# SUBSIDENCE ASSESSMENT

## Abel Upgrade Modification
Environmental Assessment

## APPENDIX A

Resource Strategies

DONALDSONCOAL
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msec mine subsidence ENGINEERING CONSULTANTS

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ABEL UNDERGROUND MINE:

# Abel Upgrade Modification - Proposed Modification of Workings in ML1618

Subsidence Predictions and Impact Assessments for the Natural Features and Surface Infrastructure in Support of the Section 75W Modification Application

## DOCUMENT REGISTER

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| 01 | Draft Issue | JB | - | 14th Oct 11 |
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Report produced to:- Support the Section 75W Modification Application for submission to the Department of Planning and Infrastructure.

Background reports available at *www.minesubsidence.com:-*

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

Donaldson Coal Pty Limited (Donaldson Coal) operates the Abel Underground Mine (ML1618), which is located in the Newcastle Coalfield of New South Wales. The mine was approved under Part 3A of the *Environmental Planning and Assessment Act 1979*, in June 2007, based on bord and pillar mining operations in the Upper and Lower Donaldson Seams.

Donaldson Coal is seeking to modify the Project Approval (05-0136), under Section 75W of the *Environmental Planning and Assessment Act 1979*, by modifying the method of extraction to include shortwalls and longwalls in the Upper and Lower Donaldson Seams, and additional first workings and pillar extraction in the Upper Donaldson Seam. The proposed mining layout is shown in Drawing Nos. MSEC492-01 to MSEC492-03, in Appendix D.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by Donaldson Coal to identify all the natural features and items of surface infrastructure and to prepare subsidence predictions and impact assessments for the proposed shortwalls, longwalls and areas of additional first workings and pillar extraction. This report has been prepared to support the Modification Application to be submitted to the Department of Planning and Infrastructure.

The Study Area has been defined, as a minimum, as the surface area enclosed by a 26.5 degree angle of draw line from the limit of proposed mining and by the predicted 20 mm subsidence contour resulting from the proposed mining. Other features which could be subjected to far-field or valley related movements and could be sensitive to such movements have also been assessed in this report.

A number of natural features and items of surface infrastructure have been identified within the Study Area, including Blue Gum Creek, Long Gully, other drainage lines, alluvium, cliffs, rock outcrops, steep slopes, rainforest, roads and tracks, rural building structures, fences, farm dams, houses and archaeological sites.

Chapter 1 of this report provides a general introduction to the study, which also includes a description of the mining geometry, seam information and overburden geology.

Chapter 2 defines the Study Area and provides summary of the natural features and items of surface infrastructure within this area.

Chapter 3 includes a brief overview of bord and pillar, shortwall and longwall mining, the development of mine subsidence and the methods that have been used to predict the mine subsidence movements resulting from the proposed mining.

Chapter 4 provides a summary of the maximum predicted subsidence parameters resulting from the proposed mining. Comparisons between the predicted mine subsidence parameters, based on the proposed modified layouts, with those previously provided in the Part 3A Environmental Assessment are also provided in this chapter.

Chapters 5 and 6 provide the descriptions, predictions and impact assessments for each of the natural features and items of surface infrastructure which have been identified within the Study Area. Comparisons between the predictions for each feature, based on the proposed modified layouts, with those previously provided in the Part 3A Environmental Assessment are also provided in these chapters.

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## Figures

Figure numbers are prefixed by the number of the chapter or the letter of the appendix in which they are presented.

## Drawings

Drawings referred to in this report are included in Appendix D at the end of this report.

| *Drawing No.* | *Description* | *Revision* |
|---|---|---|
| MSEC492-01 | General Layout | B |
| MSEC492-02 | Shortwalls and Thin Seam Workings in the Upper Donaldson Seam | B |
| MSEC492-03 | Shortwalls and Longwalls in the Lower Donaldson Seam | B |
| MSEC492-04 | Surface Level Contours | B |
| MSEC492-05 | Upper Donaldson Seam Floor Contours | B |
| MSEC492-06 | Upper Donaldson Seam Thickness Contours | B |
| MSEC492-07 | Upper Donaldson Depth of Cover Contours | B |
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| MSEC492-10 | Lower Donaldson Depth of Cover Contours | B |
| MSEC492-11 | Historic Workings and Seam Floor Contours for the Borehole Seam | B |
| MSEC492-12 | Geological Structures Identified at Seam Level | B |
| MSEC492-13 | Streams, Alluvium and Rainforests | B |
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| MSEC492-16 | Electrical Infrastructure | B |
| MSEC492-17 | Telecommunications Infrastructure | B |
| MSEC492-18 | Building Structures and Farm Dams | B |
| MSEC492-19 | Archaeological Sites, Heritage Sites, Groundwater Bores and Survey Control Marks | B |
| MSEC492-20 | Predicted Total Subsidence Contours due to the Extraction of the Proposed Shortwalls, Longwalls and Pillar Extraction Panels | B |

## 1.1. Background

Donaldson Coal Pty Limited (Donaldson Coal) operates the Abel Underground Mine (ML1618), which is located in the Newcastle Coalfield of New South Wales. The mine was approved under Part 3A of the *Environmental Planning and Assessment Act 1979*, in June 2007, based on bord and pillar mining operations in the Upper and Lower Donaldson Seams. The mining layout indicated in the Part 3A Environmental Assessment is referred to as the *Approved Layout* in this report.

Donaldson Coal is seeking to modify the Project Approval (05-0136), under Section 75W of the *Environmental Planning and Assessment Act 1979*, by modifying the method of extraction to include shortwalls and longwalls in the Upper and Lower Donaldson Seams, and additional first workings and pillar extraction in the Upper Donaldson Seam. The current mining layout is referred to as the *Modified Layout* in this report.

The comparison between the *Approved Layout* and the *Modified Layout* is provided in Fig. 1.1.

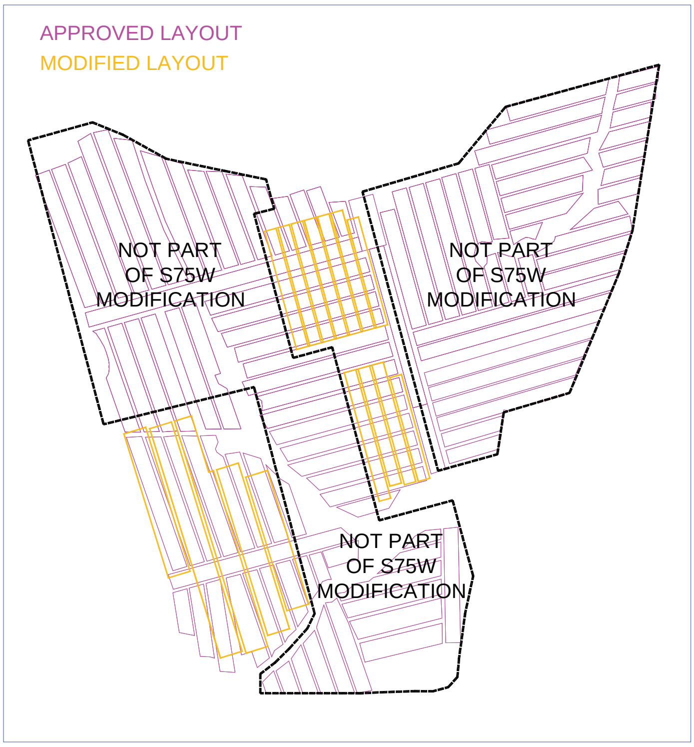


**Fig. 1.1 Comparison between the Approved Layout and the Modified Layout**

As described above, the *Modified Layout* includes mining part of the Upper Donaldson Seam, overlying the Lower Donaldson Seam, using first workings and pillar extraction methods, which is referred to as the '*thin seam*' workings in this report. Pillar extraction would only occur in the thin seam workings where it overlies the proposed longwalls in the Lower Donaldson Seam.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by Donaldson Coal to:-

- provide subsidence predictions for the proposed mining, based on the *Modified Layout*,
- compare the subsidence predictions, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*,
- identify the natural features and items of surface infrastructure located above and in the vicinity of the proposed shortwalls, longwalls and thin seam pillar extraction areas,
- provide subsidence predictions for each of these natural features and items of surface infrastructure, based on the *Modified Layout*,
- compare the subsidence predictions for the natural features and items of surface infrastructure, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, for the *Approved Layout*, and to
- provide impact assessments, in conjunction with other specialist consultants, for each of these natural features and items of surface infrastructure, based on the *Modified Layout*.

Chapter 1 of this report provides a general introduction to the study, which also includes a description of the mining geometry and geological details of the area.

Chapter 2 defines the Study Area and provides a summary of the natural features and items of surface infrastructure within this area.

Chapter 3 includes a brief overview of bord and pillar, shortwall and longwall mining, the development of mine subsidence and the methods that have been used to predict the mine subsidence movements resulting from the proposed mining.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the proposed mining, based on the *Modified Layout*, and compares these with the parameters provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

Chapters 5 and 6 provide the predictions and impact assessments for each of the natural features and items of surface infrastructure which have been identified. Recommendations for each of these features are also provided, which have been based on the predictions and impact assessments.

## 1.2. Mining Geometry

Donaldson Coal has approval to extract coal in ML1618 using bord and pillar extraction methods in the Upper and Lower Donaldson Seams. Donaldson Coal is proposing to modify the method of extraction, to include shortwalls and longwalls, and additional extraction areas in the Upper Donaldson Seam, referred to as the *thin seam workings*, which include first workings and some areas of pillar extraction.

The layouts of the proposed shortwalls and thin seam workings in the Upper Donaldson Seam are shown in Drawing No. MSEC492-02. A summary of the proposed dimensions of the shortwalls and thin seam pillar extraction panels in the Upper Donaldson Seams is provided in Table 1.1.

**Table 1.1 Geometry of the Proposed Shortwalls and Thin Seam Pillar Extraction Panels in the Upper Donaldson Seam**

| Panels | Overall Void Length Including First Workings (m) | Overall Void Width Including First Workings (m) | Overall Solid Pillar Width (m) |
|---|---|---|---|
| UDSW1 to UDSW7 (Shortwalls) | 1130 ~ 1250 | 120 | 20 |
| UDBP1 to UDBP4 (Thin Seam Pillar Extraction Panels) | 1050 ~ 1950 | 155 | 95 ~ 110 |

The proposed thin seam pillar extraction panels are located beneath historic workings in the overlying Borehole Seam. The historic workings and the seam floor contours for the Borehole Seam are shown in Drawing No. MSEC492-11. The thickness of the Borehole Seam is believed to be approximately 2.5 metres.

The layouts of the proposed shortwalls and longwalls in the Lower Donaldson Seam are shown in Drawing No. MSEC492-03. A summary of the proposed dimensions of the shortwalls and longwalls in the Lower Donaldson Seam is provided in Table 1.2.

**Table 1.2 Geometry of the Proposed Shortwalls and Longwalls in the Lower Donaldson Seam**

| Panels | Overall Void Length Including First Workings (m) | Overall Void Width Including First Workings (m) | Overall Solid Pillar Width (m) |
|---|---|---|---|
| LDSW1 to LDSW4 (Shortwalls) | 1170 ~ 1360 | 120 | 25 |
| LDLW1 to LDLW5 (Longwalls) | 1420 ~ 2470 | 230* | 30 ~ 35 |

Note: * denotes that the width of LDLW3 has been narrowed to 180 metres at the northern end, so as to limit the maximum predicted subsidence to 20 mm within the adjacent rainforest area.

The proposed longwalls in the Lower Donaldson Seam (LDLW1 to LDLW5) are located beneath the proposed thin seam pillar extraction panels in the Upper Donaldson Seam, as well as the historic workings in the overlying Borehole Seam.

The northern ends of the proposed shortwalls in the Lower Donaldson Seam (LDSW1 to LDSW4) are also located beneath the historic workings in the overlying Borehole Seam. The historic workings in this location are less than 10 metres from the surface within the base of the quarry.

## 1.3. Surface Topography

The surface level contours within the mining lease are shown in Drawing No. MSEC492-04. The main topographical feature is *Black Hill* which is a ridgeline located near the centre of the lease. The surface naturally drains into Long Gully and Blue Gum Creek, in the south-eastern part of the mining lease, into Four Mile and Viney Creeks, in the north-eastern part of the mining lease, and into Buttai Creek, in the western part of the mining lease.

The surface levels within and surrounding the mining lease vary from a high point of approximately 210 metres AHD, at the top of Black Hill, to a low point of approximately 1.5 metres AHD, within the Pambalong Nature Reserve. The natural surface gradients vary across the lease, with a maximum natural grades typically varying up to 1 in 2 (i.e. 27º, or 50 %), with isolated areas varying up to around 1 in 1 (i.e. 45º, or 100 %).

## 1.4. Seam Information

The shortwalls, first workings and thin seam pillar extraction panels indicated in Drawing No. MSEC492-02 are proposed to be extracted in the Upper Donaldson Seam. The seam floor contours, seam thickness contours and depth of cover contours for the Upper Donaldson Seam are shown in Drawing Nos. MSEC492-05, MSEC492-06 and MSEC492-07, respectively.

The depth of cover directly above the proposed shortwalls in the Upper Donaldson Seam varies between a minimum of 50 metres, above the north-eastern corner of the panels, and a maximum of 200 metres, above the southern ends of these panels.

The depth of cover directly above the first workings in the thin seam areas of the Upper Donaldson Seam varies between a minimum of 125 metres, above the north-eastern corner of the workings, and a maximum of 350 metres, above the western extent of these workings. The depth of cover directly above the thin seam pillar extraction panels varies between a minimum of 200 metres, above the southern extent of these panels, and a maximum of 350 metres, above the western extent of these panels.

The thickness of the Upper Donaldson Seam within the extents of the proposed shortwalls varies between approximately 1.6 metres and 2.8 metres. The thickness of the seam within the extents of the proposed thin seam workings varies between approximately 1.3 metres and 2.3 metres. The maximum extraction height in the Upper Donaldson Seam is proposed to be 2.8 metres.

The thin seam pillar extraction panels in the Upper Donaldson Seam are proposed to be extracted beneath the historic Stockrington No. 2 Colliery workings in the overlying Borehole Seam. The historic workings and the seam floor contours for the Borehole Seam are shown in Drawing No. MSEC492-11. The interburden thickness between the proposed panels and the historic workings varies between approximately 200 metres and 220 metres.

The shortwalls and longwalls indicated in Drawing No. MSEC492-03 are proposed to be extracted in the Lower Donaldson Seam. The seam floor contours, seam thickness contours and depth of cover contours for the Lower Donaldson Seam are shown in Drawing Nos. MSEC492-08, MSEC492-09 and MSEC492-10, respectively.

The depth of cover directly above the proposed shortwalls in the Lower Donaldson Seam varies between a minimum of approximately 150 metres, above the southern ends of these panels, and a maximum of 300 metres, above the north-western corner of these panels. The depth of cover directly above the proposed longwalls in the Lower Donaldson Seam varies between a minimum of approximately 190 metres, above the south-eastern corner of these panels, and a maximum of 370 metres, above the western extent of these panels.

The thickness of the Lower Donaldson Seam within the extent of the proposed shortwalls varies between approximately 2.6 metres and 3.2 metres. The thickness of the Lower Donaldson Seam within the extent of the proposed longwalls varies between approximately 1.9 metres and 2.9 metres. The maximum extraction height in the Lower Donaldson Seam is proposed to be 2.8 metres.

The LDLW1 to LDLW5 are proposed to be extracted beneath the proposed thin seam pillar extraction panels in the Upper Donaldson Seam (UDBP1 to UDBP4), as well as the historic Stockrington No. 2 Colliery workings in the overlying Borehole Seam. The interburden thickness contours between the Upper and Lower Donaldson Seams, in the locations of the proposed longwalls, is approximately 20 metres.

The northern ends of the proposed shortwalls in the Lower Donaldson Seam (LDSW1 to LDSW4) are also partially located beneath the historic workings in the Borehole Seam. The interburden thickness between the historic workings and the Lower Donaldson Seam is around 225 metres in this location.

The variations in the surface and seam levels are illustrated along Sections A and B in Fig. 1.2 and Fig. 1.3, respectively. The locations of these sections are shown in Drawing Nos. MSEC492-02 and MSEC492-03.

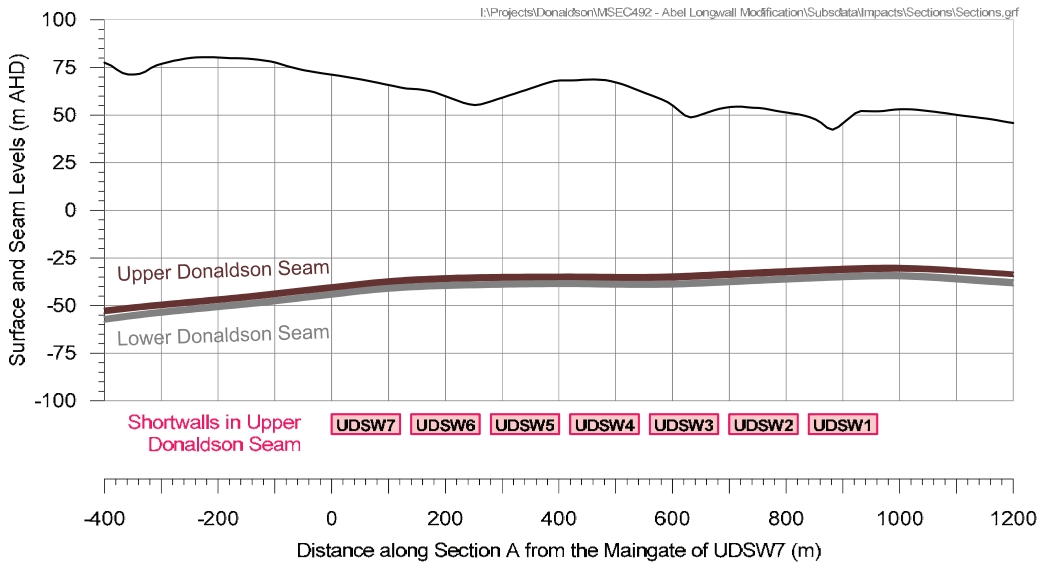


**Fig. 1.2 Surface and Seam Levels along Section-A (Shortwalls in Upper Donaldson Seam)**

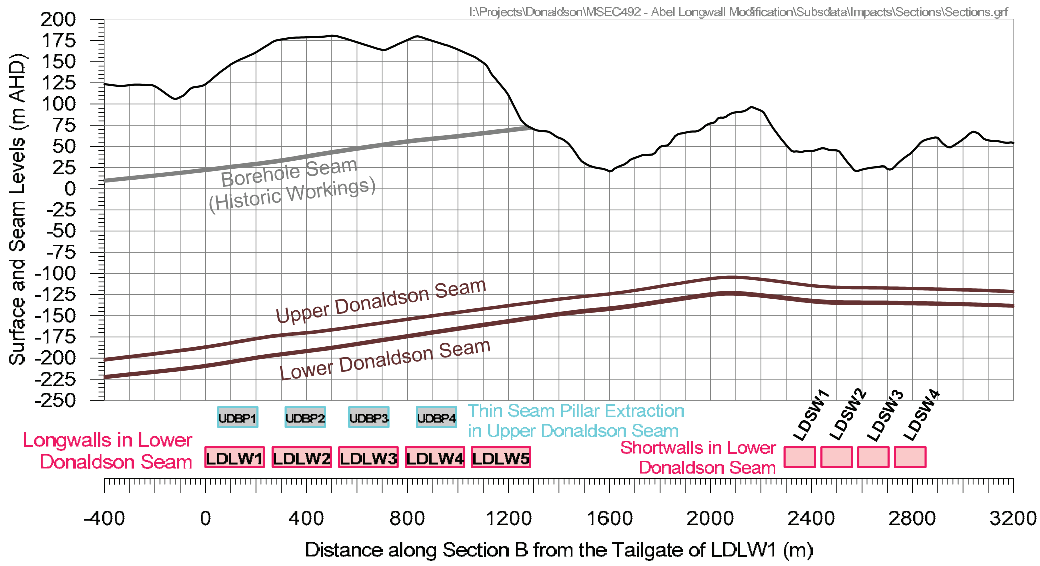


**Fig. 1.3 Surface and Seam Levels along Section-B (Thin Seam Pillar Extraction Panels, Longwalls and Shortwalls in Upper and Lower Donaldson Seams)**

It can be seen Drawing Nos. MSEC492-05 and MSEC492-08, that the Upper and Lower Donaldson Seams dip from the north-east to the south-west within the lease. The natural gradients of these seams, within the extents of the approved mining in ML1618, typically vary between 3 % (i.e. 1 in 33) and 6 % (i.e. 1 in 17).

