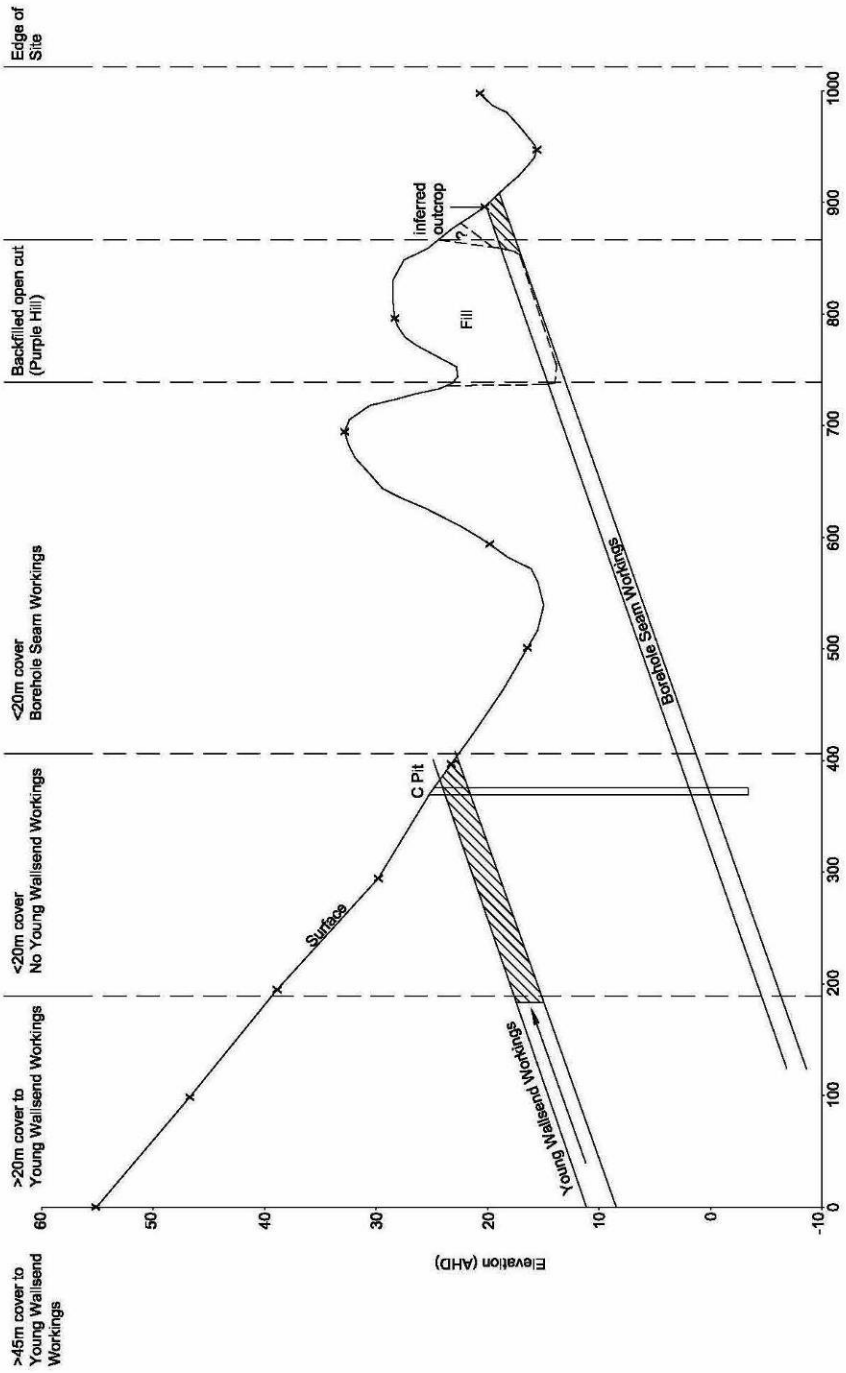


Figure 8 – Section BB of Mine Workings, refer to Drawing 1 for section location – Minmi West

4. RISK ASSESSMENT METHODOLOGY

Based on the results of the desktop assessment, including consultation with the Mine Subsidence Board, the following methodology was development for the risk assessment.

4.1 Pothole Risk

The risk of pothole subsidence was assessed as follows:

- Compile a catalogue of known potholes occurring on the proposed development site, including assessment of the corresponding depth of cover and surface conditions. Accurately survey surface features and map relative to workings;
- Investigate suspicious looking surface features which may be remnant potholes, by test pit excavation;
- Confirm the northern edge of the Young Wallsend workings as mapped on the RT, by drilling and down hole camera and ultrasound assessment. The bores were targeted to intersect the end of roadways and were core drilled in rock and also provided confirmation of the depth of cover and nature of overburden;
- In the area of the Young Wallsend seam with less than about 20 m depth of cover and no mapped workings, undertake line drilling to confirm the absence of extensive workings. The desktop study indicated that this area comprised a strip, about 150 m to 100 m wide running in an approximate east west direction from Minmi West across Minmi South, a distance of about 1200 m. Review of record traces indicated that the narrowest recorded workings (bords) were in the order of 3 m wide, and therefore a 3 m bore spacing was adopted. Each bore was to be drilled to the base of the seam. If unexpected workings were encountered they were to be mapped by additional drilling and camera/ultrasound assessment;
- Confirm the depth of cover to the Borehole Seam approximately along the 20 m cover line, and assessment of the overburden by core drilling in rock;
- Collate information to provide mapping of high risk of pothole subsidence.

4.2 Pillar Stability and Associated Potential Subsidence

In order to assess the risk of subsidence in areas with deeper cover, a pillar stability assessment was undertaken in association with estimation of worst case subsidence estimates. The work was undertaken in conjunction with Ditton Geotechnical Services Pty Ltd and comprised the following:

- Use record traces to divide the panels of pillars into the following categories:
  - Low extraction;
  - Moderate extraction;
  - High extraction.
- Develop depth of cover contours from the results of drilling, record traces and surface topography (Douglas Partners);
- Pillar stability analyses using methods developed by UNSW (Ditton);
- Prediction of worst case subsidence using LAModel software (Ditton);
- Use of the results of the subsidence predictions to zone the site according to suitable styles of development, based on consultation with the MSB.

4.3 Shaft and Entries

The location of shafts and status of abandonment were assessed by means of the following:

- Review record traces;
- Review C&A records;
- Discussions with Department of Primary Industries – Minerals;
- On site visual location of shafts;
- Accurate survey and mapping as constraints.

5. POTHOLE OBSERVATIONS

Based on the results of discussions with people familiar with the sites as well as general site walk over activities, evidence of previous potholes within the proposed development areas was collected. A register of possible potholes is presented in Table 2 below. The potholes have been plotted on Drawing 2 and numbered P1 to P7. For the reported potholes which were in locations with no mapped workings, subsurface investigation was undertaken to assess their veracity as summarised in Table 2.

Table 2 – Summary of Pothole Observations.

Number	Description	Comments
P1	Located in gully in Minmi West. Area had been clearly filled for a diameter of about 20 m. Small pothole about 2 m diameter was observed to be reforming near centre	Mapping indicates that the pothole is located over an intersection of the Wallsend Borehole Colliery workings in the Young Wallsend Seam at about 16 m depth
P2	Formed in creek bed shortly after June 2007 floods. Water from creek flowed into workings. Was repaired with concrete plug	Borehole Seam workings at shallow depth < 10 m present
P3	Probable pothole in gully, filled with waste material	Underlain by Pit A, B, C workings at about 10 m depth
P4	Possible pothole located on side of road in area of channelled runoff	Underlain by Brown Colliery Borehole Seam workings at about 18 m depth
P5	Reported pothole by Lenny Grant. No evidence of pothole at surface	Underlain by Young Wallsend Seam at about 10 m depth. No workings are mapped. Extensive line drilling at 1 m centres around reported pothole locations indicated no voids. Unlikely to be workings present apart from possible very localised tunnel
P6 and P7	Reported pothole by Lenny Grant. Evidence of slumping at the surface	Excavation of the potholes indicated the brick lined cisterns containing water to near the surface, brick and other waste material
P8	Extensive potholing on hillside in Minmi East, near Fletcher	Based on desktop assessment of cover depths the potholing is occurring in areas with less than about 10 m cover to the Cooperative Colliery Workings

Individual potholes P8 are not shown on Drawing 3; they are numerous and extensive throughout area PR4 in Minmi East (Drawing 3).