## 1.5. Geological Details

The Abel Underground Mine lies in the Newcastle Coalfield, within the Northern Sydney Basin. A typical stratigraphic section of the Newcastle Coalfield (after Ives et al, 1999, Moelle and Dean-Jones, 1995, Lohe and Dean-Jones, 1995, Sloan and Allman, 1995) is shown in Table 1.3. The strata shown in this table were laid down between the Early Permian and the Middle Triassic Periods.

**Table 1.3 Stratigraphy of the Newcastle Coalfield**
**(after Ives et al, 1999, Moelle & Dean-Jones, 1995, Lohe & Dean-Jones, 1995, Sloan & Allan, 1995)**

| Stratigraphy | | | Lithology |
|---|---|---|---|
| **Group** | **Formation** | **Coal Seams** | |
| Narrabeen Group | Clifton | | Sandstone, siltstone, mudstone, claystone |
| Newcastle Coal Measures | Moon Island Beach | Vales Point<br>Wallarah<br>Great Northern | Sandstone, shale, conglomerate, claystone, coal |
| | Awaba Tuff | | Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert |
| | Boolaroo | Fassifern<br>Upper Pilot<br>Lower Pilot<br>Hartley Hill | Conglomerate, sandstone, shale, claystone, coal |
| | Warners Bay Tuff | | Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert |
| | Adamstown | Australasian<br>Montrose<br>Wave Hill<br>Fern Valley<br>Victoria Tunnel | Conglomerate, sandstone, shale, claystone, coal |
| | Nobbys Tuff | | Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone chert |
| | Lambton | Nobbys<br>Dudley<br>Yard<br>Borehole | Sandstone, shale, minor conglomerate, claystone, coal |
| | Waratah Sandstone | | Sandstone |
| Tomago Coal Measures | Dempsey | | Shale, siltstone, fine sandstone, coal, and minor tuffaceous claystone |
| | Four Mile Creek | **Upper and Lower Donaldson** | |
| | Wallis Creek | | |
| Maitland Group | Mulbring Siltstone | | Siltstone |
| | Muree Sandstone | | Sandstone |
| | Braxton | | Sandstone, and siltstone |
| Greta Coal Measures | Paxton | Pelton | Sandstone, conglomerate, and coal |
| | Kitchener | Greta | |
| | Kurri Kurri | Homeville | |
| | Neath Sandstone | | Sandstone |
| Dalwood Group | Farley | | Shale, siltstone, lithic sandstone, conglomerate, minor marl and coal, and interbedded basalts, volcanic breccia, and tuffs |
| | Rutherford | | |
| | Allandale | | |
| | Lochinvar | | |
| Seaham Formation | | | |

The shortwalls, longwalls and thin seam workings are proposed to be extracted in the Upper and Lower Donaldson Seams, which are located within the Permian Tomago Coal Measures. The immediate overburden comprises frequently interbedded sandstone, shale, carbonaceous mudstone, tuffaceous claystone and coal. The overlying Waratah Sandstone separates the Tomago Coal and the Newcastle Coal Measures.

The historic Stockrington No. 2 Colliery workings (in the south-western part of the lease) were extracted in the overlying Borehole Seam, which is located within the Lambton Sub-Group of the Newcastle Coal Measures. The overburden to these workings comprises sandstone and conglomerate strata separated by intermittent shale layers.

The available boreholes indicate that the strata layers are frequently bedded having thickness up to around 10 metres. There were no massive sandstone or conglomerate units identified from this information.

The major geological features identified at seam level are shown in Drawing No. MSEC492-12. Zones of geological disturbance (i.e. faults and dykes) have been identified to the west and east of the proposed LDLW1 to LDLW5, which coincide with the alignments of Buttai Creek and Long Gully, respectively. A zone of geological disturbance has been identified in the southern part of the lease, roughly aligned with, but offset from the alignment of Blue Gum Creek.

The Part 3A Environmental Assessment describes that the "*Surface joint patterns on the sandstone cliff lines and outcrops around the site consist of a sub-vertical, widely spaced, planar to wavy, persistent joint sets striking between 025º and 035º (NNE to NE). A sub-vertical joint set striking at approximately 135º (NW:SE) is also present. The trends in the cliff faces are similar to the above joint sets*".

The surface lithology within the lease is shown in Fig. 1.4, which shows the proposed shortwalls and longwalls overlaid on Geological Series Sheets 9131, 9132, 9231 and 9231, which are published by the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS).

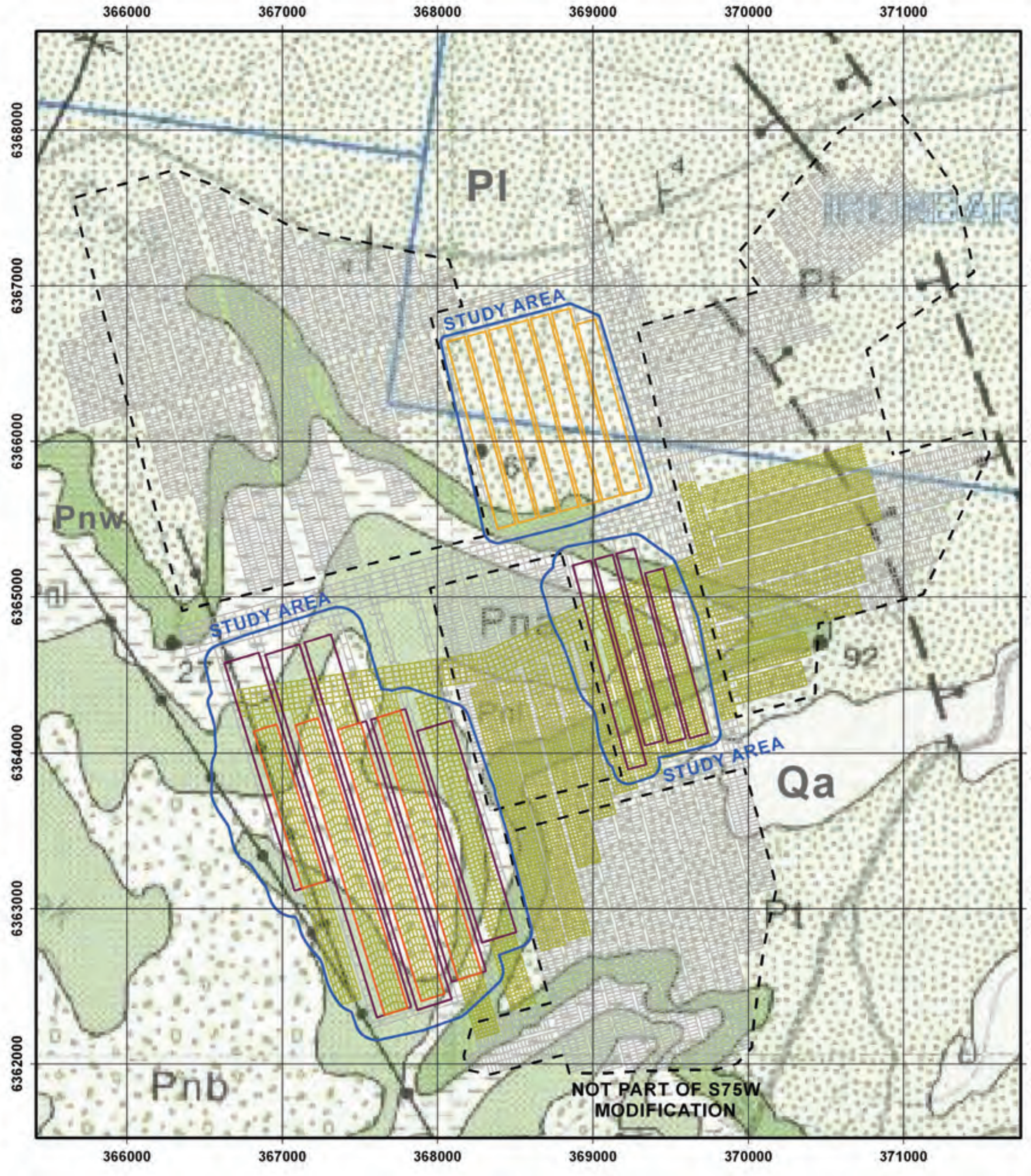


**Fig. 1.4 Surface Lithology within the Lease**
**Geological Series Sheets 9131, 9132, 9231 and 9232 (DMR, 1993)**

It can be seen from this figure, that the surface lithology along the ridgelines are derived from the Boolaroo (Pnb), Adamstown (Pna), and Lambton (Pnl) Subgroups of the Newcastle Coal Measures, with the sandstone units expressing as cliffs and rock outcropping. The lower lying areas are predominately derived from the Tomago Coal Measures (Pl), including the Dempsey, Four Mile Creek and Wallis Creek Formations. The eastern parts of Blue Gum Creek and Long Gully are derived from Quaternary alluvium (Qa). The extent of the alluvium is also illustrated in Drawing No. MSEC492-13.

## 2.1. Definition of the Extents of the Modified Mining Areas

The *Extents of the Modified Mining Areas* are defined as the maximum extents of the shortwalls, longwalls and thin seam pillar extraction panels (i.e. second workings) that are shown in Drawing Nos. MSEC492-02 and MSEC492-03. An assessment of the potential subsidence impacts for the areas of additional first workings in the Upper Donaldson Seam is not required, as these workings will be designed to be stable and not result in any measureable surface subsidence, as described in Section 4.2.1.

## 2.2. Definition of the Study Area

The *Study Area* is defined as the surface area that is likely to be affected by the proposed mining of the shortwalls, longwalls and thin seam pillar extraction panels within the Upper and Lower Donaldson Seams. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:-

- The 26.5 degree angle of draw line from the proposed *Extents of the Modified Mining Areas*, and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour resulting from the extraction of the shortwalls, longwalls and thin seam pillar extraction panels.

The depth of cover contours for the Upper and Lower Donaldson Seams are shown in Drawing Nos. MSEC492-07 and MSEC492-10, respectively. It can be seen from these drawings that the depths of cover vary considerably within the extents of the modified mining areas, between a minimum of 50 metres, above the northern ends of the shortwalls in Upper Donaldson Seam, and a maximum of 370 metres, above the proposed longwalls in the Lower Donaldson Seam.

The 26.5 degree angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 25 metres and 185 metres around the limits of the proposed *Extents of the Modified Mining Areas*.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method, which is described in Chapter 3. The predicted total subsidence contours, including the 20mm predicted subsidence contour line, resulting from the extraction of the proposed shortwalls, longwalls and thin seam pillar extraction panels, are shown in Drawing No. MSEC492-20.

A line has therefore been drawn defining the Study Area, based upon the 26.5 degree angle of draw line and the predicted total 20 mm subsidence contour, whichever is furthest from extents of the modified mining areas, which is shown in Drawing Nos. MSEC492-02 and MSEC492-03.

There are areas that lie outside the Study Area that could experience far-field or valley related movements. The surface features which are sensitive to such movements have been identified and have been included in the assessments provided in this report.

## 2.3. Overview of the Natural Features and Items of Surface Infrastructure within the Study Area

A number of the major natural features and items of surface infrastructure within the Study Area can be seen in the 1:25,000 Topographic Maps of the area, published by the Central Mapping Authority (CMA), numbered 9131, 9132, 9231 and 9232. The proposed mining and the Study Area have been overlaid on an extract of these CMA maps in Fig. 2.1.

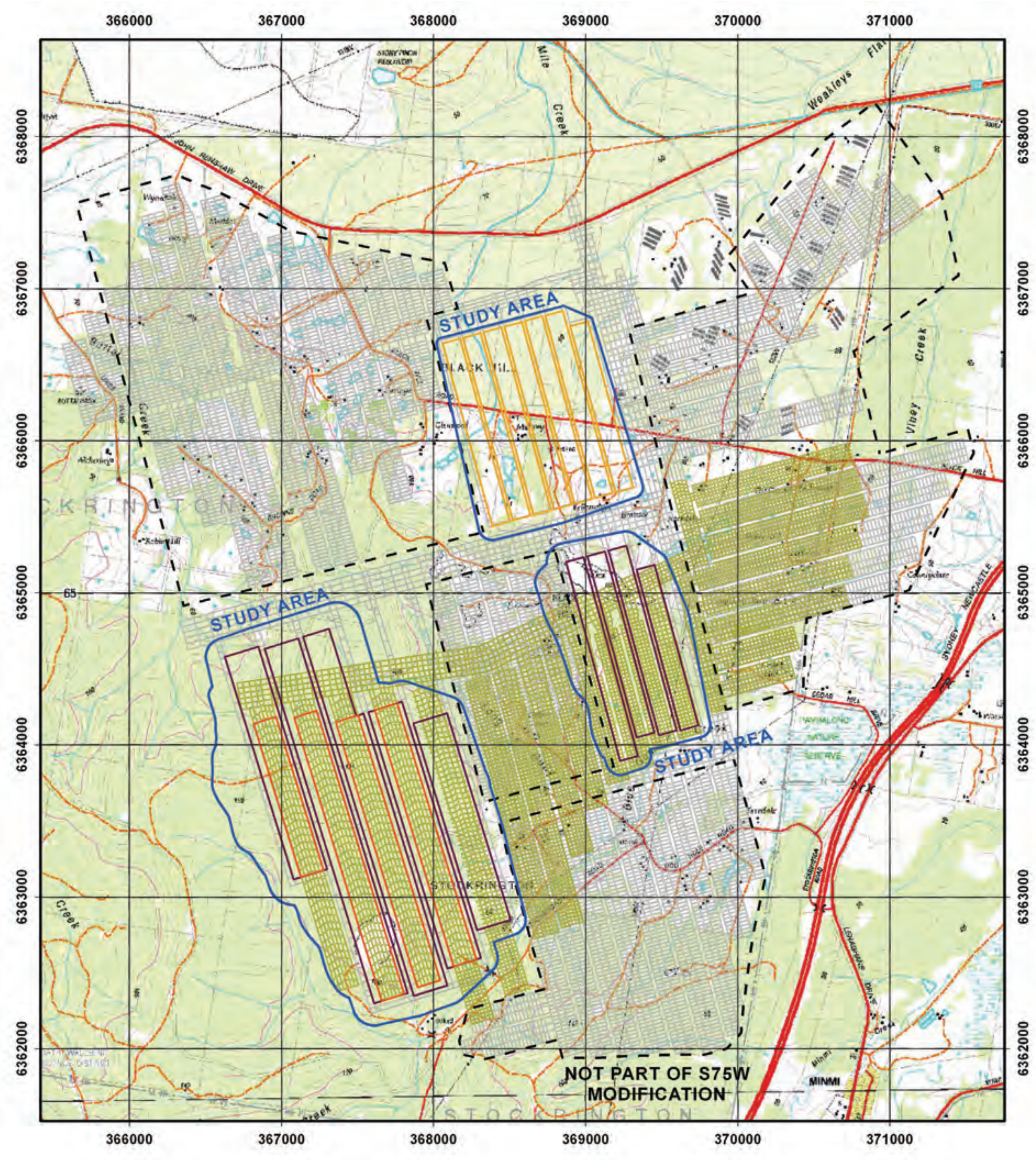


**Fig. 2.1 Proposed Shortwalls and Longwalls and Study Area Overlaid on CMA Map Nos. 9131, 9132, 9231 and 9232**

A summary of the natural features and items of surface infrastructure within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawing Nos. MSEC492-13 to MSEC492-19. The descriptions, predictions and impact assessments for each of the natural features and items of surface infrastructure identified are provided in Chapters 5 and 6.

**Table 2.1 Natural Features and Surface Infrastructure within the Study Area**

| Item | Within Study Area | Section Number |
|---|---|---|
| **NATURAL FEATURES** | | |
| Catchment Areas or Declared Special Areas | × | |
| Streams | ✓ | 5.1 |
| Aquifers or Known Groundwater Resources | ✓ | 5.2 |
| Springs or Groundwater Seeps | × | |
| Sea or Lake | × | |
| Shorelines | × | |
| Natural Dams | × | |
| Cliffs or Rock Outcrops | ✓ | 5.3 |
| Steep Slopes | ✓ | 5.4 |
| Escarpments | × | |
| Land Prone to Flooding or Inundation | ✓ | 5.5 |
| Swamps or Wetlands | ✓ | 5.6 |
| Water Related Ecosystems | ✓ | 5.7 |
| Threatened or Protected Species | ✓ | 5.8 |
| Lands Defined as Critical Habitat | × | |
| National Parks or Wilderness Areas | × | |
| State Forests | × | |
| State Recreation or Conservation Areas | × | |
| Natural Vegetation | ✓ | 5.9 |
| Areas of Significant Geological Interest | × | |
| Any Other Natural Features Considered Significant | × | |
| | | |
| **PUBLIC UTILITIES** | | |
| Railways | × | 6.1 |
| Roads (All Types) | ✓ | 6.2 & 6.3 |
| Bridges | ✓ | 6.3 |
| Tunnels | × | |
| Culverts | ✓ | 6.2 |
| Water, Gas or Sewerage Infrastructure | × | |
| Liquid Fuel Pipelines | × | |
| Electricity Transmission Lines or Associated Plants | ✓ | 6.4 |
| Telecommunication Lines or Associated Plants | ✓ | 6.5 |
| Water Tanks, Water or Sewage Treatment Works | × | |
| Dams, Reservoirs or Associated Works | × | |
| Air Strips | × | |
| Any Other Public Utilities | × | |
| | | |
| **PUBLIC AMENITIES** | | |
| Hospitals | × | |
| Places of Worship | × | |
| Schools | × | |
| Shopping Centres | × | |
| Community Centres | × | |
| Office Buildings | × | |
| Swimming Pools | × | |
| Bowling Greens | × | |
| Ovals or Cricket Grounds | × | |
| Race Courses | × | |
| Golf Courses | × | |
| Tennis Courts | × | |
| Any Other Public Amenities | × | |

| Item | Within Study Area | Section Number |
|---|---|---|
| **FARM LAND AND FACILITIES** | | |
| Agricultural Utilisation or Agricultural Suitability of Farm Land | ✓ | 6.6 |
| Farm Buildings or Sheds | ✓ | 6.7 |
| Tanks | ✓ | 6.7 |
| Gas or Fuel Storages | × | |
| Poultry Sheds | × | |
| Glass Houses | × | |
| Hydroponic Systems | × | |
| Irrigation Systems | × | |
| Fences | ✓ | 6.8 |
| Farm Dams | ✓ | 6.9 |
| Wells or Bores | ✓ | 6.10 |
| Any Other Farm Features | × | |
| | | |
| **INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS** | | |
| Factories | × | |
| Workshops | × | |
| Business or Commercial Establishments or Improvements | × | |
| Gas or Fuel Storages or Associated Plants | × | |
| Waste Storages or Associated Plants | × | |
| Buildings, Equipment or Operations that are Sensitive to Surface Movements | × | |
| Surface Mining (Open Cut) Voids or Rehabilitated Areas | ✓ | 6.11 |
| Mine Related Infrastructure Including Exploration Bores and Gas Wells | ✓ | 6.12 |
| Any Other Industrial, Commercial or Business Features | × | |
| | | |
| **AREAS OF ARCHAEOLOGICAL SIGNIFICANCE** | ✓ | 6.13 |
| | | |
| **AREAS OF HISTORICAL SIGNIFICANCE** | ✓ | 6.14 |
| | | |
| **ITEMS OF ARCHITECTURAL SIGNIFICANCE** | × | |
| | | |
| **PERMANENT SURVEY CONTROL MARKS** | ✓ | 6.15 |
| | | |
| **RESIDENTIAL ESTABLISHMENTS** | | |
| Houses | ✓ | 6.16 |
| Flats or Units | × | |
| Caravan Parks | × | |
| Retirement or Aged Care Villages | × | |
| Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts | ✓ | 6.16 |
| Any Other Residential Features | × | |
| | | |
| **ANY OTHER ITEM OF SIGNIFICANCE** | × | |
| | | |
| **ANY KNOWN FUTURE DEVELOPMENTS** | × | |

# 3.0 OVERVIEW OF MINING METHODS, THE DEVELOPMENT OF SUBSIDENCE, AND THE METHOD USED TO PREDICT THE MINE SUBSIDENCE PARAMETERS FOR THE PROPOSED LONGWALLS

## 3.1. Introduction

This chapter provides a brief overview of bord and pillar, shortwall and longwall mining, the development of mine subsidence and the methods that have been used to predict the mine subsidence movements resulting from the proposed mining. Further details on methods of mining, the development of subsidence and the methods used to predict mine subsidence movements are provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

## 3.2. Overview of Bord and Pillar Mining

Donaldson Coal is currently extracting coal using bord and pillar mining techniques in the Upper Donaldson Seam, in the north-eastern part of the mining lease. Donaldson Coal is also proposing pillar extraction of the thin seam workings in the Upper Donaldson Seam, in the south-western part of the mining lease.