It is noted that for the confirmed potholes P1 – P4, each was located in a creek, gully or area of high water flows and each was underlain by mapped mine workings at less than 20 m depth of cover. P1 – P8 are shown in the following photographs.

Pothole P1

Pothole P2

Pothole P3

Pothole P4

Reported Location of Pothole P5 - No Void Found

Brick Cistern at Reported Location of Pothole P7

Brick Cistern at Reported Location of Pothole P6

Extensive Potholing in Far Eastern Area P8

6. SHAFTS AND ENTRIES

Shafts and entries on the site were identified by a combination of review of record traces and Coal & Allied records as outlined in Section 4.3. Shaft locations are shown on Drawing 3 in Appendix D. A site walkover survey was undertaken to assess the existing condition of the entries.

A full list of shafts is presented in Table B1 in Appendix B. Many of the shafts associated with the former Browns Colliery were not found as they had probably been covered over by open cut mining operations, however only two of these are expected to be located on site and are in areas of high risk pothole subsidence. The shaft locations which are on the site and outside areas of high risk pothole subsidence are summarised in Table 3 below.

Table 3 – Locations of Shafts on Development Site (excluding high risk pothole zones)

Name	General Location	Easting	Northing	Visual Assessment 2008
C	South of Railway St in paddock	**370071**	**6360749**	Capped
Dam	NE of corner of Link Road and Woodford Street, near masonry dam.	370030	6359462	Capped
WS	West of Woodford Street, South of old school	369824	6360046	Capped
4	Gully near transmission line	**370554**	**6360069**	Not Found
6	Gully near transmission line	**370461**	**6360080**	Concrete capping observed
12	Link Road North	**371169.55**	**6358944.53**	Capped and Filled
14	Link Road North	**371651.34**	**6359088.97**	Capped
40	West side of Gully in Minmi West	**369871**	**6360646**	Capped

Bold Coordinates have been surveyed, non bold are subject to final survey.

Photographs of selected shafts are shown below.

Pit A

Pit B

Pit C

Approximate Location of Shaft B2

Approximate Location of Browns No 4 Tunnel Entry (B4)

Approximate Location of Tunnel Entry (B5)

Approximate Location of Shaft B5

Approximate Location of Shaft B6

Shaft B7

Approximate Location of Shaft B8

Approximate Location of B9

Concrete Capping on Shaft Near Dam

Possible Purple Hill Shaft

Water Shaft

Shaft No 2

Shaft No 3

Capped Shaft No 4

Capping on Shaft No 12

Capping on Shaft No 14

Shaft No 40

7. SUBSURFACE INVESTIGATIONS – SHALLOW WORKINGS

7.1 Methods

The following describes the methodology for subsurface investigations associated with assessing the shallow ground conditions, generally at 20 m or less depth of cover, associated with the assessment of pothole subsidence risk. Deeper drilling was also undertaken, for assessment of pillar stability, as described in Section 8.0.

7.1.1 Core Drilling

Core drilling was undertaken in the period 10 October 2007 to 26 October 2007 and comprised the following:

- Drilling of 11 bores (Bores 1 to 8, 10,11 and 15) to depths ranging from 17.3 m to 33.5 m;
- The bores were generally progressed by auger drilling with standard penetration testing (SPT) in soils and HQ3 coring in the underlying rock;
- On site logging by a geotechnical engineer, including core photography.

Bores 1 to 6 and 15 were located along the approximate 20 m cover line to the Borehole Seam workings. Bores 7, 8, 10 and 11 were located at the edge of the Wallsend Borehole Colliery workings with the aim of intersecting the workings at the end of roadways (bords). The bores were set out by Monteath and Powys surveyors and the locations are shown on Drawing 4 in Appendix D.

7.1.2 Percussion Line Drilling

A line of percussion bores was drilled, in the period 10 October 2007 to 17 January 2008, approximately along the centre of the strip between the 20 m cover depth to the Borehole Seam (approximately at the outcrop of the Young Wallsend Seam) and the edge of the mapped workings in the Wallsend Borehole Colliery. The bores were drilled at 3 m centres and the line was near continuous with the exception of a number of short sections due to the presence of:

- Roads;
- Power lines;
- Very steep slopes and gullies;
- Open cut mines.

The alignment of the bores is shown on Drawing 4 attached.

In a number of locations (Bores 7,8, 10 and 11) where the cored bores did not encounter the workings as planned, additional bores were drilled using percussion methods until the workings could be mapped (Drawings 10 to 13). Additional percussion bores were also drilled as follows:

- P290 to P290K – at location where Young Wallsend Seam workings were intersected by line drilling (Drawing 14);
- P227 to P255 in order to assess the presence of a possible pothole P5. In this instance bores were drilled at 1 m to 2 m centres around the perimeter of the suspect location. (Drawing 15);
- P479 to P484 in the vicinity of Pothole P4 to assess the possible presence of workings in the Young Wallsend Seam.

The percussion bores were drilled using a top hammer tracked drilling rig using a 90 mm button bit. The bores were continued to the depth of the base of the Young Wallsend Seam and were logged by experienced geotechnical engineers. The bores were backfilled on completion with fly ash grout.

Percussion Drilling in Minmi West

7.1.3 Down Hole Assessment of Bores

The Wallsend Borehole Colliery workings in the Young Wallsend seam were intersected near Bores 7, 8, 10, 11 and P290. Down hole camera and sonar methods were used to map the voids encountered to allow confirmation of the workings shown on the record trace.

The assessment comprised the following:

- Monitoring of gas prior to commencement;
- Two point calibration check on ultrasonic sensor;
- Assessment of the depth to the roof and floor using a down-hole video camera in axial mode;
- Viewing of the void using a tilt up down-hole video camera. The orientation of the camera was obtained by viewing of a magnetic card compass with the camera in vertical orientation prior to tilting up. The camera was rotated at approximately 22.5^{o} increments (e.g., N, NNE, NE, ENE etc) prior to tilting up for viewing. The video was recorded to DVD,
- Measurement of the distance from the centre of the bore to the walls/obstructions within the bord using a SICK UM30 ultrasonic sensor, with a range of 1.0 m to 6.3 m. The ultrasound measurements were taken at the same compass increments as the video camera assessment. The camera was used to interpret the sonar readings to distinguish between clear readings of the wall of the void and obstructions such as rubble.

Due to high methane concentrations, down-hole assessment was not undertaken at Bores 7 and 8.

7.2 Results

7.2.1 Core Drilling

Detailed test bore logs are attached and should be read in conjunction with the Notes Relating to This Report, which include explanations of the test and classification methods referred to on the logs.

The cored bores generally indicated a clay soil cover in the range 0.4 m to 3.5 m, with filling up to 5.7 m depth in Bore 6 underlain by inter-bedded siltstone, sandstone and laminite. The weathered rock was typically extremely low to low strength, but generally increased to medium or high strength between about 5 m and 10 m depth. Each bore was continued to the depth of the target coal seam and/or void and the depths and levels of the seams and voids are summarised in Table 4 below which also includes the results of percussion drilling undertaken to clarify the location of the edge of the workings.