Initially grids of roadways are developed off the main headings, using continuous miners, which are referred to as *first workings*. The roadways are nominally 5.5 metres wide and around 2.5 metres high. The *production panels* each comprise four or more main roadways off the main headings, with a series of cross-roadways, leaving a grid of coal pillars.

The existing *production panels* have overall widths of around 160 metres and are separated by barrier pillars having typical widths of 19.5 metres. The proposed thin seam pillar extraction panels have overall widths of around 155 metres and barrier pillars having widths around 100 metres. The lengths of the *production panels* vary between approximately 0.3 kilometres and 2 kilometres.

The development of the roadways typically extracts around 35 % of the available coal, reducing to around 25 % of the available coal in the locations of the larger coal pillars beneath the subsidence control zones. The first workings are self-supporting and, therefore, do not result in any significant subsidence at the surface (i.e. less than 20 mm of subsidence).

The coal pillars are then extracted using the continuous miners and shuttle cars. The *production panels* are mined towards the main headings (i.e. retreat mining). Small remnant pillars (referred to as stooks) are left to support the roof, during the mining operations, and are designed to yield in the long term.

The maximum achievable subsidence in the Newcastle Coalfield, for single-seam super-critical conditions, is generally 55 % to 60 % of the effective extracted thickness. The bord and pillar mining technique can extract up to 85 % of the available coal (including the coal extracted as part of the *first workings*) and, therefore, the maximum achievable subsidence is typically 47 % to 51 %, for single-seam conditions.

In some locations, such as beneath the *subsidence control zones*, the coal pillars will not be extracted. These coal pillars are designed to be stable, in the long term and, therefore, the subsidence in these locations will be less than the maximum achievable.

## 3.3. Overview of Shortwall and Longwall Mining

Donaldson Coal proposes to extract coal using shortwalls in the Upper and Lower Donaldson Seams and using longwalls in the Lower Donaldson Seam. A generic cross section through the immediate roof strata and along the length of a typical longwall, at the coal face, is shown in Fig. 3.1.

The coal is removed by a shearer, which cuts the coal from the coal face on each pass as it traverses the width of the shortwall or longwall. The roof at the coal face is supported by a series of hydraulic roof supports, which temporarily hold up the roof strata, and provide a secure working space at the coal face. The coal is then transported by a face conveyor belt which is located behind and beneath the shearer. As the coal is removed from each section of the coal face, the hydraulic supports are stepped forward, and the coal face progresses (retreats) along the length of the shortwall or longwall.

The strata directly behind the hydraulic supports, immediately above the coal seam, collapses into the void that is left as the coal face retreats. The collapsed zone comprises loose blocks and can contain large voids. Immediately above the collapsed zone, the strata remains relatively intact and bends into the void, resulting in new vertical factures, opening up of existing vertical fractures and bed separation. The amount of strata sagging, fracturing and bed separation reduces towards the surface.

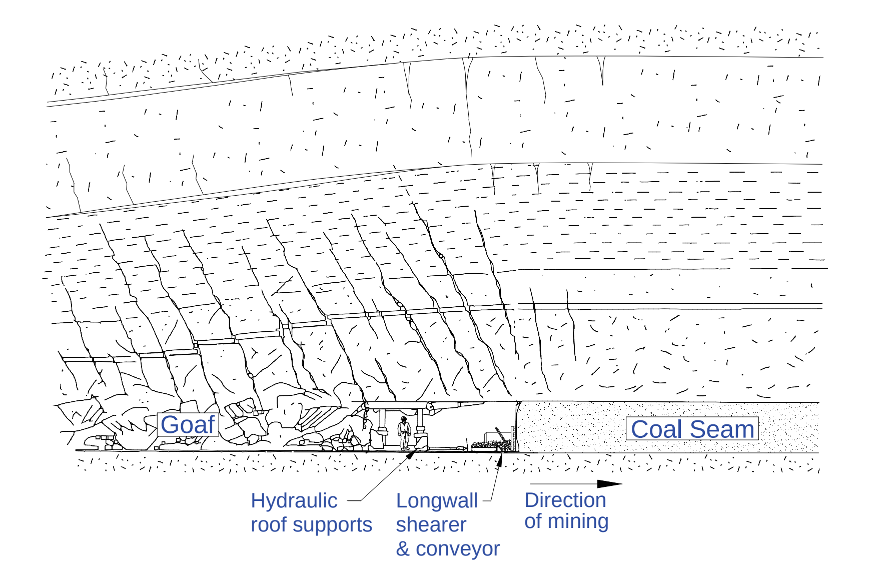


**Fig. 3.1 Cross-section along the Length of a Typical Longwall at the Coal Face**

At the surface, the ground subsides vertically as well as moves horizontally towards the centre of the mined goaf area. The maximum subsidence at the surface varies, depending on a number of factors including the mine geometry, depth of cover, extracted seam thickness and overburden geology. The maximum achievable subsidence in the Newcastle Coalfield, for a critical width of extraction and single-seam conditions, is generally 55 % to 60 % of the extracted seam thickness.

The longwalls in the Lower Donaldson Seam are proposed to be extracted beneath the proposed thin seam pillar extraction panels in the Upper Donaldson Seam, as well as the historic Stockrington No. 2 Colliery workings in the overlying Borehole Seam. The maximum achievable subsidence for multi-seam conditions is greater than that for single-seam conditions, as a result of the re-activation of the overlying goaf and pillars. Further discussions on multi-seam mining are provided in Section 3.8.2.

## 3.4. Overview of Conventional Subsidence Parameters

The normal ground movements resulting from the extraction of pillars, shortwalls, or longwalls are referred to as conventional or systematic subsidence movements. These movements are described by the following parameters:-

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the longwall goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.
- **Tilt** is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.
- **Curvature** is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres* ($km^{-1}$), but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.
- **Strain** is the relative differential horizontal movements of the ground. **Normal strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distances between two points increases and **Compressive Strains** occur when the distances between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.

- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using 2D or 3D monitoring techniques. High deformations along monitoring lines (i.e. normal strains) are generally measured where high deformations have been measured across the monitoring line (i.e. shear deformations), and vice versa.

A cross-section through a typical single extraction panel, for a horizontal seam in level terrain, showing typical profiles of subsidence, tilt, curvature and strain is provided in Fig. 3.2.

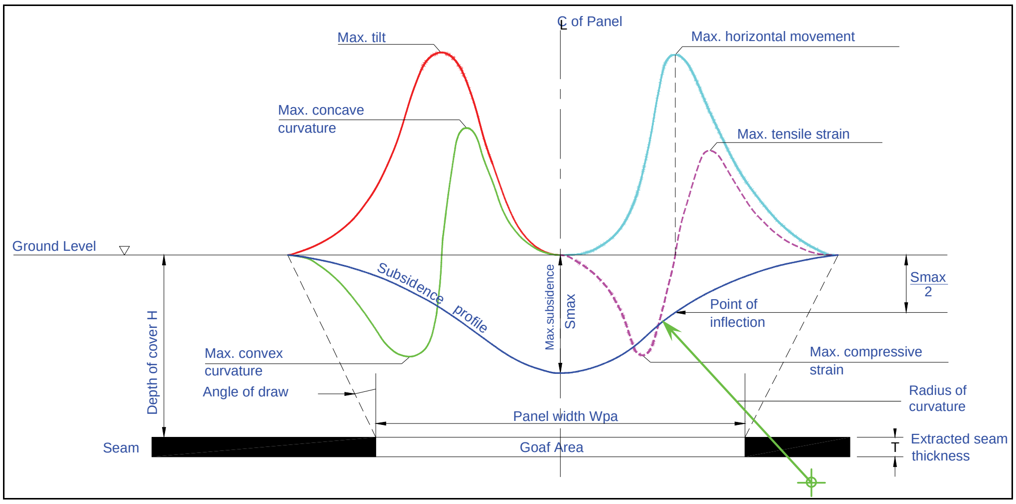


**Fig. 3.2 Typical Profiles of Conventional Subsidence Parameters for a Single Extraction Panel**

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters which result from the extraction of each panel. The **cumulative** subsidence, tilts, curvatures and strains are the accumulated parameters which result from the extraction of a series of panels. The **total** subsidence, tilts, curvatures and strains are the final parameters at the completion of a series of panels. The **travelling** tilts, curvatures and strains are the transient movements as mining occurs directly beneath a given point.

## 3.5. Far-field Movements

The measured horizontal movements at survey marks which are located beyond the longwall or panel goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. An empirical database of observed horizontal movements has been developed which confirms this.

The strata mechanisms that are believed to have caused the horizontal movements to be higher than the vertical movements, at locations beyond the longwall panel edges and over solid unmined coal, are associated with the redistribution of the in-situ horizontal compressive stresses in the strata around the panels. Before mining these in-situ stresses, which are generally compressive in all directions, are in a state of equilibrium or balance. When mining occurs, this equilibrium is disturbed and the stresses achieve a new balance by shearing through the weaker strata units allowing the strata to move or expand towards the goaf areas, where the confining stresses have been relieved.

Far-field horizontal movements have been observed at considerable distances from extracted panels. Such movements are predictable and occur whenever significant excavations occur at the surface or underground. When large horizontal movements are measured outside the goaf area, they are likely to be the result of a combination of mechanisms, including far-field and valley related movements, in addition to the conventional mine subsidence movements.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. These movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased observed horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between panels or near other previously extracted series of panels. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt and strain.

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.6 of this report.

## 3.6. Overview of Non-Conventional Subsidence Movements

Conventional subsidence profiles are typically smooth in shape and can be explained by the expected caving mechanisms associated with overlying strata spanning the extracted void. Normal conventional subsidence movements due to mining are easy to identify where panels are regular in shape, the extracted coal seams are relatively uniform in thickness, the geological conditions are consistent and surface topography is relatively flat.

As a general rule, the smoothness of the profile is governed by the depth of cover and lithology of the overburden, particularly the near surface strata layers. Where the depth of cover is high, such as in the southern part of the mining lease, the observed subsidence profiles would be expected to be generally smooth. Where the depth of cover is less than 100 metres, such as the in the northern part of the mining lease, the observed subsidence profiles are expected to be irregular. Very irregular subsidence movements are observed with much higher tilts and strains at very shallow depths of cover where the collapsed zone above the extracted panel extends up to or near to the surface.

Irregular subsidence movements are occasionally observed at the higher depths of cover along an otherwise smooth subsidence profile. The cause of these irregular subsidence movements can be associated with:-

- sudden or abrupt changes in geological conditions,
- steep topography,
- multi-seam mining conditions, and
- valley related movements.

Non-conventional movements due to shallow depths of cover, changes in geological conditions, steep topography, multi-seam mining conditions and valley related movements are discussed in the following sections.

### 3.6.1. Non-Conventional Subsidence Movements due to Shallow Depth of Cover

Irregular ground movements are commonly observed in shallow mining situations, where the collapsed zone, which develops above the extracted panels, extends near to the surface. This type of irregularity is generally only seen where panel widths are super-critical and where the depths of cover are less than 100 metres, such as the case in the northern part of the mining lease. These irregular movements appear as localised bumps and steps in the observed subsidence profiles, which are accompanied by elevated tilts, curvatures and ground strains.

The levels of irregular subsidence movement at varying depths of cover can be seen in the observed subsidence profiles over the previously extracted Whybrow Seam longwalls at South Bulga Colliery, which are shown in Fig. 3.3.

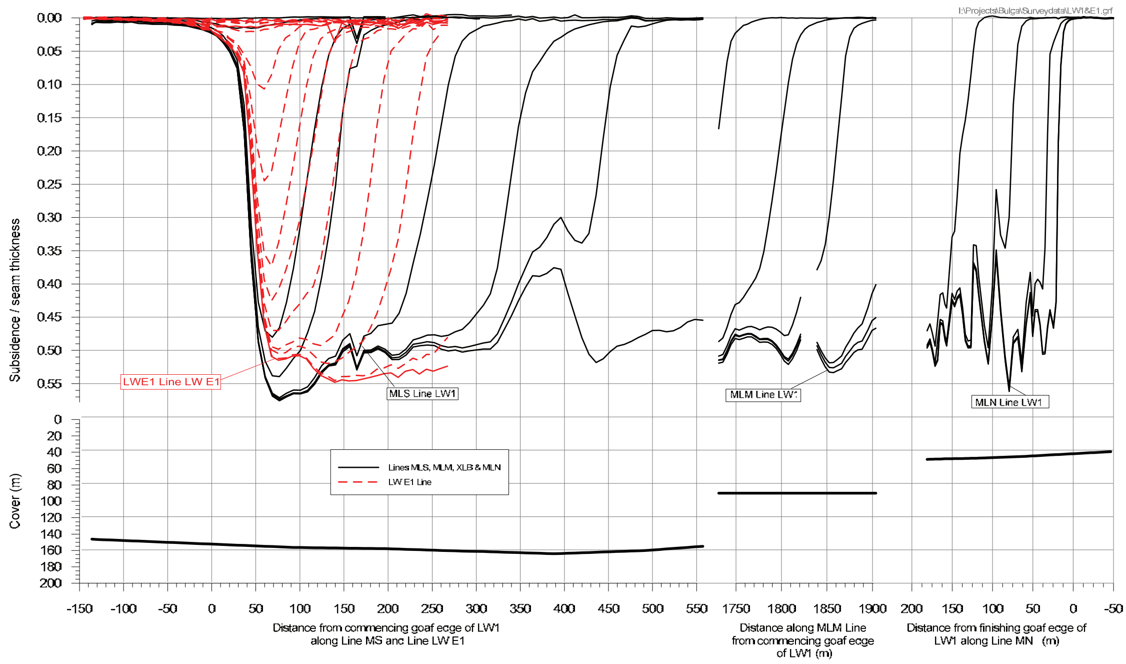


**Fig. 3.3 Observed Subsidence Profiles at South Bulga Colliery**

The observed subsidence profiles along the MLS and LWE1 monitoring lines above the southern ends of Whybrow Seam Longwalls 1 and E1, respectively, having average depths of cover of 160 metres, are shown in the left of this figure. The observed subsidence profile along the MLM monitoring line above the northern end of Longwall 1, having an average depth of cover of 90 metres, is shown near the middle of the figure. The observed subsidence profile along the MLN monitoring line above the northern end of Longwall 1, having an average depth of cover of 45 metres, is shown in the right of this figure.

The observed subsidence profiles are relatively smooth (i.e. normal or conventional) along the MLS and LWE1 monitoring lines, where the depths of cover are much greater than 100 metres. The observed subsidence profile is still relatively smooth along the MLM monitoring line, where the depth of cover is just less than 100 metres. The observed subsidence profile along the MLN line is very irregular (i.e. irregular or non-conventional), where the depth of cover is less than 50 metres.

### 3.6.2. Non-conventional Subsidence Movements due to Changes in Geological Conditions

It is believed that most non-conventional ground movements are a result of the reaction of near surface strata to increased horizontal compressive stresses due to mining operations. Some of the geological conditions that are believed to influence these irregular subsidence movements are the blocky nature of near surface sedimentary strata layers and the possible presence of unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts, curvatures and ground strains. Buckling of near surface bedrock can also occur.

Even though it may be possible to attribute a reason behind most observed non-conventional ground movements, there remain some observed irregular ground movements that still cannot be explained with the available geological information. The term "anomaly" is therefore reserved for those non-conventional ground movement cases that were not expected to occur and cannot be explained by any of the above possible causes.

It is not possible to predict the locations and magnitudes of non-conventional anomalous movements. In some cases, approximate predictions for the non-conventional ground movements can be made where the underlying geological or topographic conditions are known in advance. It is expected that these methods will improve as further knowledge is gained through ongoing research and investigation.

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.4 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural features and items of surface infrastructure, which are provided in Chapters 5 and 6, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

#### 3.6.3. Non-conventional Subsidence Movements due to Steep Topography

Non-conventional movements can also result from down slope movements where panels are extracted beneath steep slopes. In these cases, elevated tensile strains develop near the tops of the steep slopes and elevated compressive strains develop near the bases of the steep slopes. The potential impacts resulting from down slope movements include tension cracks at the tops of the steep slopes and compression ridges at the bottoms of the steep slopes.

Further discussions on the potential for down slope movements for the steep slopes within the Study Area are provided in Section 5.4 in this report.

#### 3.6.4. Non-conventional Subsidence Movements due to Multi-seam Conditions

Experience of multi-seam mining in the NSW Coalfields indicates that irregular ground movements can develop in the locations of the chain pillars or standing pillars in the existing overlying seam. Mining beneath existing workings can cause reactivation of the existing corbelling strata and existing voids adjacent to stable pillars, resulting in locally increased subsidence adjacent to the pillars and locally reduced subsidence directly above the pillars. Mining beneath unstable pillars or stooks can destabilise the pillars, resulting in locally increased subsidence directly above the pillars. In each of these cases, locally increased tilts, curvatures and ground strains develop as the result of these non-conventional movements.

#### 3.6.5. Valley Related Movements

The watercourses within the Study Area may be subjected to valley related movements, which are commonly observed along stream alignments in the Southern Coalfield, but less commonly observed in the Newcastle and Hunter Coalfields. The reason why valley related movements are less commonly observed in the northern coalfields could be that the conventional subsidence movements are typically much larger than those observed in the Southern Coalfield and, therefore, these movements tend to mask any smaller valley related movements which may occur.

Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.4. The potential for these natural movements are influenced by the geomorphology of the valley.