Table 4 – Summary of Bores

Bore	Type of Bore	Easting	Northing	Surface Level (AHD)	Depth of soil (m)	Depth to top of YW Seam (m)	Depth to base of YW Seam (m)	Thickness of YW Seam (m)	Level top YW seam AHD	Depth to top of Borehole Seam (m)	Depth to base of Borehole Seam (m)	Thickness of Borehole Seam (m)	Level top Borehole Seam AHD	Depth to top of void (m)	Depth to base of void (m)	Thickness of void (m)
1	C	369920	6360590	22.544		7.84	10.65	2.81	14.704	28.7	31.15	2.45	-6.156	0	0	0
2	C	370020	6360740	21.975	2.4	0	0	0		21.6	23.98	2.38	0.375	0	0	0
3	C	**370252.2**	**6360816.3**	**22.526**	3.52	0	0	0		18.37	20.67	2.3	4.156	17.05	20.67	3.62
4	C	**370675.9**	**6360727.5**	**25.7**	2.9	0	0	0		20.77	23.06	2.29	4.927	0	0	0
5	C	**370752.9**	**6360439**	**20.669**	2.8	2.8	4.3	1.5	17.869	22.23	24.54	2.31	-1.561	0	0	0
6	C	370940	6360420	23.631	5.7					20.75	23.1	2.35	2.881	0	0	0
7	C	369988	6360526.5	34.128	2.65	19.42	21.71	2.29	14.708					0	0	0
7a	P	**369985.4**	**6360523.3**	**33.94**	1	19.9	21	1.1	14.04							0
7b	P				1									16.5	20.2	3.7
7c	P	**369991.5**	**6360523.7**	**34.954**	1									19.4	22.1	2.7
8	C	**370235.7**	**6360534**	**34.475**	3	16.27	19.13	2.86	18.205	0	0	0		0	0	0
8a	P	**370235.7**	**6360533.7**	**34.509**	1	17			17.509					17.1	19.2	2.1
8b	**P**				1.3	15.9	18.7	2.8	-15.9							0
9	Not Drilled											0				0
10	C	**370514.7**	**6360402.3**	**29.8472**	2.95	13.1	15.95	2.85	16.7472	0	0	0				0
10a	P	370514.7	6360400.3		0.4	13.3	16	2.7	-13.3							0
10b	P	370511.7	6360401.3		0.4	13.5	16.4	2.9	-13.5							0
10c	P	370512.2	6360398.3		0.4	13.7	16.3	2.6								0
10d	P	370514.7	6360398.3		0.4	13.3	16	2.7								0
10e	P	370510.7	6360398.3		0.5	13.6	16.1	2.5								0
10f	P	370510.7	6360395.3		0.5	14.3	16.8	2.5								0
10g	P	370507.7	6360398.3		0.4	14.3	16.9	2.6								0
10h	P	370501.7	6360398.3		0.5	14.9	17.8	2.9								0

Table 4 – Summary of Bores (Continued)

Bore	Type of Bore	Easting	Northing	Surface Level (AHD)	Depth of soil (m)	Depth to top of YW Seam (m)	Depth to base of YW Seam (m)	Thickness of YW Seam (m)	Level top YW seam AHD	Depth to top of Borehole Seam (m)	Depth to base of Borehole Seam (m)	Thickness of Borehole Seam (m)	Level top Borehole Seam AHD	Depth to top of void (m)	Depth to base of void (m)	Thickness of void (m)
10i	P	370501.7	6360396.3		0.5	15	17.6	2.6								0
10j	P	**370502.8**	**6360395.9**	**31.3341**				0						14.8	17.3	2.5
10k	P	**370505.8**	**6360397.1**	**30.9611**				0						13.7	17.3	3.6
10l	P	**370508.5**	**6360398.3**	**30.7053**				0						14.2	16.8	2.6
11	C	**370628.3**	**6360071.5**	**24.1274**	3.15		21.6					0		19.15	21.3	2.15
11a	P	**370626.3**	**6360074.7**	**23.9047**	0.5	18.3		-18.3	5.6047					18.5	>21	>2.5
11b	P	**370624.6**	**6360078.2**	**23.553**	0.6	17.3	21	3.7	6.253					18.5	18.9	0.4
11c	P	**370623.5**	**6360080.3**	**23.3702**	0.6	16.8	20.5	3.7	6.5702							0
12	P	370805	6360200	23.67	Not Drilled											
12a	P	370804.5	6360203		1	8.7	11.6	2.9								0
12b	P	370804	6360206		0.3	8.8	11.2	2.4								0
12c	P	370803.5	6360209		0.2	8.5	11.4	2.9								0
12d	P	370802.5	6360214.8											10.1	12.1	2
12e	P				Not Drilled											0
12f	P	370802.8	6360213.8		0.5		12.3							10.3	11.8	1.5
12g	P	370803	6360212.8			9.2								9.4	11.8	2.4
15	C	**369867.5**	**6360744.2**	**24.8**		7.2	7.5		17.606					24.3	25.4	1.1
290	P	**370550.6**	**6360348.4**	**27.3**	0.4	11.9	14.7	2.8	15.4095			0		11.9	14.7	2.8
290a	P	370554	6360350		0.3	11.7	14.4	2.7								
290b	P	370548	6360347		0.3	12.4	15.2	2.8								
290c	P	**370549**	**6360349**	**27.4**	0.5									11.8	14.8	
290d	P	370553	6360348		0.5	11.8	14.8	3								
290e	P	370553	6360349		0.5	11.8	14.7	2.9								

Table 4 – Summary of Bores (Continued)

Bore	Type of Bore	Easting	Northing	Surface Level (AHD)	Depth of soil (m)	Depth to top of YW Seam (m)	Depth to base of YW Seam (m)	Thickness of YW Seam (m)	Level top YW seam AHD	Depth to top of Borehole Seam (m)	Depth to base of Borehole Seam (m)	Thickness of Borehole Seam (m)	Level top Borehole Seam AHD	Depth to top of void (m)	Depth to base of void (m)	Thickness of void (m)
290f	P	370552.4	6360346.9		0.5	12.1	14.9	2.8								
290g	P	**370547.1**	**6360350.6**	**27.4721**	0.3									11.3	14.2	2.9
290h	P	**370547.9**	**6360354.2**	**27.2639**	0.3	11.8			15.4639					12.2	14.5	2.3
290i	P	370552.1	6360350.4		0.3	11.7	14.4	2.7								0
290j	P	370550.6	6360350.9		0.3	11.7	14.4	2.7								0
290k	P	**370546**	**6360347.9**	**27.7295**	0.3									12.2	15.3	3.1
290l	P	370550.1	6360344.4		1	12.8	15.1	2.3								
290 m	P				0.4	11.1	13.6	2.5								

C = Cored
YW = Young Wallsend Seam
P – Percussion

7.2.2 Percussion Drilling and Down Hole Assessment

The results of percussion drilling are presented in Table A1 in Appendix A. No voids were encountered in areas where no workings had been mapped.

Voids were encountered in the Wallsend Borehole Colliery workings in the Young Wallsend seam near Bores 7, 8, 10, 11 and P290. The interpreted geometry of the workings is presented on Drawings 10 to 14, which show that the actual location of the workings was generally within 10 m or less of the mapped location on the record traces. Dead ends were established in each roadway assessed, indicating that the roadways do not continue more than 10 m past the ends shown on the record trace.

7.2.3 Depth of Cover

The depth of cover to both seams has been contoured using the following procedure:

- Calculate level at top of each seam from the following:
  - Results of drilling from current investigation;
  - Survey information provided by Monteath & Powys regarding depth to coal at Pits A, B and C, a number of previous bores to the north of the site and outcrops;
  - Seam floor levels shown on the Wallsend Borehole Colliery RTs. The evaluation of the Young Wallsend seam was calculated from seam thicknesses in nearby percussion bores. The depth to the top of the Borehole Seam was calculated from the typical inter-burden thickness of 20 m as indicated by several bores which intersected both seams.
- The surface level of each seam was contoured using SURFER;
- The depth of cover contours were calculated using 2 m surface contours provided by Coal & Allied.

The 20 m depth of cover to both the Borehole Seam and the Young Wallsend Seam are presented on Drawings 2 and 4.

8. SUBSURFACE INVESTIGATIONS – DEEPER WORKINGS

8.1 Methods

The following describes the methodology for subsurface investigations associated with assessing the deeper ground conditions, generally at greater than 30 m depth of cover, associated with the assessment of pillar stability. Shallower drilling was also undertaken, for assessment of pothole risk, as described in Section 7.0.

8.1.1 Core Drilling

Core drilling for the deeper bores was undertaken in two stages. The first stage comprised Bores 201 and 202. These were located in a part of the site where the pillar stability factors of safety for the Borehole Seam were very low. The purpose of the bores was to assess whether the pillars had already collapsed. The bores were drilled through large pillars or barriers in the overlying Young Wallsend Seam.

The second stage comprised Bores 301, 303 and 305. These bores were drilled to the North of Bores 201 and 202 in a location where the Borehole Seam was expected to be stable. The purpose of the bores was to confirm the thickness of the Borehole Seam and to measure the geometry of any bords intersected. The bores were also drilled through an area of secondary extraction in the overlying Young Wallsend Seam and were used to assess the potential for remnant subsidence in these workings.

The bores were drilled in the period 14 April 2008 to 27 May 2008 and comprised the following:

- Drilling to the base of the Borehole Seam, with depths ranging from 63.05 to 80.95 m;
- Auger/rotary drilling in the soil/overburden followed by HQ3 coring. Bores 201, 202 and 305 were fully cored from the start of rock, however Bores 301, 305 were progressed through the Young Wallsend Seam (to 40.05 m and 51.1 m respectively) prior to coring;
- On site logging by a geotechnical engineer, including core photography;

- Downhole geophysical logging was carried out at the completion of each bore. Due to the unstable nature of the bore and potential for collapse, the logging was undertaken inside the drill rods. Logging comprised the following:
  - Short spaced and long spaced density;
  - Natural gamma;
  - Borehole deviation.
- Down hole CCTV Camera assessment;
- Down hole Sonar Assessment.

8.2 Results

8.2.1 Core Drilling

Detailed test bore logs are attached and should be read in conjunction with the Notes Relating to This Report, which include explanations of the test and classification methods referred to on the logs.

The bore locations were surveyed by Monteath and Powys and the coordinates are presented in Table 5 below.

Table 5 – Summary of Deep Bores Locations

Bore	Type of Bore	Easting (MGA)	Northing (MGA)	Surface Level (AHD)
201	C	370910.7	6359633.8	48.4
202	C	370929	6359577	51.6
301	P/C	371048.8	6360061.2	48.3
303	C	370982.9	6359993.1	47.8
305	P/C	371015.0	6359998.0	48.0

C = Cored
YW = Young Wallsend Seam
P – Percussion

The strata encountered in the bores is summarised in Table 6 below and a discussion of the pertinent details is provided below.

Bores 201 and 202

- 0.55 m to 0.75 m of clay soil over weathered rock, typically siltstone and sandstone, increasing in strength with depth;
- Coal Seam, 3.71 m to 3.95 m thick, encountered between 13 m and 26 m depth. Includes numerous thin clay seams;
- Inter-burden comprising high strength laminite;
- Coal Seam, 1.1 m to 1.35 m thick, encountered between 31 m and 38 m depth;
- Inter-burden comprising medium to high strength laminite;
- Young Wallsend Seam, 2.92 m to 3.0 m thick, encountered between 51 m and 59 m depth;
- Interburden comprising high strength laminite;
- Void, ranging in thickness from 1.5 m to 2.05 m, encountered between 71 m and 79 m. Apparently full of soft soil, probably tailings;
- Water table at or near the top of the void;
- 0.67 m of rubble was encountered at the base of the void in Bore 201 and minimal rubble was encountered in Bore 202;
- Intact coal at the base of the rubble/void ranging in thickness from 0.27 m to 0.33 m;
- The height from the base of the seam to the top of the void ranged from 2.38 m to 2.44 m. The height of the void plus rubble ranged from 2.05 m 2.17 m. No coal was encountered above the void;
- Very high strength Waratah Sandstone at the base of the remnant coal seam.

Bores 301, 303 and 305

- 0.5 m to 1.4 m of clay soil over weathered rock, typically siltstone and sandstone, increasing in strength with depth;
- Coal Seam, 1.0 m to 1.26 m thick, encountered between 19 m and 24 m depth;
- Inter-burden comprising medium to high strength laminite;

- Young Wallsend Seam. Remnant intact coal was encountered in Bores 301 and 303 with thicknesses in the range 1.09 m to 2.2 m. The coal was overlain by rubble ranging from 0.5 m to 1.1 m. A thin layer of coal was encountered at the top of the void in Bore 303, suggesting a distance from the top to the base of the remnant seam in the order of 2.22. Bore 305 did not encountered intact coal, it encountered 2.25 m of rubble overlain by a 0.75 m void. The total thickness of coal, rubble and void ranged from 2.22 m to 3.0 m;
- Inter-burden comprising high strength laminite;
- Borehole Seam. Bore 305 encountered intact coal with a seam thickness of 2.33 m. Bores 301 and 303 encountered the following:
  - Void, 0.73 m to 0.8 m thick;
  - Rubble 3.71 m to 3.0 m thick;
  - Remnant seam in floor 0.25 m thick;
  - Total thickness of coal, rubble and void of 3.76 m to 3.98 m suggesting collapse of the roof above the original level of the seam.
- Very high strength Waratah Sandstone at the base of the remnant coal seam.

Table 6 – Summary of Deep Bore Profiles

Bore	Depth / Thickness of Strata (m)					
	Bore	**201**	**202**	**301**	**303**	**305**
Depth of Soil		0.55	0.75	1.0	1.4	0.5
Over-burden	Strength	LS	L-MS	ELS	NE	NE
Coal Seam	Top	13.6	17.81	NE	1.4	0.5
	Base	17.55	21.52	NE	3.5	2.5
	Thickness	3.95	3.71	NE	2.1	2.0
Inter-burden	Description	HS Laminite	HS Laminite	NE	M-HS	
Coal Seam	Top	31.7	36.42	19.6	22.32	22.7
	Base	32.8	37.77	20.6	23.58	23.65
	Thickness	1.1	1.35	1.0	1.26	1.65
Inter-burden	Description	HS Laminite	HS Laminite	HS SandS	M-HS	
YW Seam	Top Void	NE	NE	NE	39.97	38
	Base Void	NE	NE	NE	40.0	38.75
	Thickness Void	NE	NE	NE	0.03 (coal)	0.75
	Top Rubble	NE	NE	37.2	40	38.75
	Base Rubble	NE	NE	37.7	41.1	41
	Thickness Rubble	NE	NE	0.5	1.1	2.25
	Top Seam	50.8	55.85	37.7	41.1	NE
	Base Seam	53.8	58.77	39.9	42.19	NE
	Thickness of Coal	3.0	2.92	2.2	1.09	NE
	Total Thickness	**3.0**	**2.92**	**2.7**	**2.22**	**3.0**
Inter-burden	Description	HS Laminite	HS Laminite	HS Laminite	HS SandS	HS Laminite Laminite
Borehole Seam	Top Void	71.38	76.3	56.0	57.52	
	Base Void	72.88	78.35	56.8	58.25	
	Thickness Void	1.5	2.05	0.8	0.73	
	Top Rubble	72.88	NE	56.8	58.25	
	Base Rubble	73.55	NE	59.51	61.25	
	Thickness Rubble	0.67	NE	2.71	3.0	
	Top Seam	73.55	78.35	59.51	61.25	59.3
	Base Seam	73.82	78.68	59.76	61.5	61.63
	Thickness of Coal	0.27	0.33	0.25	0.25	2.33
	Total Thickness Coal, Rubble and Void	**2.44**	**2.38**	**3.76**	**3.98**	**2.33**
Waratah Sandstone	Depth of Bore	77.9	80.95	63.05	65.85	66.15

Notes: ELS = Extremely Low Strength LS = Low Strength, MS = Medium Strength, HS = High Strength

8.2.2 Results of CCTV Camera Inspections

CCTV camera inspections were undertaken in Boreholes 201, 202, 301 and 303 to assess the condition and extent of the workings. The camera can be used in axial mode (vertically down-hole) which provides a view of the boreholes sides, as well as in tilt up mode which is used inside sufficiently large voids to view the floor, walls and roof of the void.

Each borehole was flushed with clean water to remove drill cuttings from within the bore and then dosed with aluminium sulphate shortly after completion of geophysical logging. Axial camera footage was obtained for Bores 201, 202, 301 and 303. Tilt up of the camera mode was attempted in Bores 202 and 301 with limited success.

Bore 201

- Water was flowing from the Young Wallsend Seam into the borehole;
- Water table at the top of the void in the Borehole Seam at 71.3 m;
- The void was too small to allow tilt up camera operation;
- The void has collapsed at 71.6 m, fragments of rubble partly visible.