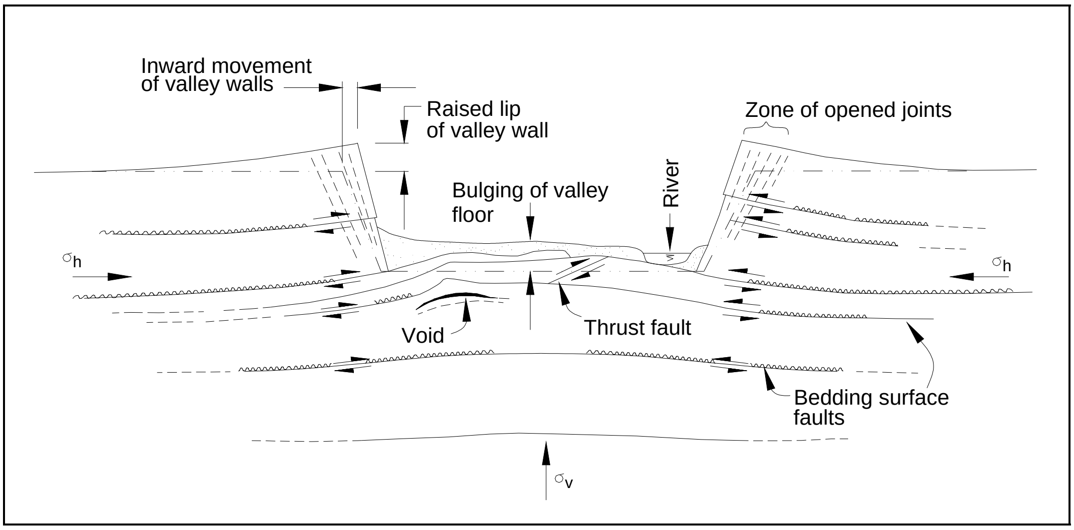


**Fig. 3.4 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)**

Valley related movements can also be caused by or accelerated by mine subsidence as the result of a number of factors, including the redistribution of horizontal in-situ stresses and down slope movements. Mining induced valley related movements are normally described by the following parameters:-

- **Upsidence** is the reduced subsidence within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley. The term uplift is used for the cases where the ground level is raised above the pre-mining level, i.e. when the upsidence is greater than the subsidence. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides.
- **Compressive Strains** occur within the bases of valleys as a result of valley closure and upsidence movements. **Tensile Strains** also occur in the sides and near the tops of the valleys as a result of valley closure movements. The magnitudes of these strains, which are typically expressed in the units of *millimetres per metre (mm/m)*, are calculated as the changes in horizontal distance over a standard bay length, divided by the original bay length.

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in Australian Coal Association Research Program (ACARP) Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

## 3.7. The Incremental Profile Method

The predicted conventional subsidence parameters for the shortwalls and longwalls were determined using the Incremental Profile Method, which was developed by MSEC, formally trading as Waddington Kay and Associates. The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales.

The database consists of detailed subsidence monitoring data from collieries in NSW including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Blakefield South, Bulli, Chain Valley, Clarence, Coalcliff, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Gretley, Invincible, John Darling, Kemira, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, NRE, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each longwall within a series of longwalls. It can be seen from the normalised incremental subsidence profiles within the database, that the observed shapes and magnitudes are reasonably consistent where the mining geometry and local geology are similar.

Subsidence predictions made using the Incremental Profile Method use the database of observed incremental subsidence profiles, the longwall geometries, local surface and seam information and geology. The method has a tendency to over-predict the conventional subsidence parameters (i.e. is slightly conservative) where the mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the mining area.

Further details on the Incremental Profile Method are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

## 3.8. Calibration of the Incremental Profile Method

The available boreholes indicate that the strata layers within the lease are frequently bedded having thickness up to around 10 metres. There were no massive sandstone or conglomerate units identified from the available information and, therefore, the standard Incremental Profile Method for the Newcastle Coalfield was used for the subsidence predictions.

The Incremental Profile Method was calibrated for local conditions using the available ground monitoring data from the existing bord and pillar mining operations within the lease. Donaldson Coal is using *total pillar extraction* techniques in some areas, where the majority of the coal pillars are extracted, leaving only small remnant pillars (i.e. stooks) to support the roof during mining.

The maximum achievable subsidence in the Newcastle Coalfield, for single-seam super-critical conditions, is generally 55 % to 60 % of the effective extracted thickness. The total extraction mining technique can extract up to around 85 % of the available coal (including the coal extracted as part of the *first workings*) and, therefore, the maximum achievable subsidence for this type of mining is typically around 47 % to 51 %, for single-seam conditions.

The locations of the available ground monitoring lines for the previous mining at the Abel Underground Mine are shown in Drawing No. MSEC492-01. The subsidence profiles along these monitoring lines were back-predicted using the standard Incremental Profile Method for the Newcastle Coalfield.

The comparisons between the observed and predicted profiles of subsidence along the *Panel 1 Centreline* and *Panel 1 Crossline* are shown in Fig. 3.5 and Fig. 3.6, respectively.

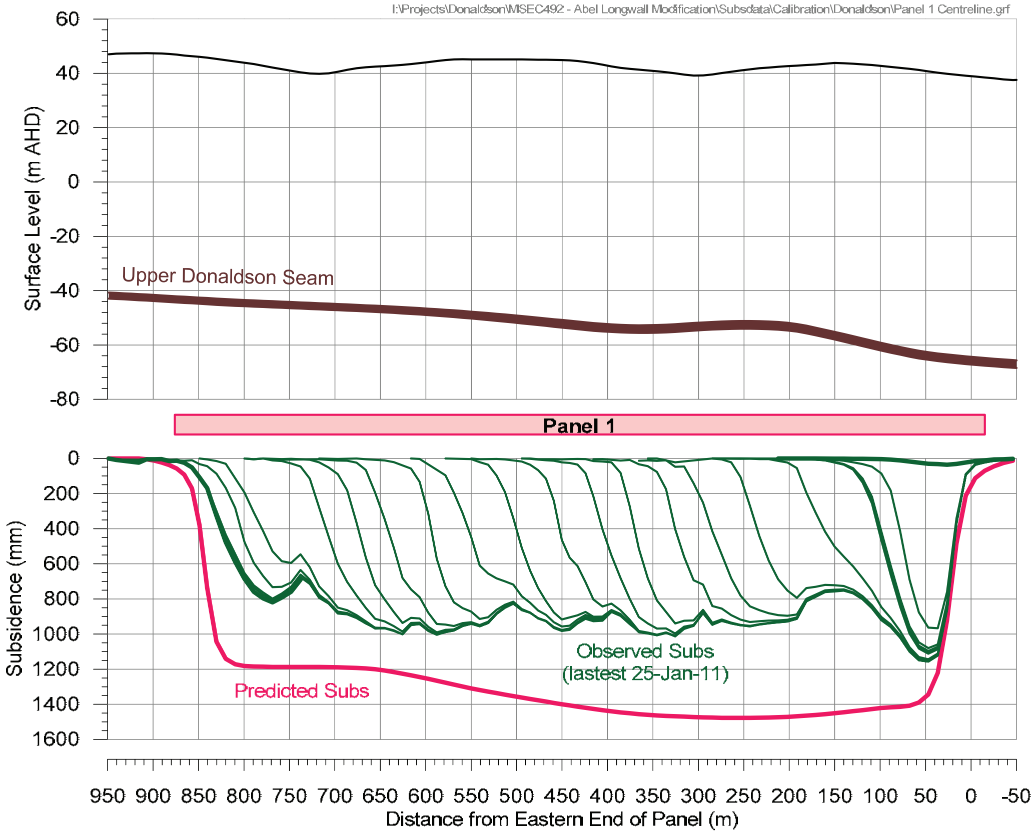


**Fig. 3.5 Comparisons between Observed and Back-Predicted Subsidence for Panel 1 Centreline**

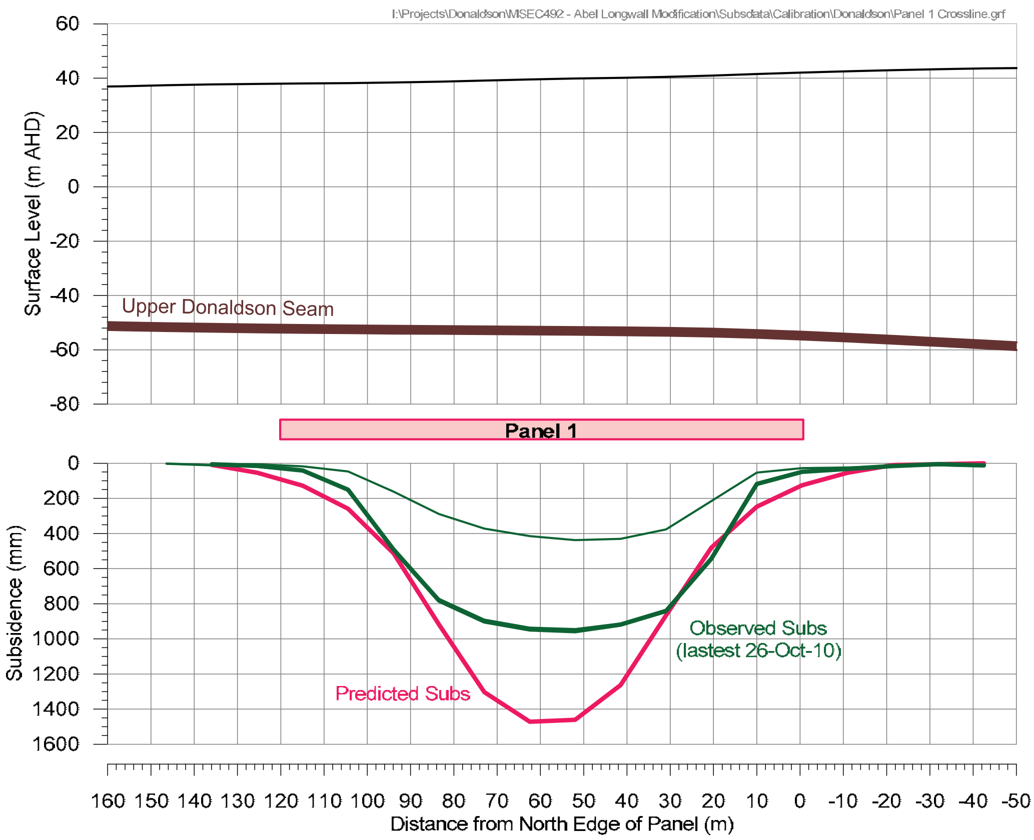


**Fig. 3.6 Comparisons between Observed and Back-Predicted Subsidence for Panel 1 Crossline**

It can be seen from the above figures, that the maximum observed subsidence along these monitoring lines were less than the maximum predicted. The maximum observed subsidence of approximately 1150 mm represents around 41 % of the maximum extraction height of 2.8 metres.

It can be inferred from the steepness of the subsidence profiles, that the maximum observed tilts are reasonably similar to the maxima predicted. The maximum observed tilt is approximately 40 mm/m, which represents a change in grade of around 4 %, or 1 in 25.

It has been considered, therefore, that the standard Incremental Profile Method for the Newcastle Coalfield provides reasonable, if not slightly conservative, predictions for the previous mining within the mining lease. It has not been considered necessary to calibrate the standard method for local conditions, based on the available ground monitoring data.

### 3.8.1. Method of Prediction for Single-seam Conditions

Donaldson Coal proposes to extract shortwalls in the Upper and Lower Donaldson Seams away from the previous mining in the Borehole Seam (i.e. single-seam conditions). The longwalls and the northern ends of the proposed shortwalls in the Lower Donaldson Seam, however, are located beneath the historic workings in the Borehole Seam and the discussions on the calibration for multi-seam conditions are provided in Section 3.8.2.

The overall void widths of the shortwalls are proposed to be 120 metres and the widths of the chain pillar are proposed to be 20 metres to 25 metres. The width-to-depth ratios of the shortwalls in the Upper Donaldson Seam typically vary between 0.6 (at a maximum depth of cover of 200 metres) and 2.4 (at a minimum depth of cover of 50 metres). The width-to-depth ratios of the shortwalls in the Lower Donaldson Seam typically vary between 0.4 (at a maximum depth of cover of 300 metres) and 0.8 (at a minimum depth of cover of 150 metres).

The shortwalls therefore range between sub-critical conditions (width-to-depth ratios less than 0.7) through to super-critical conditions (width-to-depth ratios greater than 1.4). The empirical database includes mining cases with these ranges of width-to-depth ratios. This is illustrated in Fig. 3.7, which shows the distribution of the panel width-to-depth ratio for the case in the empirical database.

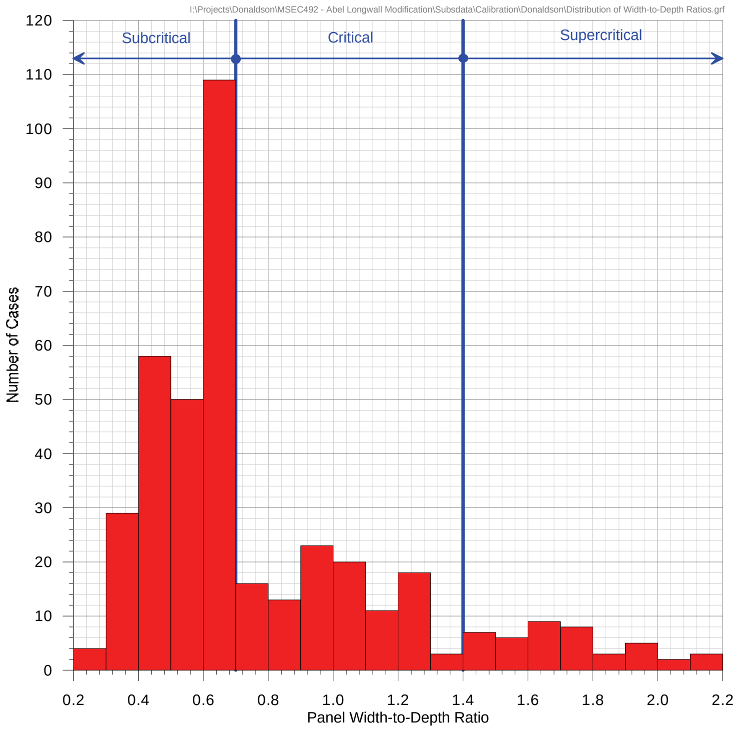


**Fig. 3.7 Distribution of Panel Width-to-Depth Ratio from the Empirical Database**

The maximum achievable subsidence in the Newcastle Coalfield, for single-seam super-critical conditions, is generally 55 % to 60 % of the effective extracted thickness. For this study, the maximum predicted subsidence for the proposed shortwalls in the Upper and Lower Donaldson Seams has been taken as 60 % of the extraction thickness.

The comparisons between the observed and predicted profiles of subsidence, tilt and curvature for monitoring lines in the Newcastle and Hunter Coalfields, where the panel width-to-depth ratios are 0.4, 0.7 and greater than 2.0, are shown in Fig. 3.8, Fig. 3.9 and Fig. 3.10, respectively.

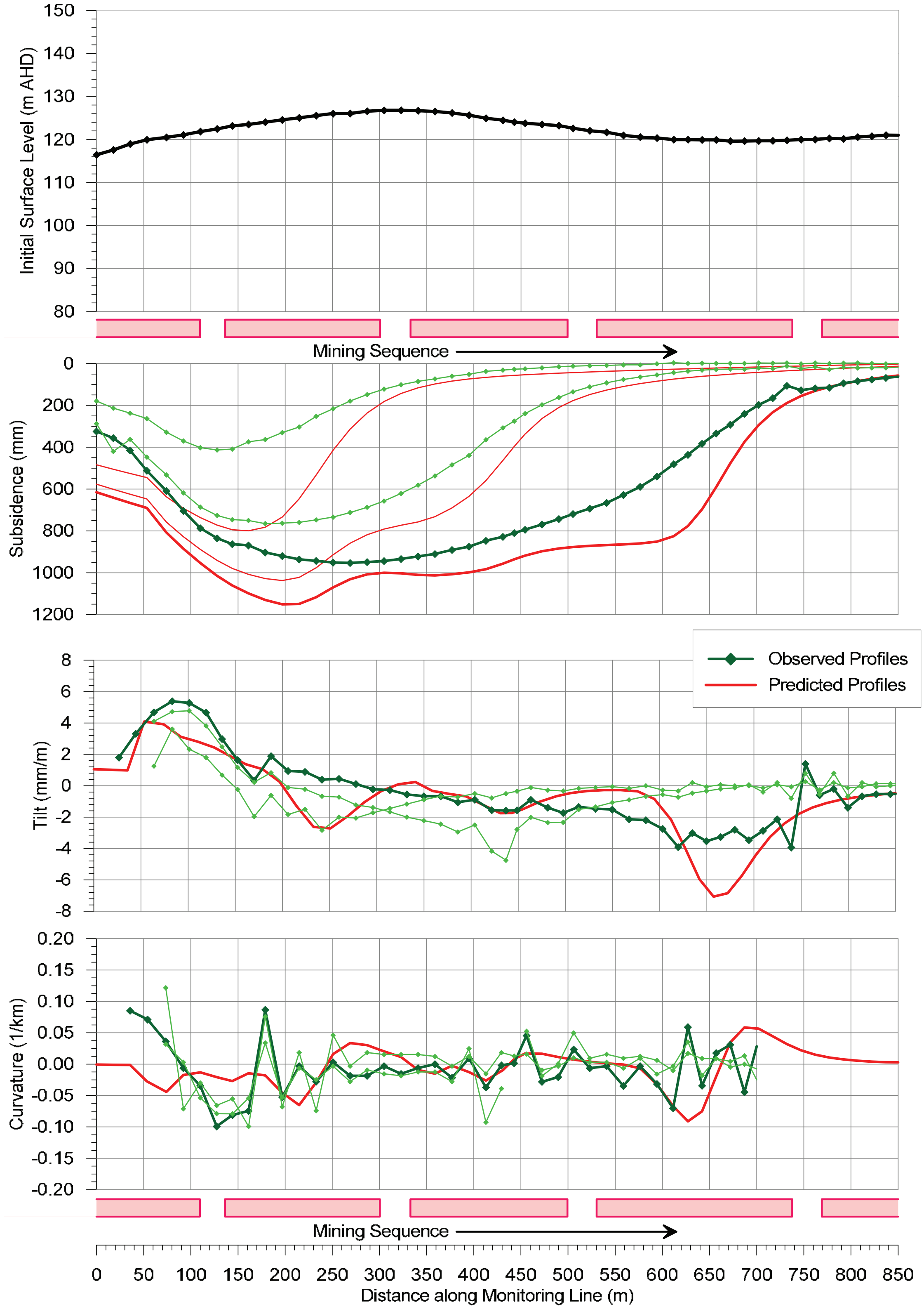


**Fig. 3.8 Comparison of Observed and Back-Predicted Subsidence, Tilt and Curvature along a Monitoring Line in the Newcastle Coalfield with Panel W/H Ratio around 0.4**

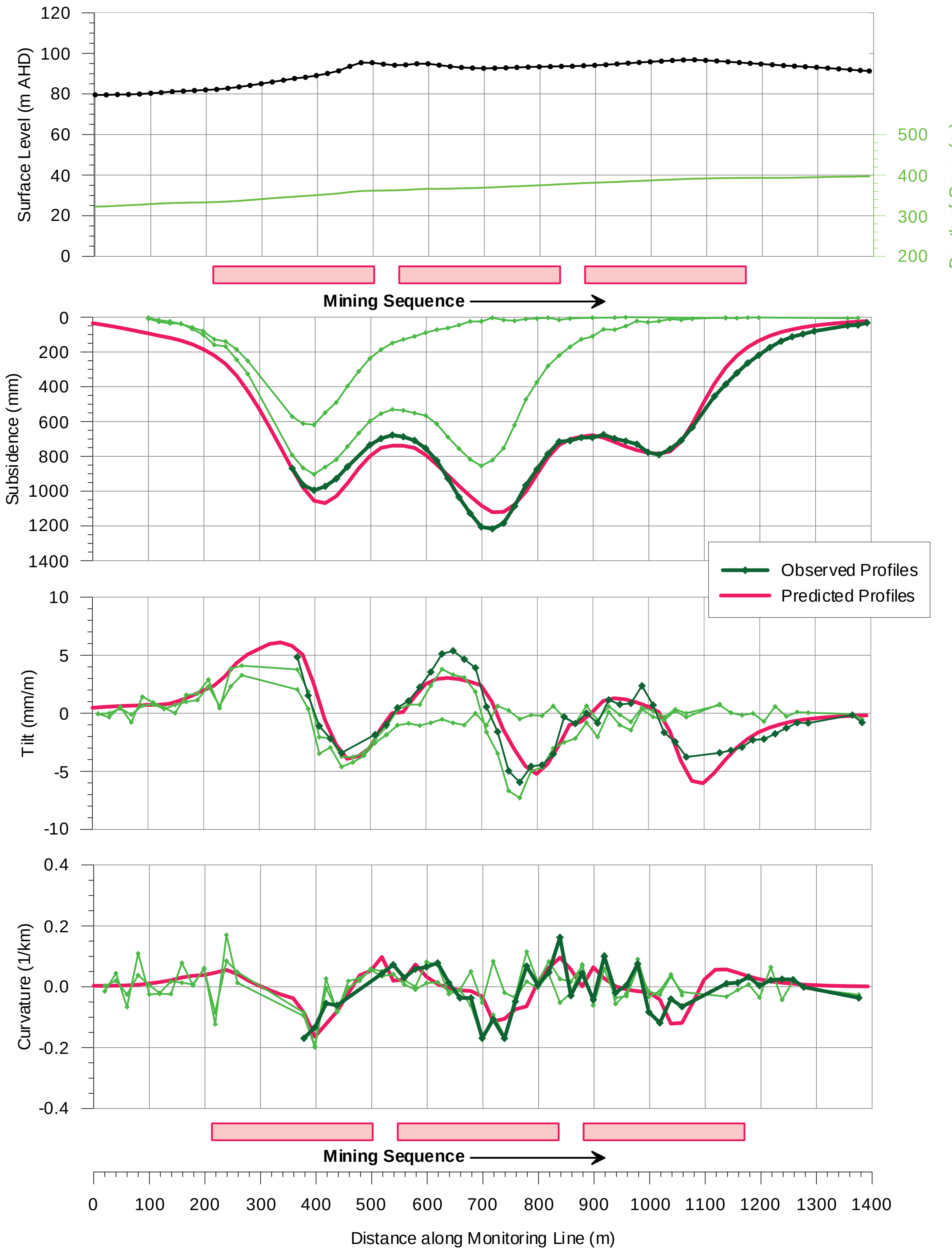


**Fig. 3.9 Comparison of Observed and Back-Predicted Subsidence, Tilt and Curvature along a Monitoring Line in the Hunter Coalfield with Panel W/H Ratio around 0.7**

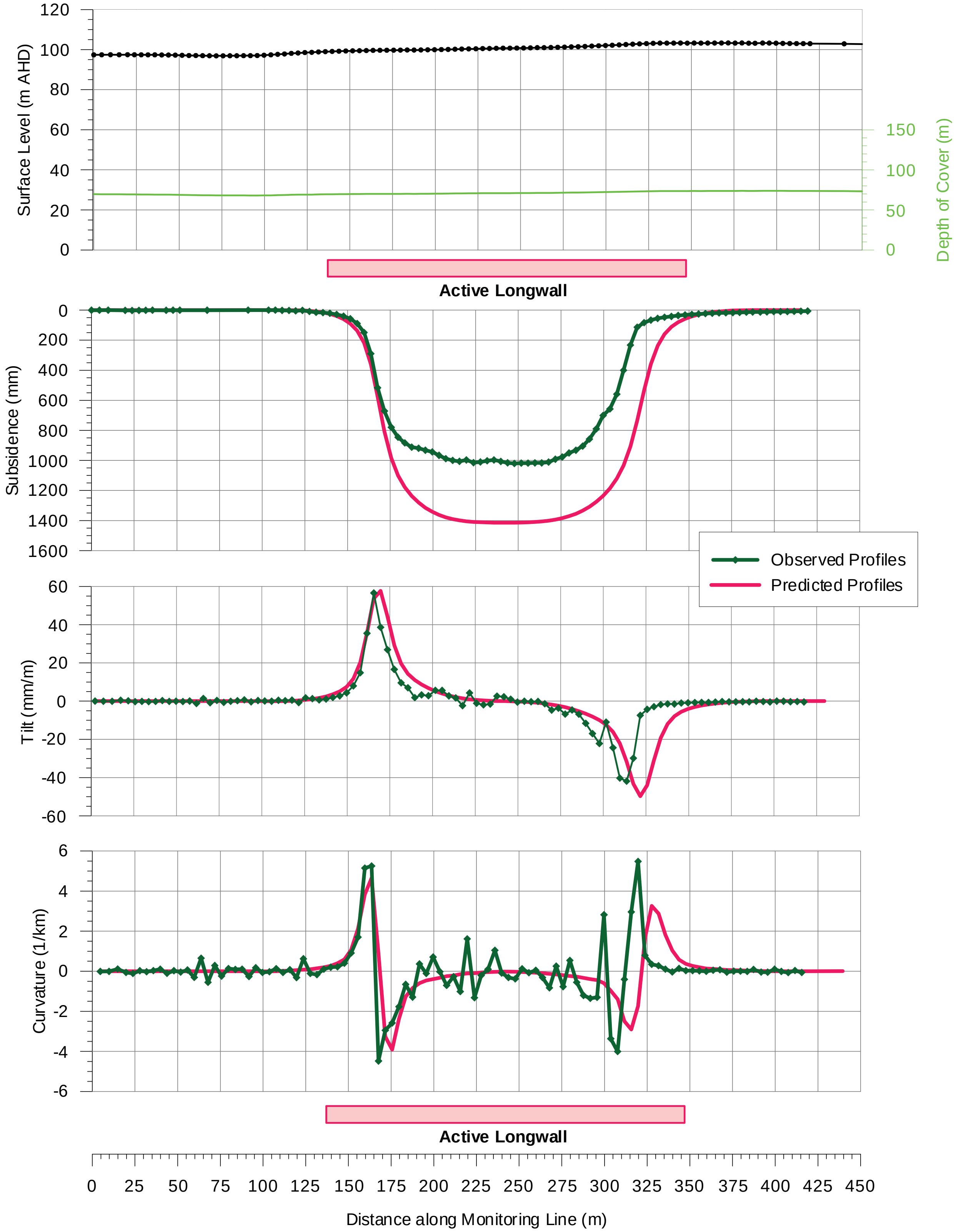


**Fig. 3.10 Comparison of Observed and Back-Predicted Subsidence, Tilt and Curvature along a Monitoring Line in the Hunter Coalfield with Panel W/H Ratio Greater than 2.0**

It can be seen from the above figures, that the observed profiles of subsidence, tilt and curvature along these monitoring lines reasonably match those back-predicted using the standard Incremental Profile Method for the Newcastle Coalfield. In some locations, there are small lateral shifts between the observed and predicted profiles, which could be the result of surface dip, seam dip, or variations in the overburden geology.

The maximum observed subsidence along the monitoring lines were similar to or less than the maxima predicted using the standard Incremental Profile Method. In Fig. 3.10, the longwall was super-critical and, in this case, the standard Incremental Profile Method adopted a maximum achievable subsidence of 65 % of extracted seam thickness, whereas the maximum observed subsidence was around 45 % of the extracted seam thickness.

The magnitudes of the observed tilts and curvatures along the monitoring lines were also reasonably similar to those predicted using the standard Incremental Profile Method. It can be seen, however, that the observed tilts and curvatures were less than those predicted, in some locations, whilst the observed tilts and curvatures exceed those predicted in other locations. This demonstrates the difficultly in predicting tilts and curvatures at a point, especially at shallow depths of cover. It is important then to recognise, that there is greater potential for variation between observed and predicted movements at a point as the depth of cover decreases.

Based on these comparisons, it has been considered that the standard Incremental Profile Method for the Newcastle Coalfield provides reasonable predictions of subsidence, tilt and curvature in these cases, where the panel width-to-depth ratios are 0.4, 0.7 and greater than 2.0. It has not been considered necessary, therefore, to provide any specific calibration of the standard model for the proposed shortwalls and longwalls in the Upper and Lower Donaldson Seams.

### 3.8.2. Method of Prediction for Multi-seam Conditions

The thin seam pillar extraction panels in the Upper Donaldson Seam are proposed to be extracted beneath the historic Stockrington No. 2 Colliery workings in the overlying Borehole Seam. The proposed longwalls in the Lower Donaldson Seam will then extracted beneath the proposed thin seam pillar extraction panels in the Upper Donaldson Seam. Also, the northern ends of the proposed shortwalls in the Lower Donaldson Seam are also located beneath the historic workings in the Borehole Seam.

The following sections provide discussions on the calibration of the Incremental Profile Method for multi-seam conditions for the proposed thin seam pillar extraction panels, longwalls and shortwalls.

*Calibration for the Proposed Thin Seam Pillar Extraction Panels*

The thin seam pillar extraction panels in the Upper Donaldson Seam are proposed to be extracted beneath the historic workings in the overlying Borehole Seam, which are shown in Drawing No. MSEC492-11. The extents of the historic pillar extraction shown in this drawing were determined by Donaldson Coal using the record tracings. It can be seen from this drawing, that the majority of the historic workings in the proposed mining area are first workings only (i.e. standing pillars), with only small areas of total extraction.

The historic Stockrington No. 2 Colliery workings appear to have been mined using the *Welsh Bord* extraction method, at depths of cover ranging between 35 metres and 112 metres (Strata Engineering [SE], 2006). The conditions of these workings and whether the remnant pillars are standing or completely collapsed are not known (SE, 2006). It is noted, that investigations of other nearby historic workings in the Borehole Seam, as part of the construction for the Hunter Expressway, found that large areas of pillars were still standing, but also found areas with timber roof supports where pillars had been removed, and other areas with standing pillars which were indicated as full extraction on the record tracings (Kingsland, et al, 2011).

The remnant pillar sizes are typically 35 metres by 11 metres, but in some areas the remnant pillars reduce to 14 metres by 11 metres. The roadways are typically 5.5 metres wide. The percentage void area based on the typical pillar size, therefore, can be determined as follows:-

**Equation 1** $$A_{void} = 1.0 - \frac{35 * 11}{(35 + 5.5) * (11 + 5.5)} = 0.42$$ (i.e. 42 % void area)

The thickness of the Borehole Seam is believed to be approximately 2.5 metres. The maximum achievable subsidence in the Newcastle Coalfield, for a critical width of extraction and single-seam conditions, is generally 55 % to 60 % of the extracted seam thickness. The maximum achievable subsidence due to the reactivation of the historic workings in Borehole Seam, therefore, has been calculated as follows:-

**Equation 2** $$S_{bh.\max} = 0.42 * 0.60 * 2.5m = 0.7m$$

The interburden thickness between the proposed thin seam pillar extraction panels and the historic workings varies between approximately 200 metres and 220 metres. The width-to-depth ratios for these panels, based on the interburden thickness, therefore, are around 0.7 to 0.8 (i.e. sub-critical to critical widths).

The maximum predicted subsidence for the thin seam pillar extraction panels, therefore, has been taken as that predicted for single-seam mining conditions plus an additional 700 mm due to the reactivation of the historic workings in the Borehole Seam.

Whilst the record tracings indicate that the majority of the historic workings in the proposed mining area are first workings only (i.e. standing pillars), it is possible that the areas of pillar extraction could be larger than those shown. If there are areas with partial extraction, or areas with total extraction where the stooks have remained stable, it is possible that the subsidence resulting from the reactivation of the Borehole Seam could be greater than described above.

The upperbound subsidence for the reactivation of the historic workings in the Borehole Seam, assuming total extraction where the stooks have remained stable, can be calculated as follows:-

**Equation 3** $$S_{bh.upperbound} = V_{bh} * S_{\max} * T_{bh}$$

where $V_{bh}$ = Percentage (%) volume of the voids in the Borehole Seam, taken as 85 % based on 15 % stooks,

$S_{max}$ = Maximum achievable subsidence for single-seam super-critical conditions, taken as 60 % for the Newcastle Coalfield, and

$T_{bh}$ = Thickness of the Borehole Seam, which is believed to be 2.5 metres.

The upperbound subsidence resulting from the reactivation of the historic workings in the Borehole Seam, therefore, is approximately 1300 mm, which represents 50 % of the seam thickness (i.e. 85 % x 60 %).

Whilst there is some uncertainty with the maximum predicted subsidence for the proposed thin seam pillar extraction panels, due to the conditions of the historic workings in the overlying Borehole Seam, the surface above the proposed panels mostly comprises natural bushland with limited surface features. The impact assessment for the natural features and surface infrastructure located above the proposed panels, provided in Chapters 5 and 6, include discussions based on both the predicted and upperbound subsidence due to the reactivation of the historic workings.

It is recommended that the historic workings in the Borehole Seam are investigated further, as part of the Extraction Plan Applications for the thin seam pillar extraction panels and longwalls, to confirm the existing conditions of these workings. It is also recommended that pillar stability assessments are undertaken, based on the findings of these investigations, so that the multi-seam subsidence predictions can be further refined.

*Calibration for the Proposed Longwalls*

The proposed LDLW1 to LDLW5 in the Lower Donaldson Seam will then be extracted beneath the proposed thin seam pillar extraction panels in the Upper Donaldson Seam. The predictions for the thin seam pillar extraction panels assumed the full reactivation of the historic workings in the Borehole Seam. The predicted subsidence resulting from the extraction of the proposed LDLW1 to LDLW5, therefore, includes the additional subsidence due to the reactivation of the proposed thin seam pillar extraction panels in the Upper Donaldson Seam, but assumes negligible reactivation of the historic workings in the Borehole Seam.

Monitoring data from multi-seam longwall mining in the NSW Coalfields and overseas show that the maximum subsidence, as proportions of the extracted seam heights, are greater than those for equivalent single-seam mining cases. The monitoring data from the multi-seam cases also show that the shapes of the subsidence profiles are affected by the locations and stabilities of the overlying goafs and pillars in the previously extracted seam as the longwalls in the lower seam passes underneath.

Empirical multi-seam data for longwall mining beneath total extractions include the following cases:-

- Newstan Colliery Longwalls 1, 2, 3 and 4 – below extracted pillar workings,
- Wyee Colliery Longwalls 1, 2, 3, 4, 7 and 9 – below extracted pillar workings,
- John Darling Colliery Longwall 1 – below extracted pillar workings,
- Teralba Colliery Longwalls 6, 7, 8 and 9 – below extracted pillar workings, and
- Kemira Colliery Longwalls 1 to 6 – below extracted pillar workings.

Other empirical multi-seam data for longwalls mining beneath longwalls include the following cases:-

- Newstan Colliery, LW8 in the Fassifern Seam – below LW6 in the Great Northern Seam,
- Sigma Colliery (South Africa), LW4A in the No. 2B Seam – below LW4 in the No. 3 Seam,
- Liddell Colliery, Longwall 3 in the Middle Liddell Seam – below LW1 in the Upper Liddell Seam,
- Cumnock Colliery, LW17 in the Lower Pikes Gully Seam – below LW3 in the Liddell Seam, and
- Blakefield South, LW1 in the Blakefield Seam – below longwalls in the Whybrow Seam.

The empirical multi-seam data for these cases are illustrated in Fig. 3.11, below, which shows the maximum observed subsidence, as a proportion of the extracted seam thickness, versus the longwall width-to-depth ratio. The multi-seam cases for longwalls mining beneath bord and pillar workings are shown as the red diamonds and the cases for longwalls mining beneath longwalls are shown as the blue diamonds. Single-seam mining cases are also shown in this figure, for comparison, as the light grey diamonds.

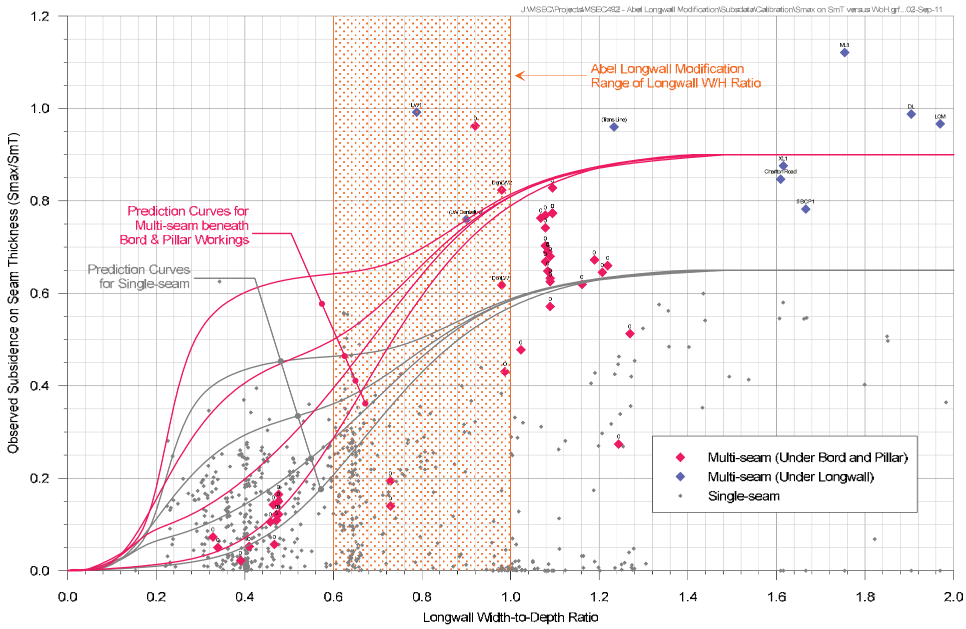


**Fig. 3.11 Maximum Observed Subsidence versus Longwall Width-to-Depth Ratio for Historical Multi-seam Mining Cases**

It can be seen from the above figure, that the maximum observed subsidence, as a proportion of the extracted seam thickness, for multi-seam cases are greater than those for single-seam cases having similar width-to-depth ratios.

The typical prediction curves used for single-seam mining conditions are shown as the grey lines, in the above Fig. 3.11, for various mine geometries. These prediction curves have been scaled up, so as to achieve a maximum predicted incremental subsidence of 90 % of extracted seam thickness, which are shown as the red curves in this figure. It can be seen, that these prediction curves provide reasonable estimates of the maximum subsidence for the multi-seam cases for longwalls beneath bord and pillar workings (i.e. red diamonds).

The multi-seam prediction curves provide subsidence around 40 % greater than those obtained using the standard single-seam prediction curves. In reality, the additional subsidence, due to multi-seam mining conditions, will be dependent on a number of factors, including the interburden thickness, the extraction heights in both seams, the conditions of the remnant pillars in the overlying seam.

It is considered, that the multi-seam prediction curves, illustrated in Fig. 3.11 as the red curves, should provide reasonable predictions of the maximum subsidence, as a proportion of the extraction height, for the proposed longwalls.

*Calibration for the Proposed Shortwalls*

The northern ends of the proposed shortwalls in the Lower Donaldson Seam are also located beneath the historic workings in the Borehole Seam. The historic workings in this location are less than 10 metres from the surface within the base of the Black Hill Quarry. The interburden thickness between the Borehole Seam and the Lower Donaldson Seam is around 225 metres.

The subsidence for the proposed shortwalls, based on multi-seam conditions, has used the same approach as for the proposed thin seam pillar extraction panels. That is, the maximum predicted subsidence for the shortwalls has been taken as that predicted for single-seam mining conditions plus an additional 700 mm due to the reactivation of the historic workings in the Borehole Seam.

As described for the proposed thin seam pillar extraction panels, it is possible that the subsidence resulting from the reactivation of the Borehole Seam could be greater, if there are areas with partial extraction, or areas with total extraction where the stooks have remained stable. For this reason, an upperbound subsidence resulting from the reactivation of the historic workings in the Borehole Seam, of 1300 mm, has also been considered in the impact assessments provided in Chapters 5 and 6.

*Shapes of the Multi-seam Subsidence Profiles*

The multi-seam mining cases for mining beneath bord and pillar extractions indicate that the observed subsidence profiles are flatter and wider than those for the equivalent single-seam mining conditions. This is the result of the reactivation of the goaf and pillars outside the extent of the mining. This is illustrated in Fig. 3.12, which compares the observed subsidence profiles for multi-seam cases with those for single-seam cases in the Newcastle Coalfield.