Bore 202

- Water was flowing from the Young Wallsend Seam into the borehole;
- Water table at the top of the void in the Borehole Seam;
- Tilt up camera work was attempted, however no vision was possible as the void appeared to contain coal fines, which were smeared over the camera upon retrieval;
- Axial mode assessment after minor roof collapse had occurred indicated small fragments of probable roof material on a dark background (probable tailings).

Bore 301

- Partial drilling blow-out directly above Young Wallsend Seam in sandstone;
- Walls of bore through Young Wallsend Seam are highly irregular showing fragmentation of the coal;
- Open void below 56 m which seems to be a large parting in the roof. The tilt up camera indicated that the parting extended laterally in all directions probably at least 1 m (approximate limit of visibility). The top and base of the of the void were sub-horizontal with minor undulations;
- The bore below the initial void, described above, had opened up a hole about 0.3 m diameter with large fragments near the top and smaller fragments with depth. The bore seemed to close with depth.

Bore 303

- Irregular enlarged bore through the upper half of the Young Wallsend Seam showing fragmented coal in sides of bore;
- Uniform bore suggesting intact coal for the low portion of the Young Wallsend Seam;
- Increasing water flow into the borehole below the Young Wallsend Seam resulting in reduced visibility and therefore the camera footage was stopped before reaching the Borehole Seam.

8.2.3 Results of Sonar Assessment

Sonar assessment was undertaken within Bore 201 and although the sonar was able to be lowered into the 'void', the sonar readings indicated the absence of a void. When the sonar was retrieved from the bore it was smeared with coal fines, suggesting that the 'void' is full of a low strength coal fines, possibly tailings.

Inspection of Bore 202 was attempted, however roof collapse closed the 'void' and the testing was aborted. Sonar was not undertaken in Bores 301, 303 and 305 as the workings were dry.

8.2.4 Borehole Gas Monitoring

Borehole gas monitoring was undertaken during the drilling and down hole camera/sonar inspections as well as a final round of gas testing. The testing during drilling was undertaken for health and safety purposes, using a personal gas meter and generally indicated the absence of explosive gases, with the exception of Bores 7 and 8 which indicated up to 15% of LEL (lower explosive limit) of methane equivalent to less than 1% total methane.

Monitoring of bores that encountered voids was undertaken on 30 October 2008. The bores had been cased and capped to allow collection of methane, if present. The monitoring was undertaken using a portable landfill gas analyser and the measurement in several bores were checked using a personal gas meter. Bores that had intersected voids in the Young Wallsend Seam were generally found to have positive pressure and flow when uncapped, however no flow was noted in the bores to the Borehole Seam. The gas measurements were taken from below the capping at the top of the casing. The results are presented in Table 4a below.

Table 4a – Results of Borehole Gas Monitoring.

Bore	CH_4 (%)	0_2 (%)	CO_2 (%)	CO (%)	H_2S (%)	Comments
7b	0	10.9	7.1	0	0	Flowing
7c	0	16.6	3.1	0	0	Flowing
8a	0	16.3	3.7	0	0	Flowing
8a	0	16.3	-	0	0	Check test
10l	0	12.9	5.6	0	0	Flowing
10j	0	12.8	5.6	0	0	Flowing
11	0	13.5	3.2	0	0	Flowing
12	0	2.0	11.5	0	1	Flowing
12	0	3.5	-	0	3	Check test
290H	0	12.7	5.3	0	0	Flowing
290G	0	13.3	12.7	0	0	Flowing
290K	0	13.2	4.9	0	0	Flowing
201	0	20.6	0	0	0	Stagnant
202	0	20.7	0	0	0	Stagnant
301	0	20.5	0	0	0	Stagnant
303	0	20.5	0	0	0	Stagnant
305	0	20.4	0	0	0	Stagnant

9. COMMENTS

9.1 Risk of Pothole Subsidence

9.1.1 History of Potholes

Extensive site walkover surveys in conjunction with discussions with people familiar with the history of the site have been undertaken and a number of potential potholes were identified. Subsurface investigation was undertaken for possible potholes identified in areas which did not match with the location of mapped workings and the results indicated that most of these were actually backfilled underground cisterns used extensively in the past for storage of water. Extensive line drilling was undertaken around a reported pothole (P5) beside Neal Close, for which there was no surface evidence, and no voids were encountered (Drawing 15).

A number of genuine potholes were identified on the main parts of the site (Potholes P1 to P4). Each of these was located over known mapped workings with a depth of cover of less than 20 m. Each of these was also located in a water course or drainage path.

Extensive pothole subsidence was also observed at shallow workings of the Cooperative Colliery on a parcel of land on the far eastern part of the site near Fletcher, Area PR 4 in Minmi East. The depth of cover where potholes are occurring is probably less than about 10 m depth, although this has not been confirmed by drilling.

9.1.2 Limit of Workings of Wallsend Borehole Colliery Workings

The edge of the Wallsend Borehole Colliery workings was intersected at six locations (at or near Bores 7, 8, 10, 11, 12 and P290). A combination of percussion drilling and down hole camera and ultrasound measurements was used to map the workings and confirm the end of the workings (Drawings 10 to 14, in Appendix D). In each case the northern extent of the workings was confirmed to be within 10 m of the location from the record trace.

This is consistent with information from Mr Kevin Price, former mine surveyor for Gretley Colliery who indicated that the accuracy of these record traces would be expected within about 3 m to 5 m.

Therefore it is considered that there is a low risk of these mine workings extending more than 10 m past the limit of workings shown on the RT.

9.1.3 Possible unmapped workings in Young Wallsend Seam

An extensive drilling program has been undertaken, comprising a near continuous line of bores at 3 m centres for a distance of about 1.2 km, running along the strip of land between the edge of the mapped Wallsend Borehole Colliery workings and the expected outcrop of the seam. The bores were drilled to the base of the coal seam and were logged by a geotechnical engineer. Several voids were encountered, however these were at locations of mapped workings. No voids were encountered in locations with no mapped workings.

Therefore it is considered that there is an absence of extensive unmapped workings in the Young Wallsend Seam. There may be a small risk that some localised workings, such as narrow exploratory tunnels may be present, however the risk of pothole subsidence associated with such possible workings is considered very low and can be accounted for by appropriate design.

9.1.4 Boreholes

The boreholes generally indicated relatively thin soil, typically less than 1 m, underlain by weathered rock, with more than 10 m of cover of medium or high strength rock over the coal seams or voids.

The thickness of the Borehole Seam was typically in the order of 2.3 m to 2.4 m, decreasing in thickness to the south and towards the west. Voids were encountered in two of the bores, 3.6 m high in Bore 3 and 1.1 m in Bore 15. In Bore 3, 0.2 m of coal was left in the floor and about 1.3 m of roof ravelling has occurred above the top of the seam. The depth of cover to the original seam was about 18.7 m. In Bore 15, there was no coal in the floor or the roof, suggesting a seam thickness of less than 1.1 m. It is considered this was probably an exploratory tunnel as suggested from the record trace.

The thickness of the Young Wallsend Seam was typically in the range 2.6 m to 2.9 m, with voids, where encountered, ranging in thickness from about 2.1 m to 3.1 m. The down-hole camera assessment indicated rubble on the floor of the workings at most locations suggesting the coal tops and possibly some minor roof breakage had occurred, however no extensive unravelling of the roof was encountered at any location, probably due to the presence of medium to high strength rock.

9.1.5 Overall Pothole Risk

An established rule of thumb for pothole subsidence is that potholes can typically progress above the roof of the workings through weathered rock a distance of up to five times the working section (original height of void). Based on a typical working section indicated from record traces of 1.65 m in the Borehole Seam and 2.3 m to 2.4 m in the Young Wallsend Seam, this would suggest a critical depth of cover of 8 to 12 m deep.

A number of potholes have been observed at the site at depths typically in the order of 10 m to 16 m depth of cover, and these were located in creeks, gullies and drainage lines.