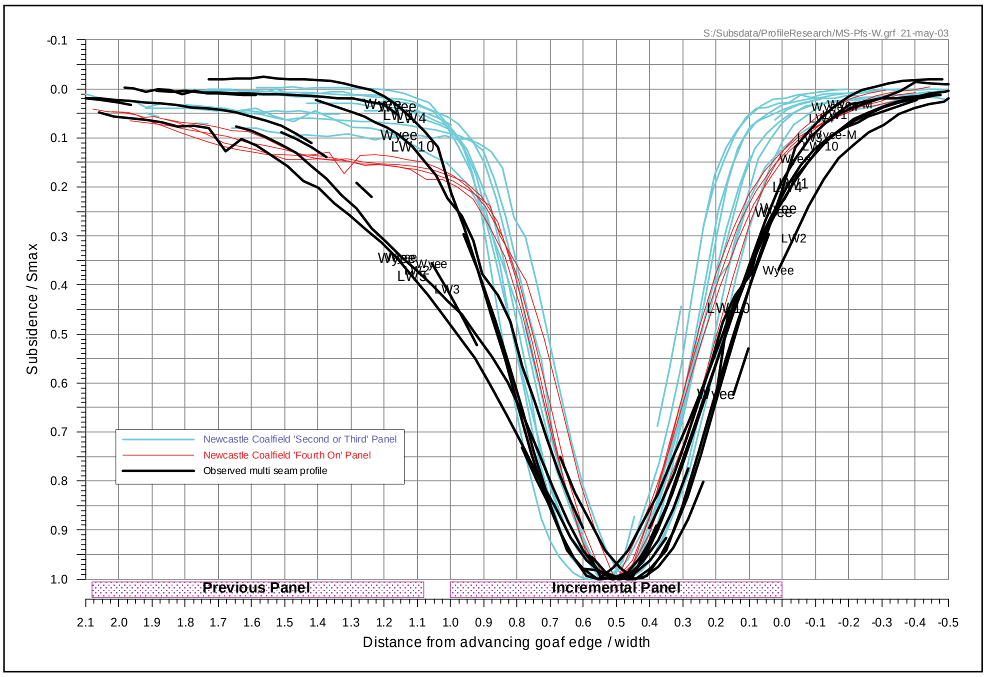


**Fig. 3.12 Comparison of Observed Single-seam and Multi-seam Subsidence Profiles**

The shapes of the subsidence profiles for multi-seam conditions are expected to more irregular, when compared with those resulting from single-seam mining conditions, due to subsidence developing from various components, including the yielding and destabilisation of overlying pillars and the re-activation of the overlying goaf. The potential for irregular movements are discussed further in the impact assessments provided in Chapters 5 and 6 of this report.

## 3.9. Reliability of the Predicted Conventional Subsidence Parameters

The Incremental Profile Method is based upon a large database of observed subsidence movements in the NSW Coalfields and has been found, in most cases, to give reasonable, if not, slightly conservative predictions of maximum subsidence, tilt and curvature. The predicted profiles obtained using this method also reflect the way in which each parameter varies over the mined area and indicate the movements that are likely to occur at any point on the surface.

The prediction of the conventional subsidence parameters at a specific point is more difficult. Variations between predicted and observed parameters at a point can occur where there is a lateral shift between the predicted and observed subsidence profiles, which can result from seam dip or variations in topography. In these situations, the lateral shift can result in the observed parameters being greater than those predicted in some locations, whilst the observed parameters being less than those predicted in other locations.

The prediction of strain at a point is even more difficult as there tends to be a large scatter in observed strain profiles. It has been found that measured strains can vary considerably from those predicted at a point, not only in magnitude, but also in sign, that is, the tensile strains have been observed where compressive strains were predicted, and vice versa. The following reasons contribute to why strain predictions cannot be provided with the same degree of confidence as subsidence and tilt predictions:-

- Variations in local geology can affect the way in which the near surface rocks are displaced as subsidence occurs. In the compression zone, the surface strata can buckle upwards or can fail by shearing and sliding over their neighbours. If the surface strata layers are thinly bedded or if localised cross bedding exists within the top strata layer, then shearing can occur at relatively low values of stress. These variations in the local geology can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zones around mined voids, existing joints can be opened up at relatively low strain values and new fractures can be formed at random, leading to localised concentrations of tensile strain.

- Where a thick surface layer of soil, clay or rock exists, the underlying movements in the bedrock are often transferred to the surface at reduced levels and the measured strains are, therefore, more evenly distributed and hence more conventional in nature than they would be if they were measured at rockhead.
- Strain measurements can sometimes give a false impression of the state of stress in the ground. For example:-
    - buckling of the near-surface strata can result in localised cracking and apparent tensile strain in areas where overall, the ground is in fact being compressed, because the actual values of the measured strains are dependent on the locations of the survey pegs.
    - where existing natural joints open up or new cracks develop in the tensile phase, it may be difficult for these joints to close up during the compressive phase, if the joints fill with soil or if shearing occurs during the movements. In these cases, the ground can appear to be in tension when, in reality, it is actually in compression.
- Sometimes, survey limitations or errors can also affect the measured strain values and these can result from movement in the benchmarks, inaccurate instrument readings, or disturbed survey pegs. In these circumstances it is not surprising that the predicted conventional strain at a point does not match the measured strain. For example, it is difficult to measure variations in baylengths more accurately than ±5 mm, especially where tripods have to be set over sunken survey marks. Over a typical baylength of 20 metres, surveying error variations of ±0.25 mm/m are commonly seen in the observed strain data.
- In sandstone dominated environments, much of the earlier tensile ground movements can be concentrated at existing natural joints. These concentrations of strain at these pre-existing joints results in higher strain values being observed at the natural joints accompanied by lower values between the joints.
- Current conventional horizontal movement prediction methods are principally based on factors being applied to the predicted ground curvature movements and do not account for the release of in situ horizontal stress, the far-field movement mechanisms or valley related movements.
- It is also recognised that the ground movements above a panel can be affected by the gradient of the coal seam, the direction of mining and the presence of faults and dykes above the panel, which can result in a lateral shift in the subsidence profile.

It is also likely that some localised irregularities will occur in the subsidence profiles due to near surface geological features. The irregular movements are accompanied by elevated tilts, curvatures and strains, which often exceed the conventional predictions. In most cases, it is not possible to predict the locations or magnitudes of these irregular movements. For this reason, the strain predictions provided in this report are based on a statistic analysis of measured strains in the Newcastle and Hunter Coalfields, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. Further discussions on irregular movements are provided in Section 4.7.

The Incremental Profile Method approach allows site specific predictions for each natural feature or item of infrastructure and hence provides a more realistic assessment of the subsidence impacts than by applying the maximum predicted parameters at every point, which would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts.

There is greater uncertainty for the multi-seam subsidence predictions where the proposed thin seam pillar extraction panels, shortwalls and longwalls will be extracted beneath the historic workings in the Borehole Seam. For this reason, impact assessments have been provided in this report based on upperbound subsidence predictions, where the standing pillars have been assumed to fully collapse as the result of the proposed mining. It is also noted, that the surface above the historic workings mostly comprises natural bushland with limited surface features.

It has been recommended that the historic workings in the Borehole Seam are investigated further, as part of the Extraction Plan Applications for the thin seam extraction panels, shortwalls and longwalls, to confirm the existing conditions of these workings. It has also recommended that pillar stability assessments are undertaken, based on the findings of these investigations, so that the multi-seam subsidence predictions can be further refined.

### 3.10. Reliability of the Predicted Upsidence and Closure Movements

The predicted valley related movements resulting from the proposed mining were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

The development of the predictive methods for upsidence and closure are the result of recent and ongoing research and the methods do not, at this stage, have the same confidence level as conventional subsidence prediction techniques. As further case histories are studied, the method will be improved, but it can be used in the meantime, so long as suitable factors of safety are applied. This is particularly important where the predicted levels of movement are small, and the potential errors, expressed as percentages, can be higher.

Whilst the major factors that determine the levels of movement have been identified, there are some factors that are difficult to isolate. One factor that is thought to influence the upsidence and closure movements is the level of in-situ horizontal stress that exists within the strata. In-situ stresses are difficult to obtain and not regularly measured and the limited availability of data makes it impossible to be definitive about the influence of the in-situ stress on the upsidence and closure values. The methods are, however, based predominantly upon the measured data from Tower Colliery in the Southern Coalfield, where the in-situ stresses are high. The methods should, therefore, tend to over-predict the movements in areas of lower stress.

## 4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the proposed shortwalls, longwalls and thin seam workings, based on the *Modified Layout*. The predicted subsidence parameters and the impact assessments for the natural features and items of surface infrastructure are provided in Chapters 5 and 6.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and show the conventional movements and do not include the valley related upsidence and closure movements, nor the effects of faults and other geological structures. Such effects have been addressed separately in the impact assessments for each feature.

## 4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

The subsidence predictions provided in this report were determined using the Incremental Profile Model, which is described in Sections 3.7 and 3.8. The predicted subsidence contours, resulting from the extraction of the proposed shortwalls, longwalls and thin seam pillar extraction panels in the Upper and Lower Donaldson Seams, based on the *Modified Layout*, are shown in Drawing No. MSEC492-20.

The maximum predicted total subsidence resulting from the extraction of the proposed thin seam pillar extraction panels in the Upper Donaldson Seam and proposed longwalls in the Lower Donaldson Seam (i.e. multi-seam mining) is 3100 mm. The maximum predicted total subsidence resulting from the extraction of the proposed shortwalls in the Upper and Lower Donaldson Seams is 1700 mm.

It can be seen from these drawings, that the magnitudes of the predicted subsidence varies across the extents of the modified mining areas, as a result of variations in the depths of cover, extraction heights, methods of mining and multi-seam mining conditions. It can also be inferred from the spacing of the contours shown in these drawings, that the magnitudes of the predicted tilts and curvatures also vary over the extents of the modified mining areas.

To illustrate the variation in the subsidence parameters across the mining areas, the predicted profiles of conventional subsidence, tilt and curvature have been determined along two predictions lines, the locations of which are shown in Drawing No. MSEC492-20. The predicted profiles of conventional subsidence, tilt and curvature along Prediction Lines 1 and 2 are shown in Figs. C.01 and C.02, respectively, in Appendix C.

Summaries of the maximum predicted conventional subsidence parameters for the thin seam workings, shortwalls and longwalls, based on the *Modified Layout*, are provided in the following sections.

### 4.2.1. First Workings in the Thin Seam Areas of the Upper Donaldson Seam

The proposed first workings in the thin seam areas of the Upper Donaldson Seam are shown in Drawing No. MSEC492-02. The first workings are designed to be stable and self-supporting and, therefore, are not expected to result in any measurable subsidence at the surface (i.e. less than 20 mm of vertical subsidence).

Provided that the first workings are designed to be stable as the proposed shortwalls in the Lower Donaldson Seam are mined beneath them, then no additional subsidence is expected to result from presence of these workings (i.e. equivalent to single-seam mining conditions).

The predicted tilts, curvatures and strains resulting from the extraction of the first workings are negligible and are not expected to be measurable at the surface using normal ground monitoring techniques.

### 4.2.2. Shortwalls in the Upper and Lower Donaldson Seams

The locations of the proposed shortwalls in the Upper Donaldson Seam are shown in Drawing No. MSEC492-02. A summary of the maximum predicted values of total conventional subsidence, tilt and curvatures for these shortwalls is provided in Table 4.1.

**Table 4.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures due to the Extraction of the Shortwalls in the Upper Donaldson Seam**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| UDSW1 to UDSW7 | 1700 | 60 | 2.5 | 2.5 |

The maximum predicted subsidence resulting from the extraction of the shortwalls in the Upper Donaldson Seam is 1700 mm, which represents around 60 % of the maximum extraction height of 2.8 metres. The maximum predicted tilt is 60 mm/m (i.e. 6 %), which represents a change in grade of 1 in 17.

The maximum predicted conventional curvature resulting from the extraction of the shortwalls in the Upper Donaldson Seam are 2.5 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvature of 0.4 kilometre.

It is noted, that the maximum predicted tilt and curvatures for the shortwalls in the Upper Donaldson Seam occur in the north-eastern corner of the mining area, where the minimum depth of cover is around 50 metres. Elsewhere, the depths of cover above these shortwalls typically range between 70 metres and 200 metres. The predicted tilts and curvatures above the shortwalls in the Upper Donaldson Seam, therefore, are generally less than the maxima provided in Table 4.1.

The locations of the proposed shortwalls in the Lower Donaldson Seam are shown in Drawing No. MSEC492-03. A summary of the maximum predicted values of total conventional subsidence, tilt and curvatures for these shortwalls is provided in Table 4.2.

**Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures due to the Extraction of Shortwalls in the Lower Donaldson Seam**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| LDSW1 to LDSW4 | 1700 | 25 | 1.0 | 1.5 |

The maximum predicted subsidence resulting from the extraction of the shortwalls in the Lower Donaldson Seam is 1700 mm, which represents around 60 % of the maximum extraction height of 2.8 metres. It is noted, that the maximum predicted subsidence occurs at the northern ends of the proposed shortwalls and includes the additional subsidence resulting from the reactivation of the historic workings in the overlying Borehole Seam (i.e. multi-seam conditions).

The maximum predicted tilt is 25 mm/m (i.e. 2.5 %), which represents a change in grade of 1 in 40. The maximum predicted conventional curvatures resulting from the extraction of the shortwalls in the Lower Donaldson Seam are 1.0 $km^{-1}$ hogging and 1.5 $km^{-1}$ sagging, which represent minimum radii of curvature of 1.0 kilometre and 0.7 kilometres, respectively.

As described in Section 3.8.2, the predicted subsidence at the northern ends of the proposed shortwalls includes an additional subsidence of 700 mm resulting from the reactivation of the historic workings in the overlying Borehole Seam. As described in that section, it is possible that the subsidence resulting from the reactivation of the Borehole Seam could be greater, if there are areas with partial extraction, or areas with total extraction where the stooks have remained stable. For this reason, an upperbound additional subsidence resulting from the reactivation of the historic workings in the Borehole Seam, of 1300 mm, has also been considered in the impact assessments provided in Chapters 5 and 6.

### 4.2.3. Pillar Extraction Panels in the Thin Seam Areas of the Upper Donaldson Seam

The extents of the proposed thin seam pillar extraction panels in the Upper Donaldson Seam are shown in Drawing No. MSEC492-02. A summary of the maximum predicted values of total conventional subsidence, tilt and curvatures resulting from the extraction of these panels, beneath the historic workings in the overlying Borehole Seam, is provided in Table 4.3. The calibration of the Incremental Profile Method for multi-seam conditions is described in Section 3.8.2.

**Table 4.3 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature due to the Extraction of the Thin Seam Pillar Extraction Panels in the Upper Donaldson Seam**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| UDBP1 to UDBP4 (Thin Seam Pillar Extraction Panels) | 1300 | 15 | 0.5 | 0.5 |

The maximum predicted subsidence resulting from the mining of the thin seam pillar extraction panels in the Upper Donaldson Seam is 1300 mm, which represents around 80 % of the average extraction height of 1.6 metres. It is noted, that the maximum predicted subsidence is greater than 60 % of seam thickness (i.e. maximum for single-seam conditions) due to the additional subsidence resulting from the reactivation of the historic workings in the overlying Borehole Seam (i.e. multi-seam conditions).

The maximum predicted tilt is 15 mm/m (i.e. 1.5 %), which represents a change in grade of 1 in 65. The maximum predicted conventional curvature resulting from the extraction of the thin seam pillar extraction panels in the Upper Donaldson Seam are 0.5 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvature of 2 kilometres.

As described in Section 3.8.2, the predicted subsidence for the thin seam pillar extraction panels includes an additional subsidence of 700 mm resulting from the reactivation of the historic workings in the overlying Borehole Seam. As described in that section, it is possible that the subsidence resulting from the reactivation of the Borehole Seam could be greater, if there are areas with partial extraction, or areas with total extraction where the stooks have remained stable. For this reason, an upperbound additional subsidence resulting from the reactivation of the historic workings in the Borehole Seam, of 1300 mm, has also been considered in the impact assessments provided in Chapters 5 and 6.

### 4.2.4. Longwalls in the Lower Donaldson Seam

The locations of the proposed longwalls in the Lower Donaldson Seam are shown in Drawing No. MSEC492-03. A summary of the maximum predicted values of total conventional subsidence, tilt and curvatures for these longwalls, beneath the proposed thin seam pillar extraction panels and historic workings, is provided in Table 4.4. The calibration of the Incremental Profile Method for multi-seam conditions is described in Section 3.8.2.

**Table 4.4 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature due to the Extraction of Longwalls in the Lower Donaldson Seam**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| LDLW1 to LDLW5 | 2100 | 25 | 0.7 | 0.7 |

The maximum predicted subsidence resulting from the extraction of the longwalls in the Lower Donaldson Seam is 2100 mm, which represents around 75 % of the maximum extraction height of 2.8 metres. It is noted, that the maximum predicted subsidence is greater than 60 % of seam thickness (i.e. maximum for single-seam conditions) due to the additional subsidence resulting from the reactivation of the thin seam pillar extraction panels in the overlying Upper Donaldson Seam.

The maximum predicted is 25 mm/m (i.e. 2.5 %), which represents a change in grade of 1 in 40. The maximum predicted conventional curvature resulting from the extraction of the longwalls in the Lower Donaldson Seam is 0.7 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvature of 1.5 kilometres.

### 4.2.5. Maximum Predicted Total Subsidence Parameters due to the Thin Seam Pillar Extraction Panels in the Upper Donaldson Seam plus the Longwalls in Lower Donaldson Seam

The maximum predicted subsidence parameters resulting from the extraction of the proposed thin seam pillar extraction panels only were summarised in Table 4.3 and the maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls only were summarised in Table 4.4. These predictions include the additional subsidence resulting from the reactivation of the historic workings in the overlying Borehole Seam.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvatures resulting from the extraction of both the proposed thin seam pillar extraction panels and the proposed longwalls is provided in Table 4.5. These predictions also include the additional subsidence resulting from the reactivation of the historic workings in the overlying Borehole Seam.

**Table 4.5 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature due to the Extraction of the Thin Seam Pillar Extraction Panels and the Longwalls**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| UDBP1 to UDBP4 and LDLW1 to LDLW5 | 3100 | 30 | 1.0 | 1.0 |

It is noted, that the maximum predicted total subsidence is not the sum of the maxima shown in Table 4.3 and Table 4.4, as the maximum predicted subsidence due to the extraction of the proposed longwalls is located outside the extents of the thin seam pillar extraction panels.

The maximum predicted total subsidence resulting from the extraction of the proposed thin seam pillar extraction panels plus the proposed longwalls is 3100 mm, which represents around 74 % of the combined extraction height of 4.2 metres in this location. The component of subsidence resulting from the reactivation of the historic workings in the Borehole Seam is 700 mm.

As described in Section 3.8.2, it is possible that the subsidence resulting from the reactivation of the Borehole Seam could be greater, if there are areas with partial extraction, or areas with total extraction where the stooks have remained stable. The upperbound component of subsidence resulting from the reactivation of the historic workings in the Borehole Seam is 1300 mm.

The upperbound total subsidence, therefore, resulting from the extraction of the proposed thin seam pillar extraction panels plus the proposed longwalls, including the upperbound reactivation of the historic workings, is 3700 mm (i.e. 3100 mm plus 1300 mm minus 700 mm).

### 4.2.6. Predicted Limit of Vertical Subsidence, Including Potential Effects of Increased Subsidence due to Reactivation of Historic Workings and Pillar Run

The predicted limit of vertical subsidence, taken as the predicted 20 mm subsidence contour, is shown as the cyan line in Drawing No. MSEC492-20. The predicted subsidence contours shown in this drawing include the additional subsidence resulting from the reactivation of the historic workings in the Borehole Seam, above the proposed thin seam pillar extraction panels and proposed longwalls, and above the northern ends of the proposed shortwalls in the Lower Donaldson Seam.

As described in Section 3.8.2, it is possible that the subsidence resulting from the reactivation of the Borehole Seam could be greater, if there are areas with partial extraction, or areas with total extraction where the stooks have remained stable. If the upperbound subsidence of 3700 mm were to occur above the proposed thin seam pillar extraction panels and proposed longwalls, or the upperbound additional subsidence were to occur above the northern ends of the proposed shortwalls in the Lower Donaldson Seam, then the predicted limit of subsidence (i.e. 20 mm subsidence contours) would still be similar to the extents that are shown in Drawing No. MSEC492-20.

The predicted limit of subsidence could extend further than shown in this drawing, however, if pillar run were to occur in the historic workings in the Borehole Seam. It can be seen from Drawing No. MSEC492-11, however, that the historic workings only partially extend beyond the eastern and southern sides of the proposed longwalls and only partially beyond the eastern and northern sides of the proposed shortwalls in the Lower Donaldson Seam. Also, the record tracings indicate that total pillar extraction has occurred in the historic workings on the northern side of the proposed longwalls and that the historic workings are discontinuous with some barrier pillars on the western sides of the proposed longwalls and the proposed shortwalls in the Lower Donaldson Seam.

The potential for pillar run outside the extents of the proposed thin seam pillar extraction panels, proposed longwalls and the northern ends of the proposed shortwalls in the Lower Donaldson Seam, therefore, is reduced due to the limited extents and discontinuity of the historic workings. It is recommended, that the historic workings in the Borehole Seam are investigated further, as part of the Extraction Plan Applications for the thin seam extraction panels, shortwalls and longwalls, to confirm the existing conditions of these workings. It is also recommended that pillar stability assessments are undertaken, based on the findings of these investigations, so that the potential for pillar run can be better defined.

## 4.3. Comparison of the Maximum Predicted Conventional Parameters with those Provided in the Part 3A Environmental Assessment

The predicted subsidence parameters, based on the *Approved Layout*, were provided in the report by Strata Engineering (SE, 2006) which supported the Part 3A Environmental Assessment for the Abel Underground Mine. Comparisons of the maximum predicted conventional subsidence, tilt and curvature, for the bord and pillar mining based on the *Approved Layout*, with those for the proposed shortwalls, longwalls and pillar extraction panels based on the *Modified Layout*, are provided in Table 4.6 to Table 4.8.

**Table 4.6 Comparison of the Maximum Predicted Subsidence Parameters for the Shortwalls in the Upper Donaldson Seam with those Provided in the Part 3A**

| Case | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Bord and Pillar (Panels D and H) | 1330 | 48 | 3.24 | 4.12 |
| Modified Shortwalls UDSW1 to UDSW7 | 1700 | 60 | 2.5 | 2.5 |

**Table 4.7 Comparison of the Maximum Predicted Subsidence Parameters for the Shortwalls in the Lower Donaldson Seam with those Provided in the Part 3A**

| Case | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Bord and Pillar (Panel M) | 1480* | 41 | 1.54 | 1.95 |
| Modified Shortwalls LDSW1 to LDSW4 | 1700 | 25 | 1.0 | 1.5 |

**Table 4.8 Comparison of the Maximum Predicted Subsidence Parameters for the Thin Seam Pillar Extraction Panels in the Upper Donaldson Seam and the Longwalls in the Lower Donaldson Seam with those Provided in the Part 3A**

| Case | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Bord and Pillar (Panels N, O and P) | 990* | 17 | 0.81 | 1.02 |
| Modified UDBP1 to UDBP4 and LDLW1 to LDLW5 | 3100 | 30 | 1.0 | 1.0 |

Note: * denotes that the report by Strata Engineering (SE, 2006) also stated that "*it is possible that increase[d] subsidence due to the undermining of the WBH Seam workings could range between 0 and 20 % of the WBH Seam mining height (i.e. up to 600 mm for an assumed mining height of 3 m). In the extreme, if a total collapse of the marginally stable pillars were to occur, the subsidence increase could be in the order of 50 % of the WBH Seam mining height (i.e. 0.85 x 58 % of the mining height) or 1.5 m for an assumed mining height of 3 m*".

As described in Sections 3.8.2, it is possible that the subsidence resulting from the reactivation of the Borehole Seam could be greater, if there are areas with partial extraction, or areas with total extraction where the stooks have remained stable. The upperbound subsidence resulting from the extraction of the proposed thin seam pillar extraction panels plus the proposed longwalls, including the upperbound reactivation of the historic workings, is 3700 mm, based on the *Modified Layout*.

It can be seen from the above tables, that the predicted maximum subsidence for the proposed shortwalls, longwalls and thin seam pillar extraction panels, based on the *Modified Layout*, are greater than those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*. It is then highlighted, that the potential for impacts on the natural features and surface infrastructure are dependent on the differential subsidence (i.e. tilt, curvature and strain), rather than the magnitude of vertical subsidence.

It can be seen from Table 4.6 and Table 4.8, that the predicted maximum tilt due to the shortwalls in the Upper Donaldson Seam and due to the proposed thin seam pillar extraction panels and proposed longwalls, based on the *Modified Layout*, are greater than those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*. Otherwise, the predicted maximum tilt for the proposed shortwalls in the Lower Donaldson Seam, based on the *Modified Layout*, is less than the maximum provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

The predicted maximum curvatures due to the proposed shortwalls, longwalls and thin seam pillar extraction panels, based on the *Modified Layout*, are similar to or less than those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

Further comparisons between the predicted mine subsidence parameters, based on the *Modified Layout* and the *Approved Layout*, are provided in the impact assessments for the natural features and surface infrastructure in Chapters 5 and 6.

## 4.4. Predicted Strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

It has been found that applying a constant factor to the predicted maximum curvatures provides a reasonable prediction for the normal or conventional strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Newcastle Coalfield, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

A summary of the maximum predicted conventional strains for the proposed shortwalls, longwalls and thin seam pillar extraction panels, based on applying a factor of 10 to the maximum predicted conventional curvatures, is provided below:-

- Shortwalls in Upper Donaldson Seam - 25 mm/m tensile and compressive,
- Shortwalls in the Lower Donaldson Seam - 10 mm/m tensile and 15 mm/m compressive,
- Thin seam pillar extraction panels in Upper Donaldson Seam - 5 mm/m tensile and compressive, and
- Longwalls in the Lower Donaldson Seam - 7 mm/m tensile and compressive.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this report, therefore, we have provided a statistical approach to account for the variability, instead of just providing a single predicted conventional strain.

The range of potential strains above the proposed shortwalls, longwalls and thin seam pillar extraction panels has been determined using monitoring data from the previous mining in the Newcastle and Hunter Coalfields. The data used in the analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related movements, which are addressed separately in this report. The strains resulting from damaged or disturbed survey marks have also been excluded.

The strain distributions were analysed with the assistance of the centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS). A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided the best fit to the raw strain data.

The depth of cover varies considerably above the proposed shortwalls, longwalls and thin seam pillar extraction panels and, therefore, the magnitudes of the ground strains will also vary considerably over the mining area. The potential strains have been determined separately for mining in the Upper and Lower Donaldson Seams, which are provided in the following sections.

### 4.4.1. Distribution of Strain Resulting for the Proposed Shortwalls in the Upper Donaldson Seam

The width-to-depth ratios of the shortwalls in the Upper Donaldson Seam vary between 0.6 (at a maximum depth of cover of 200 metres) and 2.4 (at a minimum depth of cover of 50 metres). The ground strains will vary considerably across the mining area, with the greatest strains occurring in the locations of shallowest depths of cover and lower strains occurring in the locations of higher depths of cover.

There is no surface infrastructure identified towards the northern ends of the shortwalls, where the depths of cover are the shallowest, with the surface comprising natural bushland. The majority of the surface infrastructure is located where the depths of cover typically vary between 100 metres (i.e. width-to depth ratio of 1.2) to 160 metres (i.e. width-to-depth ratio of 0.8 metres).

The range of potential strains above the proposed shortwalls in the Upper Donaldson Seam has been determined using monitoring data from previously extracted panels in the Newcastle and Hunter Coalfields, where the width-to-depth ratios were between 0.8 and 1.2.

Comparisons of the void widths, depths of cover, width-to-depth ratios and extraction heights for the proposed shortwalls with those for the historical cases are provided in Table 4.9.

**Table 4.9 Comparison of the Mine Geometry for the Shortwalls in the Upper Donaldson Seam with the Panels in the Newcastle and Hunter Coalfields used in the Strain Analysis**

| Parameter | Shortwalls in the Upper Donaldson Seam | | Panels Used in Strain Analysis | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| Width | 120 | 120 | 160 ~ 200 | 175 |
| Depth of Cover | 50 ~ 200 | 120 | 140 ~ 250 | 175 |
| W/H Ratio | 0.6 ~ 2.4 | 1.0 | 0.8 ~ 1.2 | 1.0 |
| Extraction Height | 1.6 ~ 2.8 | 2.5 | 2.1 ~ 4.8 | 4.4 |

It can be seen from the above table, that the range of the panel width-to-depth ratios used in the strain analysis was between 0.8 and 1.2, so as to match that for the proposed shortwalls in the Upper Donaldson Seam, excluding from the northern ends of the proposed shortwalls. The average extraction height for the panels used in the strain analysis was greater than the average extraction height for the proposed shortwalls.

The strain analysis, therefore, should provide a reasonable indication of the range of potential strains for the proposed shortwalls in the Upper Donaldson Seam, away from the northern ends of the proposed shortwalls. The range of strains above the northern ends of these shortwalls is expected to be greater, however, there is no surface infrastructure identified in this location.

The available monitoring lines have been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted panels. The frequency distribution of the maximum observed tensile and compressive strains measured in survey bays above goaf is provided in Fig. 4.1. The probability distribution functions, based on the fitted GPDs, are also shown in this figure.

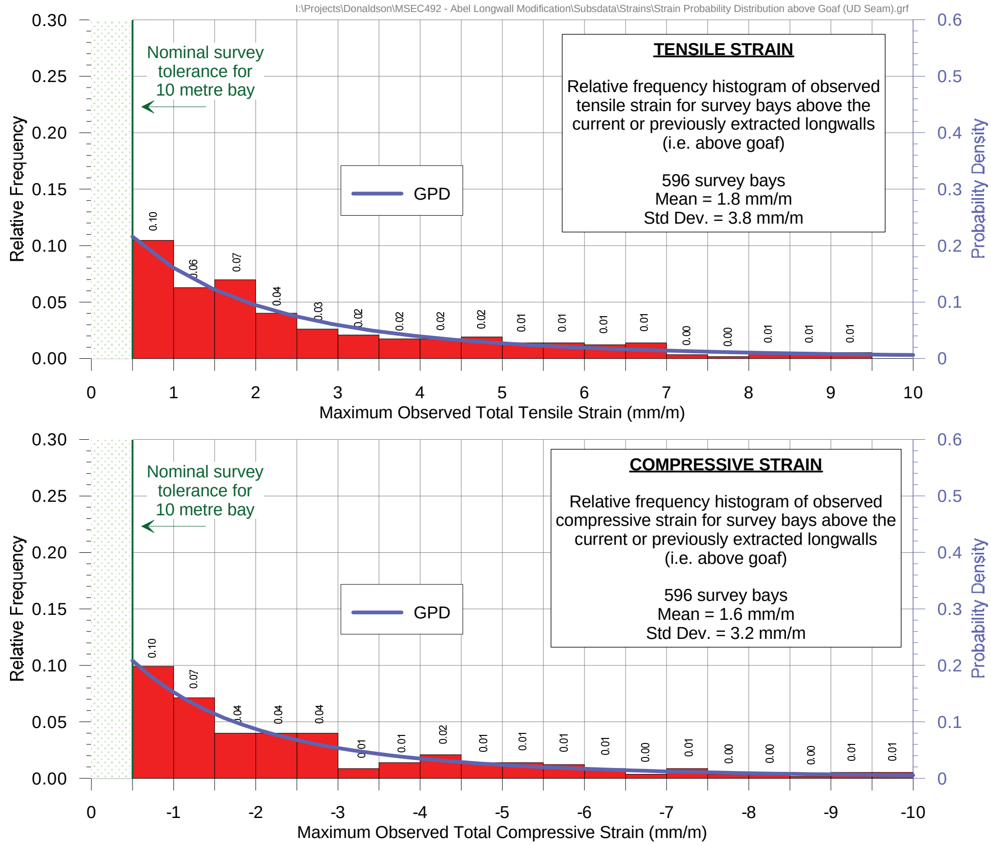


**Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains in the Newcastle and Hunter Coalfields for Panels having W/H Ratios between 0.8 and 1.2**

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The 95 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining were 8 mm/m tensile and 7 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining were 19 mm/m tensile and 17 mm/m compressive.

### 4.4.2. Distribution of Strain for the Proposed Shortwalls in the Lower Donaldson Seam

The width-to-depth ratios of the shortwalls in the Lower Donaldson Seam vary between 0.4 (at a maximum depth of cover of 300 metres) and 0.8 (at a minimum depth of cover of 150 metres). The range of potential strains above these proposed shortwalls has been determined using monitoring data from previously extracted panels in the Newcastle and Hunter Coalfields, where the width-to-depth ratios over a similar range.

Comparisons of the void widths, depths of cover, width-to-depth ratios and extraction heights for the proposed shortwalls with those for the historical cases are provided in Table 4.10.

**Table 4.10 Comparison of the Mine Geometry for the Shortwalls in the Lower Donaldson Seam with the Panels in the Newcastle and Hunter Coalfields used in the Strain Analysis**

| Parameter | Shortwalls in the Lower Donaldson Seam | | Panels Used in Strain Analysis | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| Width | 120 | 120 | 130 ~ 260 | 220 |
| Depth of Cover | 150 ~ 300 | 200 | 180 ~ 520 | 410 |
| W/H Ratio | 0.4 ~ 0.8 | 0.6 | 0.4 ~ 0.8 | 0.6 |
| Extraction Height | 2.6 ~ 2.8 | 2.7 | 2.2 ~ 6.0 | 4.0 |

It can be seen from the above table, that the range of the panel width-to-depth ratios used in the strain analysis was similar to that for the proposed shortwalls in the Lower Donaldson Seam. The average extraction height for the panels used in the strain analysis was greater than that for the proposed shortwalls. The strain analysis, therefore, should provide a reasonable indication of the range of potential strains resulting from the extraction of the shortwalls in the Lower Donaldson Seam.

The available monitoring lines have been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted panels. The frequency distribution of the maximum observed tensile and compressive strains measured in survey bays above goaf is provided in Fig. 4.2. The probability distribution functions, based on the fitted GPDs, are also shown in this figure.

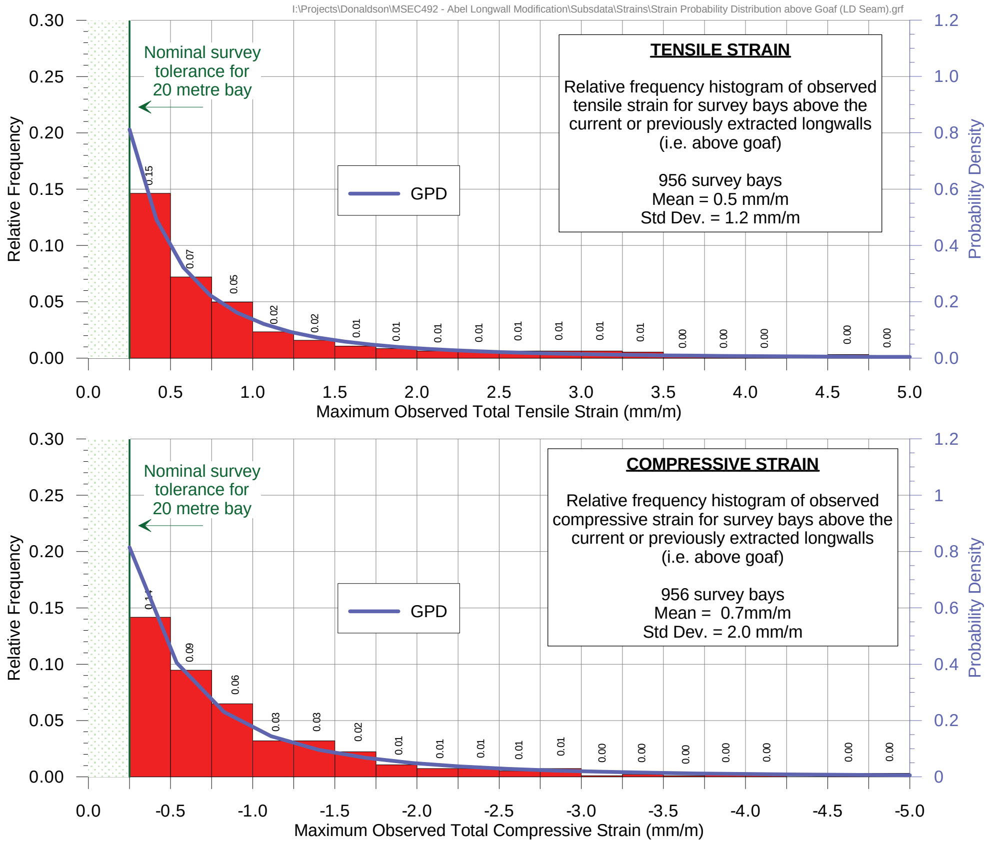


**Fig. 4.2 Distributions of the Measured Maximum Tensile and Compressive Strains in the Newcastle and Hunter Coalfields for Panels having W/H Ratios between 0.4 and 0.8**

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The 95 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining were 2 mm/m tensile and 3 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining were 6 mm/m tensile and 7 mm/m compressive.

### 4.4.3. Distribution of Strain for the Thin Seam Pillar Extraction Panels in the Upper Donaldson Seam and the Proposed Longwalls in the Lower Donaldson Seam

There is very limited ground monitoring data for multi-seam cases where the pillars or longwalls have been extracted beneath existing bord and pillar workings, where the width-to-depth ratios, depths of cover, interburden thicknesses and overburden geology were similar to those for the proposed longwalls. It is not possible, therefore, to provide a similar distribution for the range of potential strains for the proposed thin seam pillar extraction panels and the proposed longwalls, as was done for the proposed shortwalls.

The predicted conventional strains, based on applying a factor of 10 to the maximum predicted conventional curvatures, can be used to provide a guide as to the typical strains experienced above the proposed thin seam pillar extraction areas and longwalls. Localised elevated strains will also develop as the result of non-conventional ground movements due to the multi-seam mining conditions.

The impact assessments for the natural features and surface infrastructure discuss the potential impacts result from strains, including those resulting from non-conventional movements due to the multi-seam conditions.

## 4.5. Predicted Conventional Horizontal Movements

The predicted conventional horizontal movements over the proposed panels are calculated by applying a factor to the predicted conventional tilt values. In the Newcastle Coalfield a factor of 10 is generally adopted, being the same factor as that used to determine the maximum conventional strains from the maximum curvatures, and this has been found to give a reasonable correlation with measured data. This factor will in fact vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted conventional tilt within the Study Area, at any time during or after the extraction of the proposed shortwalls and longwalls, is 60 mm/m, which occurs at the northern ends of the shortwalls in the Upper Donaldson Seam. The maximum predicted conventional horizontal movement is, therefore, approximately 600 mm, i.e. 60 mm/m multiplied by a factor of 10.

Horizontal movements do not directly impact on natural features or items of infrastructure, rather impacts occur as the result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of ground strain on the natural features and items of infrastructure are addressed in the impact assessments for each feature in Chapters 5 and 6.

## 4.6. Predicted Far-field Horizontal Movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to the proposed panels, and the predicted valley related movements along the creeks, it is also likely that far-field horizontal movements will be experienced during the proposed mining.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data from the NSW Coalfields, but predominantly from the Southern Coalfield. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwall. At very low levels of far-field horizontal movements, however, there was a high scatter in the orientation of the observed movements.