It is considered that there is a high risk of potholes occurring in areas with less than 20 m depth of cover, particularly in creeks and gullies. For the areas of the Young Wallsend Seam with no mapped workings and a depth of cover of less than 20 m to the coal seam, it is considered that there is a low risk of pothole subsidence due to the demonstrated absence of unmapped workings and greater than 20 m cover to the underlying Borehole Seam. Areas of the site with more than 20 m cover to either seam are considered to have a low risk of pothole subsidence, however such potholes can form at depths of up to 30 m, although this is very uncommon and there is no history of such events on this site.

Based on this risk assessment the site has been zoned according to pothole risk as follows:

High Pothole Risk – these areas, designated PR1 – PR8 are mapped on Drawing 2 in red and include the following:

- PR1 – extensive generally between Railway St and the former Purple Hill Open cut, however also including a gully to the south, where there is less than 20 m cover to the Borehole Seam;
- PR2 – this is an area to the west of the former Back Creek open cut mine, generally extending west to a gravel track;
- PR3 – This is an area of ground at the south in Minmi East which was not subject to open cut mining and is underlain by mine workings at less than 20 m cover;
- PR4 – This area at the east of Minmi East, near Fletcher, where the site walkover has indicated extensive pothole subsidence;
- PR5 – This is a localised pocket where several roadways of the Wallsend Borehole Colliery workings extend past the 20 m depth of cover line;
- PR6 - This is similar to PR5, however the location is in a gully and a pothole has formed and been backfilled in the past;
- PR7 – This is a narrow strip where the depth to the Wallsend Borehole Colliery workings is generally less than 20 m depth along the line of a gully / creek bed. The area has been extended to the east in an area with extensive second workings with less than 25 m to 30 m cover. The area was extended in this direction as the workings are considered likely to be still standing in places, possibly leaving wide open galleries where the risk of pothole subsidence is increased;

- PR8 – This is near the entry point to the Wallsend Borehole Colliery workings where the depth of cover is less than 20 m. Much of these workings may have been filled as part of backfilling works for the mine closure. From the results of Bore 12, however the stability and extent of this backfilling is questionable as evidenced by the reported wash outs and repeated filling operations described in Section 3.

Low Pothole Risk these areas are mapped as orange on Drawing 2 and are summarised as follows:

- Extensive strip between mapped workings in Wallsend Borehole Colliery and 20 m cover depth to the Borehole Seam. This area extends from the western boundary of Minmi West to the Eastern boundary of Minmi South. This is the area subject to extensive line drilling;
- There are also strips of ground between the Purple Hill Open Cut Mine and the Browns Open Cut Mine and the mapped outcrop of the coal seam where the depth of cover is very low and only highly weathered coal is expected, otherwise the open cut operations would have continued to the very outcrop. It is considered there is a low risk of underground mine workings being present in these areas.

9.1.6 Likely Development Restrictions

Appropriate development restrictions are subject to confirmation by the Mine Subsidence Board, however based on discussions to date the following restrictions to development are expected in pothole risk zones:

High Risk Pothole Zones (PR1 to PR 8)

- For residential development, full grouting of workings would be required;
- It may be possible to extend allotments to depths of cover of at least 15 m, provided no construction is undertaken in these areas, however access to these areas would require further assessment as discussed below;

- Roads in such areas may require grouting. Alternatively the consequences of a pothole forming in such an area could be mitigated by using geogrid (plastic mesh) reinforcement of the pavement to span a pothole. In this case the road, drainage and pothole would still need to be repaired, however the risk of harm to pedestrians and vehicle occupants would be significantly reduced;
- Buried services should ideally be located along existing roads or new roads treated by grouting, otherwise they will need to be designed to span across potholes;
- Access to high risk pothole areas will need to be managed appropriately to reduce the risk to public safety. This may include fencing and/or signage in particular for high risk areas such as the creek and drainage lines or where the depth of cover is less than 15 m. The 15 m depth of cover line is shown on Drawing 1. Pedestrian access to riparian zones could still be maintained by constructing suitably designed boardwalks with appropriate fencing and footings designed to span a potential pothole. A plan of management should be developed and should be based on a detailed risk assessment for specific areas undertaken prior to development.

Low Risk Pothole Zones

- Discussions with the MSB indicate that in low risk pothole zones, construction should be limited to single storey houses with pier and beam footings and suspended floors to allow for filling of potholes if they occur beneath the structure.

9.2 Grouting of Workings

Typical Procedure

Grouting of high risk pothole areas of workings would typically comprise the following:

- Confirmation of the extent of the workings. In some areas there are limited workings mapped, however the MSB indicated they expect the workings to be potentially more extensive than mapped in these areas;

- Drilling and placement of low slump grout to block off roadways near the edge of the target area, most likely near the 20 m cover contour;
- Mass infilling the closed off area using high slump grout;
- Grout mixes would depend on the availability of suitable materials, however, may include blends of fly ash, bottom ash, slag, lime or cement;
- In areas where partial collapse of workings has already occurred, special attention would be required to ensure that the voids are filled. This may require additional drilling of bores to fill localised voids and careful attention to verification of the grouting;
- Verification of the grouting would be achieved by a combination of review of grouting records, such as grout takes, as well as by verification drilling.

Estimated Volumes

The estimated volume of workings in high risk pothole areas, potentially requiring infill grouting has been estimated for various parts of the site. In the case of the Wallsend Borehole Colliery workings where the record traces were considered reliable the volumes were estimated from the record traces and a typical void height of 3 m.

For the Borehole Seam workings the RTs are considered less reliable and the estimates were based on an overall area of the zone, the approximate upper bound extraction ratio of about 70% and an upper bound void height of about 2.5 m.

The level of certainty in the volume calculations will therefore vary based on the strength of the input data. In areas with limited data, additional investigation is recommended to refine the volume calculations.

Table 5 below provides estimated volumes of the workings, together with a summary of the strength of the data supporting the estimation.

Table 5 - Estimated Volume of Workings

Zone	Estimated Volume of Workings in High Risk Pothole Area (m3)	Basis of Estimate
PR1	300,000	Area of zone is about 16 ha. Extraction ratio of 70%. Void Height of 2.5 m.
PR2	100,000	Area of zone is about 5.7 ha. Extraction ratio of 70%. Void Height of 2.5 m.
PR3	18,000	Area of zone is 1 ha. Extraction ratio of 70%. Void Height of 2.5 m.
PR4	210,000	Area of zone is 12 ha Extraction ratio of 70%. Void Height of 2.5 m.
PR5	1,500-2,000	Estimate from record trace with 3 m high and 5 m wide voids.
PR6	2,500-3,000	Estimate from record trace with 3 m high and 5 m wide voids.
PR7	15,000-20,000	This only accounts for area of bord and pillars with less than 20 m cover. The area of pillar extraction would only be feasible to develop over if the workings have collapsed.
PR8	10,000	Estimate from record trace with 3 m high and 5 m wide voids.

9.3 General Subsidence Risk

Detailed pillar stability assessment and subsidence estimates have been undertaken by Ditton Geotechnical Services Pty Ltd (DGS), the results of which are presented in detail in the report in Appendix C.

9.3.1 Pillar Stability

The pillar stability assessment was undertaken in accordance with UNSW methodology as outlined in the DGS report. Much of the site is underlain by bord and pillar workings from Browns Colliery / Duckenfield No 1 (RT 457) with minimal pillar extraction below the site. Most of the Gretley Colliery workings and much of the Wallsend Borehole Colliery workings in the Young Wallsend Seam were subject to pillar extraction, with some remnant pillars present in the northern areas of the site.

The majority of information from historical records and record traces indicated that the working section in the Browns Colliery workings was 1.65 m, with a typical seam thickness of 1.9 m and 0.25 m of coal left in the floor. The full seam thickness, however, has been used in stability modelling. Historical information suggests a typical seam thickness of 1.9 m for the Browns Colliery workings but from the results of drilling, the seam thickness is typically about 2.35 m and at least 0.25 m has been left in the floor. Therefore a working section of 2.1 m was used for the assessment on the basis that the coal tops have collapsed, but the floor is intact.

Pillar dimensions were measured from the scaled and geo-referenced record traces and the site was divided into similar panels for the assessment.

The results of the general pillar stability assessment undertaken by DGS indicated the following:

- For depths of cover in the Borehole Seam ranging from less than 45 m on the eastern parts of the site to less than about 60 m on the central and western parts of the site, the pillar factor of safety was greater than 2.1 for full tributary loading or 1.6 for single abutment loading, indicating a low risk of pillar instability;
- In some instances in the Borehole Seam the factor of safety was less than 1.4 (with individual pillar stability as low as 0.7) for panels with narrow pillars and/or high depths of cover. Bores 201 and 202 were drilled in such an area, however the results of the drilling indicated that pillar crush had **not** occurred. This suggests one or more of the following:
  - The stability of the workings in these areas is very marginal;
  - The high strength roof, with only minor roof collapse noted, is allowing substantial load spreading between the pillars;
  - The pillar dimensions shown on the record trace are not accurate and the pillars are actually larger;
  - The pillar integrity is generally higher than for the pillars used in the data base which the empirical pillar stability assessment is based on.

An area of the Young Wallsend Seam second workings, generally at less than about 40 m cover and where large stooks / remnant pillars were left (with an overall extraction ratio of about 70%) was identified as having been subject to only partial crush. This is evidenced by the results of Bores 301, 303 and 305, as well as the absence of any surface cracking in this area. It is considered likely that remnant pillars /stooks have yielded to their residual strength and further subsidence would be unlikely.

9.3.2 Predicted Maximum Subsidence

As outlined in Section 4, each seam was zoned into areas of high extraction, medium extraction and low extraction for purpose of the subsidence assessment. In areas of low and medium extraction the pillar stability was taken into account and for factors of safety of less than 2.1 under full tributary loading, it was assumed that the pillars could potentially crush out. In areas of high extraction it was assumed that the workings had already goafed (i.e. collapsed).

Details of the actual modelling are presented in the DGS report in Appendix C. Predicted subsidence parameters, assuming areas of the Borehole Seam workings with a factor of safety of 2.1 or more under full tributary loading are long term stable, are presented on the following figures in the DGS report:

- Total Subsidence – Figure 12a;
- Final Tilts – Figure 12b;
- Final Strains – Figure 12c;
- Final Curvatures – Figure 12d.

In summary there was a range of results across the site as follows:

Areas With Stable Pillars, No Workings or Pillar Extraction

Predicted subsidence in these areas is less than 0.4 m with tilts of less than 4 mm/m and strains less than 2 mm/m and curvatures greater than 10 km. These areas are likely to be suitable for two storey brick veneer development up to 30 m length. These areas are mapped as Light Blue on Drawing 1 in Appendix D.

For depths of cover between 20 m and 25 m cover, where there are mapped workings the MSB have suggested that pier and beam footings will be required as there is some risk of pothole subsidence. Therefore in these areas, marked as solid blue on Drawing 1, pier and beam footings will be required, with conventional slab footings possible on the remaining parts of the area.

Areas With Deep Cover However Potentially Unstable Pillars

Predicted subsidence in these area is generally in the order of 0.5 m to 1.0 m, however for depths of cover of more than about 80 m the tilts are less than 7 mm/m and ground strains are typically less than 2 mm/m and curvatures generally greater than 5 km, and often greater than 10 km. These areas are likely to be suitable for single storey brick veneer development, or similar. These areas are mapped as Light Green on Drawing 1.

Areas of Shallow Cover With Potentially Unstable Pillars

In areas where there was potential for pillar crush in the Borehole Seam (FOS<2.1) the predicted subsidence was typically in the range 0.5 m to 1.3 m. Based on the final subsidence profile, tilts, strains and curvatures were generally similar to the areas of deeper cover, described above, however tilts and strains increased at the edge of failed panels. Strains at the edge of panels were generally less than 3 mm/m. Tilts at the edge of the panels often ranged from 7 mm/m to 12 mm/m with up to about 14 mm/m in some cases on the northern fringes with less cover. The areas with possible tilts over 7 mm/m, strains over 4 mm/m and curvatures less than 5 km are shown as hatched on Figures 12b, 12c and 12d and hatched yellow on Drawing 1.

Such predicted settlements are greater than those recommended for brick veneer construction. The performance of single storey dwellings with clad construction such as weatherboard and slabs on ground can generally remain safe, serviceable and repairable for tilts exceeding 7 mm/m, however design of structures to accommodate tilts approaching 14 mm/m is challenging. In this instance re-levelling of the structures would be required in the case of a panel crush, possibly with more extensive repairs required. Such high residual tilts would only be expected to occur over a relatively narrow strip at the edges of a failed panel. Structures in these areas are expected to require specific engineering design.

Reference to Figures 15a, 15b, 16a, 16b of the DGS report, which show the potential final tilt profile for two cross sections across the site, indicate the following:

- The majority of tilts across the site are less than 7 mm/m with less than 5% of the site having residual predicted tilts of more than 7 mm/m;
- Tilts of more than 7 mm/m only occur for depths of cover of less than about 80 m and for band widths in the order of about 50 m to 100 m, generally for less than 10% of the width of the susceptible panels shown hatched on Figure 12c;
- The susceptible area includes numerous panels separated by barriers and therefore would be expected to behave independently, i.e. the risk of multiple panels crushing is less than for any individual panel.

Development in these areas should take into account the potential for significant subsidence with localised tilts exceeding 7 mm/m, and peaks of up to about 14 mm/m. The consequences of a pillar crush in these areas can be reduced and the following should be taken into account in the urban and structural design:

- Provide structures with a high tolerance to such subsidence. This would include but not necessarily be limited to the following:
  - Limit the height of the structures generally to one storey;
  - Reduce the footprint of the structure, preferably to 20 m or less and articulate where possible;
  - Flexible cladding types such as weatherboards. Brick veneer is not suitable;
  - The use of a stiff raft slab can allow the use of synthetic grout injection to re-level structures if the structure is affected by mine subsidence.

- Limit the density of development in these areas.

The Mine Subsidence Board is likely to provide a more favourable review of the development if the proposal takes account of the potential for the predicted subsidence such that the risk of repairs to structures and infrastructure is limited.

It is noted that the DGS report also includes predicted subsidence if all remnant Borehole Seam pillars on the site crush, ignoring calculated factors of safety. In this case the extent of the site subject to tilts greater than 7 m would increase as shown on Figure 10b in the DGS report. The potential extended area would generally cover parts of the site which have been assessed as low risk pothole (single storey pier and beam) or high risk pothole (no development without grouting) with some areas currently suggested for two storey brick veneer. If the MSB were to enforce a 'no risk' of mine subsidence requirement then development restrictions similar to those described above would also apply for these areas. Therefore it is recommended that contingency for this be included in planning options at this stage.

9.4 Services

It should be noted that buried services should be designed to accommodate the potential subsidence. This would include provision of adequate fall for stormwater and gravity sewerage and flexible joints. Services in the areas of pothole risk may need to be designed to span a five metre pothole.

Driveways and paving should include regular articulation to accommodate movement.

9.5 Shafts and Tunnels

Table B1 in Appendix B provides a summary of shafts with those in the areas with higher potential for development (outside high pothole risk, PR1 – PR8) shown in Table 3, including coordinates.

The MSB advise that they will not allow building development over shafts. An exception to this could be in the case of shallow mine workings where the workings and shafts have been fully grouted. Therefore the urban design should take into account the presence of these shafts, which could be incorporated into landscaping areas, pavements of car parks.

There are three former mine entries to the Wallsend Borehole workings buried at the northern end of a former open cut pit in Minmi South. One of the these entries is reported to have had a number of wash-outs in the past. The filling of these mine entries will need checking and improving, as necessary, in accordance with the appropriate guidelines of DPI – Minerals and MSB.

Current NSW DPI guidelines for the permanent filling and capping of service entries to coal mines (MDG-6001) indicates the following:

- Shafts are to be filled and capped. The cap is be designed to take a load of 7 kPa neglecting any soil support from filling of the shaft. The cap is normally reinforced concrete, designed to span across the shaft;
- Adits and drifts (tunnel entries) are to be filled to 20 m length with at least 15 m penetration into rock.

All of the shafts within the readily developable areas, as listed in Table 3, are capped, however it is uncertain if all of them have been filled and the strength of the capping is also uncertain. The capping and filling of the shafts will need to be checked and upgraded as necessary as part of development of the site, and in consultation with DPI-Minerals.

9.6 Open Cut Pits

The potential constraints associated with former open cut pits are as follows:

- Potential instability of cut faces;

- The mine spoil is likely to have been placed without compaction and therefore there is potential for large settlements. This could be managed by removal of the filling, re-compaction of the filling, piling of building footings to below the base of the filling, or a combination of the above;
- Piling is not recommended for former open cut pits in the Young Wallsend Seam as there is 20 m cover to the Borehole Seam from the base of the open cut workings, and although the risk of pothole subsidence is low for such a cover depth, repair of piled footings affected by pothole subsidence would be very difficult. These pits include two pits in Minmi South as well as the Pit at the eastern end of Minmi East;
- The filling in the base of the open cuts is likely to be saturated, probably requiring dewatering of the excavations for any reworking to be undertaken;
- Differential settlements occur in the backfill close to the alignment of the mine high wall; significant structures should not straddle the buried high wall;
- It is likely that the open cut pits broke into the underground workings in places and therefore there may also be a need to cap any such workings exposed by reworking the filling.

Additional comments regarding the open cut pits are provided in the Preliminary Geotechnical and Contamination report (Ref 3).

9.7 Additional Investigations

Some areas which have been mapped as low risk pothole, especially around the edge of open cut pits near the seam outcrop and it is expected that potential development restrictions could be lifted subject to additional investigation to provide the absence of workings.

The depth of cover to the workings in the far eastern part of Minmi East will require confirmation.

There may be some limited areas of the Borehole Seam workings which are currently mapped as high risk pothole zones, which have no workings mapped. The most likely areas for this are the gully on the southern end of Zone PR1 and some limited areas at the southern end of Zone PR2.

9.8 Future Resource Extraction

Future mining at the site is unlikely but possible. Future mining at the site, if it occurred, may affect the standard guidelines outlined above. Restrictions on development due to future mining are provided by the DARZL committee and a formal application to the MSB is required for consideration by DARZL.

Monitoring of borehole gas concentrations was undertaken to assess the potential for future extraction of coal seam methane. The results indicated low concentrations of methane in some of the bores immediately following drilling, however subsequent monitoring indicated no measurable concentrations suggesting any methane which was present was limited and quickly dissipated. Therefore the site is not expected to be suitable for methane extraction from the former mine workings.

10. SUMMARY

10.1.1 General

The site has been subject to extensive open cut and underground mining. Constraints mapping has been provided to assist in urban design of the proposed development, and details of investigation and analyses have been provided for consideration of the proposed development by the Mine Subsidence Board. The final development restrictions applied by the MSB may vary from these and formal application should be made to the MSB to confirm their requirements.

The constraints are summarised as follows:

- ***High Pothole Risk***: Grouting of workings would be required prior to development and the site should be managed to limit risk to the public. Mapped as red on Drawing 1. For Details see Sections 9.1 and 9.2;
- ***Low Pothole Risk:*** No extensive workings are expected, however localised tunnels may be present. Construction should be single storey with suspended floor. Mapped as orange on Drawing 1;

- ***Limited Subsidence:*** Expected subsidence is within normally acceptable limits for two storey brick veneer construction. Mapped as blue on Drawing 1;
- ***Moderate Subsidence:*** Expected subsidence is within normally acceptable limits for single storey brick veneer construction. Mapped as light green on Drawing 1;
- ***High Subsidence:*** Expected subsidence is generally higher than acceptable for brick veneer construction. Light weight (clad) construction with stiffened raft slabs and limited footprints would be more suited to these areas, however it may be necessary to limit density of development. Infrastructure would need to take into account potential subsidence. Mapped as yellow on Drawing 1;
- ***Shafts:*** There are a number of capped shafts in the readily developable areas (outside high risk pothole zones). Development directly over these shafts is inappropriate and they should be incorporated into landscaping;
- ***Roads and Services:*** Roads and paving and services should be designed to accommodate the potential subsidence including the spanning of potholes in areas of high risk potholing as well change in drainage grades design and flexure from the predicated subsidence of up to about 1 m on parts of the site.
- ***Open Cut Mines*** These former mines typically contain, and are surrounded by, uncontrolled mine spoil filling and may have connections to buried workings. Development over these area will generally need to include appropriate re-compaction of the spoil and sealing of connections to underground workings, however piled footings may be appropriate in some instances.

The constraints are summarised below for each area of the site:

10.1.2 Minmi North

- Minmi North has no mapped workings and is expected to be free of Mine Subsidence Constraints

10.1.3 Minmi West

Minmi West contains a range of constraints.

- The northern parts of the area have no known mine workings, however does contain filling from previous mining operations to the south (mapped as blue);
- The former Purple Hill **Open Cut mine** is located on the central parts of the site and contains significant filling within and to the north of the mine. Shallow unmapped workings to the north of the former open cut mine are possible, however unlikely (mapped as orange);
- **High pothole risk zone** on the central parts of the area (shown as red) to the south of the former open cut pit;
- **Low pothole risk zone** on the southern central parts of the area;
- **Limited Subsidence** is expected on the southern parts of the area;
- A number of capped **shafts** have been located in this area.

10.1.4 Minmi East

- Former **open cut mine** on western parts of area;
- **Low pothole risk** to north of former open cut mine and **High pothole risk** to the south;
- Former **open cut mine** on eastern part of site containing filling which will need to be re-compacted;
- **High subsidence risk** within the former open cut mine due to underlying Borehole Seam workings;
- **High pothole risk** and numerous **shafts** surrounding the open cut mine on eastern part of site.

10.1.5 Minmi South

- Former Back Creek **open cut mine** on north east boundary of area;
- **High pothole risk** adjacent to former open cut mine in north east part of area;

- **High pothole risk** in gully running down central northern parts of the area;
- Strip of **low pothole risk**;
- The north western parts of the site are mapped as **limited subsidence** (two storey brick veneer or equivalent) based on the low likelihood of pillar failure. The magnitude of subsidence in the unlikely case of pillar failure would be high and if the MSB require a 'no risk' profile then this area would need to be re-mapped as High Subsidence;
- The mid and eastern parts of the area are mapped as **High subsidence risk** (specialised single storey clad construction);
- The southern parts of the this area are mapped as **moderate subsidence risk** (one storey brick veneer or equivalent);
- This area contains several capped **shafts.**

10.1.6 Link Road North

- The northern parts of the area are mapped as **High subsidence risk** (specialised single storey clad construction);
- The southern parts of this area are mapped as **Moderate subsidence risk** (one storey brick veneer or equivalent);
- This area contains several capped **shafts**.

10.1.7 Link Road South

- The northern parts of this area are mapped as **Moderate subsidence risk** (one storey brick veneer or equivalent);
- The southern parts of the area are mapped as **Limited subsidence** (two storey brick veneer or equivalent) generally based on the absence of mapped workings;
- There are some small zones mapped as **High subsidence risk** (specialised single storey clad construction) on the central parts of the site coinciding with remnant pillars in the Gretley workings;

11. LIMITATIONS OF THIS REPORT

Conditions on site different to those identified during this assessment may exist. Therefore DP cannot provide unqualified warranties nor does DP assume any liability for site conditions not recorded in the data available for this assessment.

It is noted that the site is within a proclaimed mine subsidence district. This report outlines the potential risks associated with mine subsidence and presents guidelines for managing the risk and obtaining Mine Subsidence Board consideration for the proposed development. It is noted that the guidelines presented are not intended to fully prevent damage to property or person, rather reduce the risks and Douglas Partners accept no liability with respect to such damage. The Mine Subsidence Board should be consulted with respect to the proposed development to obtain their consent of the proposal.

This report and associated documentation and the information herein have been prepared solely for the use of Coal and Allied Operations Pty Limited. Any reliance assumed by other parties on this report shall be at such party's own risk. Any ensuing liability resulting from use of the report by other parties cannot be transferred to DP.

DOUGLAS PARTNERS PTY LTD

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