The observed incremental far-field horizontal movements, resulting from the extraction of a single panel, is provided in Fig. 4.3. The confidence levels, based on fitted GPDs, have also been shown in this figure to illustrate the spread of the data.

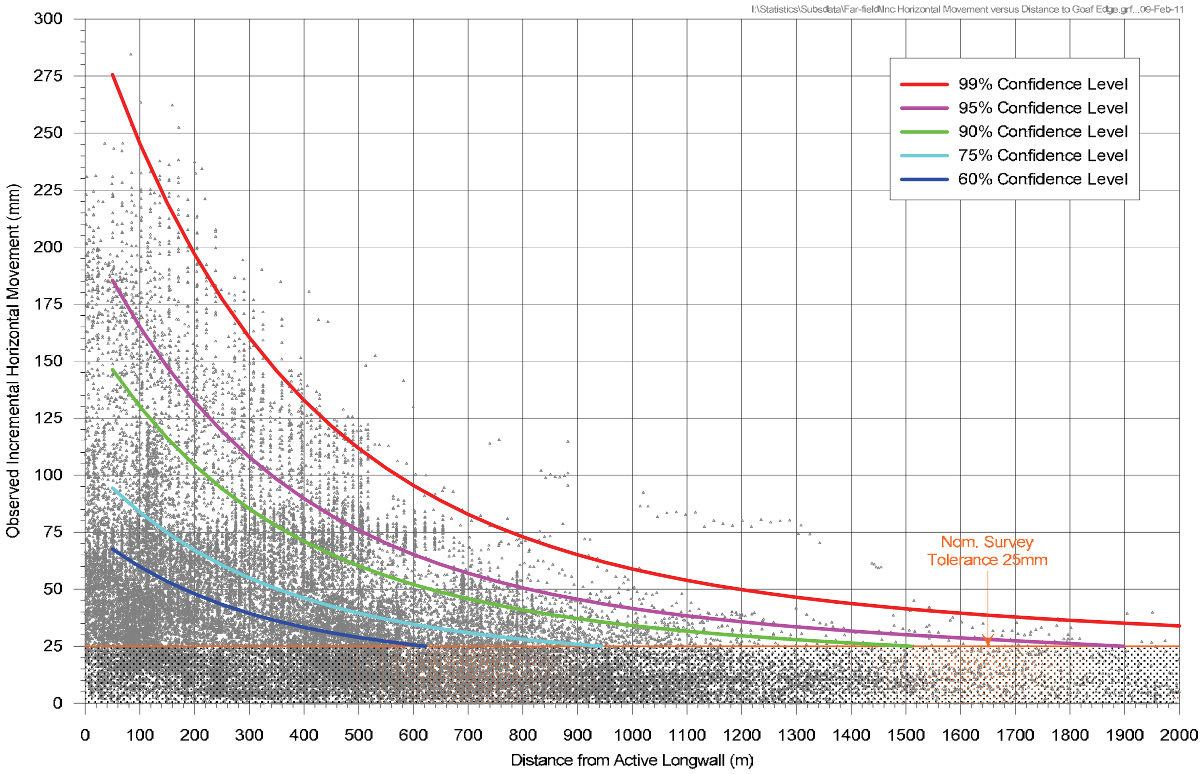


**Fig. 4.3 Observed Incremental Far-Field Horizontal Movements**

As successive panels within a series are mined, the magnitudes of the incremental far-field horizontal movements decrease. This is possibly due to the fact that once the in-situ stresses within the strata has been redistributed around the collapsed zones above the first few extracted longwalls, the potential for further movement is reduced. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual panels.

The predicted far-field horizontal movements resulting from the extraction of the proposed panels are very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally in the order of survey tolerance. The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the proposed mining is not expected to be significant, except possibly at the F3 Freeway and Hunter Expressway bridges, which are discussed further in Chapter 6 in this report.

## 4.7. Non-Conventional Ground Movements

It is likely non-conventional ground movements will occur within the Study Area, due to near surface geological conditions, steep topography and valley related movements, which were discussed in Section 3.6. These non-conventional movements are often accompanied by elevated tilts, curvatures and strains which are likely to exceed the conventional predictions.

In most cases, it is not possible to predict the exact locations or magnitudes of the non-conventional anomalous movements due to near surface geological conditions. For this reason, the strain predictions provided in this report are based on a statistic analysis of measured strains in the Newcastle and Hunter Coalfields, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4.

Specific predictions of upsidence, closure and compressive strain due to the valley related movements are provided for the drainage lines in Section 5.1. The impact assessments for the streams are based on both the conventional and valley related movements. The potential for non-conventional movements associated with steep topography is discussed in the impact assessments for the steep slopes provided in Section 5.4.

## 4.8. General Discussion on Mining Induced Ground Deformations

Shortwall, longwall and bord and pillar mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

Fractures and joints in bedrock occur naturally during the formation of the strata and from subsequent erosion and weathering processes. Shortwall and longwall mining can result in additional fracturing in the bedrock, which tends to occur in the tensile zones, but fractures can also occur due to buckling of the surface beds in the compressive zones. The incidence of visible cracking at the surface is dependent on the pre-existing jointing patterns in the bedrock as well as the thickness and inherent plasticity of the soils that overlie the bedrock.

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the panel perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the panel perimeters. The cracks will generally be parallel to the longitudinal edges of the longwalls.

At shallow depths of cover, it is also likely that transient surface cracks will occur above and parallel to the moving extraction face, i.e. at right angles to the longitudinal edges of the panel, as the subsidence trough develops. This cracking, however, tends to be transient, since the tensile phase of the travelling wave, which causes the cracks to open up, is generally followed by a compressive phase, which partially recloses them. It has been observed in the past, however, that surface cracks which occur during the tensile phase of the travelling wave do not fully close during the compressive phase, and tend to form compressive ridges at the surface.

At shallow depths of cover, such as the case above the north-eastern ends of the proposed shortwalls in the Upper Donaldson Seam, surface cracking and heaving can potentially occur in any location above the extracted panels. The larger and more permanent cracks, however, are usually located in the final tensile zones around the perimeters of the longwalls. Open fractures and heaving, however, can also occur due to the buckling of surface beds that are subject to compressive strains.

The incidence of surface cracking is dependent on the location relative to the extracted panel goaf edges, the depth of cover, the extracted seam thickness and the thickness and inherent plasticity of the soils that overlie the bedrock. The widths and frequencies of the cracks are also dependent upon the pre-existing jointing patterns in the bedrock. Large joint spacing can lead to concentrations of strain and possibly the development of fissures at rockhead, which are not necessarily coincident with the joints.

It has been found, from past longwall mining experience, that the surface crack widths in the order of 150 mm and step heights in the order of 100 mm have been observed at shallow depths of cover, say less than 100 metres, such as the case above the northern ends of the proposed shortwalls in the Upper Donaldson Seam. It has also been found, that surface crack widths and step heights reduced as the depth of cover increases, and crack widths in the order of 30 mm to 50 mm and step heights less than 50 mm are typically observed where the depths of cover are greater than 150 metres, such as the case above the proposed shortwalls in the Lower Donaldson Seam.

Photographs of typical surface cracking observed from previous mining at shallow and high depths of cover are provided in Fig. 4.4 and Fig. 4.5, respectively.

**Fig. 4.4 Photographs of Typical Surface Cracking in the Hunter Coalfield (Less than 100 metres Depth of Cover)**

**Fig. 4.5 Photographs of Typical Surface Cracking in the Southern Coalfield (Greater than 400 metres Depth of Cover)**

It is likely, that large surface cracking will also occur along the steep slopes due to down slope movements resulting from the extraction of the proposed shortwalls and longwalls. The potential for surface cracking from down slope movements is discussed in Section 5.4.

Further discussion on surface cracking is provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

## 4.9. Estimated Height of the Fractured Zone

The estimated heights of fracturing in the overburden for the proposed shortwalls, longwalls and thin seam pillar extraction panels have been determined using the method described in the ACARP Research Project C10023 (ACARP, 2003). This method was previously used to estimate the heights of fracturing in the Part 3A Environmental Assessment, based on the *Approved Layout*.

As described in the Part 3A Environmental Assessment, "*Continuous sub-surface cracking refers to the extent of fracturing above a total extraction panel that would provide a direct flow-path or hydraulic connection to the workings, if a sub-surface aquifer or coal seam were intersected*" (SE, 2006). The height of continuous cracking is referred to as the "*A Horizon*".

Also, as described in the Part 3A Environmental Assessment, "*Discontinuous fracturing refers to the extent above a total extraction panel that could experience a general increase in horizontal and vertical permeability with the rock mass, due to bending or curvature deformation of the overburden. This type of fracturing does not provide a direct flow path or connection to the workings and is more likely to interact with surface cracks or joints*" (SE, 2006). The height of discontinuous cracking is referred to as the "*B Horizon*".

The estimated heights of continuous and discontinuous fracturing are based on the depth of cover and either the maximum 'smooth profile' (i.e. conventional) tensile strain or the '*overburden curvature index*'. The relationship between the estimated heights of the *A Horizon* and the *B Horizon*, based on the maximum conventional tensile strain, are illustrated in Fig. 4.6.

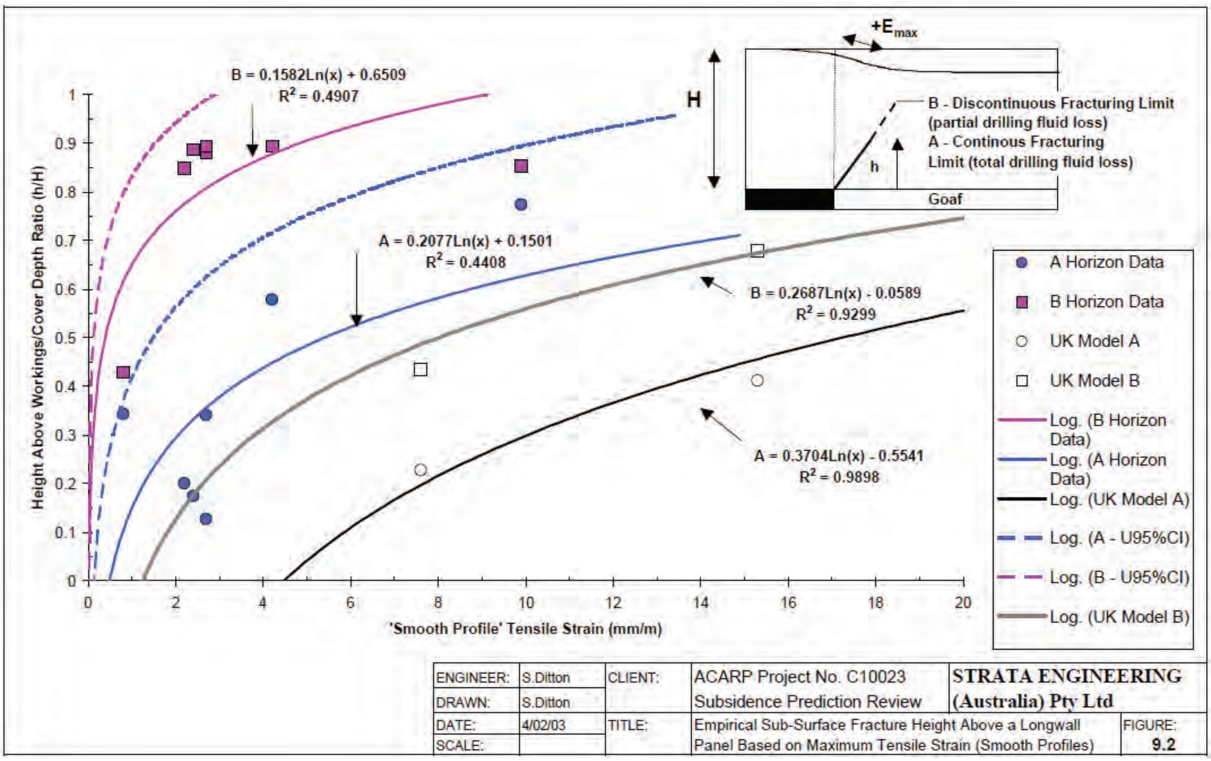


**Fig. 4.6 Estimated Heights of the A and B Horizons (ACARP, 2003)**

The estimated heights of continuous and discontinuous fracturing as proportions of the depths of cover, based on the maximum conventional tensile strain, are provided by the following equations (ACARP, 2003):-

**Equation 4** $A = 0.2077Ln(+E_{max}) + 0.150$ *Height of continuous fracturing divided by cover*

$B = 0.1582Ln(+E_{max}) + 0.651$ *Height of discontinuous fracturing divided by cover*

where $+E_{max}$ = the maximum conventional tensile strain (mm/m)

The estimated heights of continuous and discontinuous fracturing as proportions of the depths of cover, based on the '*overburden curvature index*', are provided by the following equations (ACARP, 2003):-

**Equation 5** $A = 0.2295Ln(S_{max} / W^2) + 1.132$ *Height of continuous fracturing divided by cover*

$B = 0.1694Ln(S_{max} / W^2) + 1.381$ *Height of discontinuous fracturing divided by cover*

where $S_{max}$ = maximum subsidence (mm)

W = width of panel (m)

A summary of the estimated heights of continuous and discontinuous fracturing for the proposed shortwalls, longwalls and thin seam pillar extraction panels, based on the ACARP 2003 method, is provided in Table 4.11. The heights of fracturing have been based on the greater of those determined using the maximum conventional tensile strain and the maximum subsidence.

**Table 4.11 Estimated Heights of Continuous and Discontinuous Cracking Based on ACARP 2003**

| Location | Depth of Cover (m) | Maximum Predicted Conventional Tensile Strain (mm/m) | Maximum Predicted Subsidence (mm) | Estimated Height of the A Horizon (m) | Estimated Height of the B Horizon (m) |
|---|---|---|---|---|---|
| Shortwalls in the Upper Donaldson Seam | 50 | 25 | 1700 | 41 ~ 112 | 50 ~ 192 |
| | 200 | 5 | 1200 | | |
| Shortwalls in the Lower Donaldson Seam | 150 | 10 | 1700 | 96 ~ 141 | 150 ~ 267 |
| | 300 | 1 | 800 | | |
| Thin Seam Pillar Extraction Panels and Longwalls | 170 | 10 | 3100 | 133 ~ 238 | 170 ~ 350 |
| | 350 | 3 | 2000 | | |

It can be seen from the above table, that continuous cracking is predicted to extend up to the surface where the depths of cover are shallowest above the proposed shortwalls in the Upper Donaldson Seam. It is also possible, that discontinuous cracking could extend up to the surface elsewhere above the proposed shortwalls in the Upper Donaldson Seam, as well as above the proposed shortwalls in the Lower Donaldson Seam and the thin seam pillar extraction panels and proposed longwalls.

Further details on sub-surface strata movements are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

The following sections provide the descriptions, predictions and impact assessments for the natural features identified within the Study Area. Comparisons of the predictions, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, are also provided in this chapter.

All significant natural features located outside the Study Area, which may be subjected to valley related or far-field horizontal movements and may be sensitive to these movements, have also been included as part of these assessments.

## 5.1. Streams

### 5.1.1. Description of the Streams

There are no named rivers within the Study Area. There are number of creeks and drainage lines within the mining lease which are shown in Drawing No. MSEC492-13. A summary of the Schedule 2 (i.e. third order and above) streams which are located within or immediately adjacent to the Study Area is provided in Table 5.1.

**Table 5.1 Schedule 2 Streams within or Adjacent to the Study Area**

| Stream Name | Strahler Stream Order | Description |
|---|---|---|
| Blue Gum Creek | 3rd and 4th Order | Located to the south of the shortwalls and longwalls in the Lower Donaldson Seam. Not directly mined beneath. |
| Long Gully | 3rd Order | Located between the shortwalls and longwalls in the Lower Donaldson Seam. Not directly mined beneath. |
| Buttai Creek | 3rd Order | Located on the western perimeter of the mining lease. Not directly mined beneath. |
| Viney Creek | 3rd Order | Located east of the shortwalls in the Upper Donaldson Seam. Not directly mined beneath. |

The Schedule 2 streams are ephemeral, but have isolated ponds in the flatter sections of the streams. The eastern parts of Blue Gum Creek and Long Gully are founded in alluvial deposits, with the extent shown in Drawing No. MSEC492-13. The western sections of Blue Gum Creek and Long Gully, as well as Buttai and Viney Creeks, are founded in the natural surface soils, with the sandstone bedrock outcropping in isolated locations. The rock outcropping is most extensive in the upper reaches of the creeks, which form a number of small cascades and ponds.

Photographs of Blue Gum Creek, Long Gully, Buttai Creek and Viney Creek are provided in Fig. 5.1 to Fig. 5.3.

**Fig. 5.1 Photograph of Blue Gum Creek**

**Fig. 5.2 Photographs of Upper Reaches (Left) and Lower Reaches (Right) of Long Gully**

**Fig. 5.3 Photographs of Buttai Creek (Left, after Fig. 6.3 of SE, 2006) and Viney Creek (Right, after Fig. 6.4 of SE, 2006)**

There are also a number of Schedule 1 (i.e. first and second order) ephemeral streams within the Study Area which are shown in Drawing No. MSEC492-13. The land in the south-eastern part of the mining lease drains into Long Gully and Blue Gum Creeks, the land in the north-eastern part of the mining lease drains into Viney Creek, Weakleys Flat Creek and Four Mile Creek, and the land in the western part of the mining lease drains into Buttai Creek.

Long Gully and Blue Gum Creek drain into the Pambalong Nature Reserve, which is located in the eastern part of the mining lease, and is described in Section 5.6.

### 5.1.2. Predictions for the Streams

As part of the Statement of Commitments for the Abel Underground Mine, Donaldson Coal has made the commitment for the *Schedule 2 Streams* for *"the provision of a minimum barrier of 40m between the 20 millimetre line of subsidence and the bank of any Schedule 2 Streams"*. The Project Approval 05-0136 requires Donaldson Coal to *"limit mining operations to first workings beneath, and ensure that mining causes no subsidence impacts requiring mitigation works"*. Subsidence control zones have been established around the Schedule 2 streams based on the 40 metre buffers, which are shown in Drawing No. MSEC492-13.

The proposed shortwalls, longwalls and thin seam pillar extraction panels have been setback from the Schedule 2 streams so that no more than 20 mm of subsidence is predicted within the 40 metre buffer zones from the banks of these streams. Whilst it is still possible that the Schedule 2 streams could experience subsidence slightly greater than 20 mm, the streams would not be expected to experience any significant conventional tilts, curvatures or strains.

The lower reaches of the Schedule 2 streams have shallow incisions into the natural surface soils and, therefore, would not be expected to experience any significant upsidence and closure movements. The upper reaches of these streams are more incised, with rock outcropping in some locations. These sections of the streams could experience small upsidence and closure movements, generally less than 20 mm, due to the relatively small valleys and the setbacks of the shortwalls and longwalls from these streams.

The Schedule 1 streams are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

### 5.1.3. Comparison of the Predictions for the Streams with those Provided in the Part 3A Environmental Assessment

The *Approved Layout* adopted in the Part 3A Environmental Assessment used the same subsidence control zones for the Schedule 2 streams, with the bord and pillar mining setback so that no more than 20 mm of subsidence was predicted within the 40 metre buffer zones from the banks of these streams. The predicted subsidence parameters for the Schedule 2 streams, based on the *Modified Layout*, therefore, are the same as those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

The *Approved Layout* adopted in the Part 3A Environmental Assessment mined directly beneath the Schedule 1 streams and, therefore, these streams were predicted to experience the full range of mine subsidence movements. It can be seen from Section 4.3, that the predicted tilts and curvatures (i.e. differential subsidence), based on the *Modified Layout*, are similar to or less than the predicted maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

The maximum predicted subsidence above the proposed shortwalls in the Upper Donaldson Seam and the proposed longwalls in the Lower Donaldson Seam are greater than the maxima predicted in the Part 3A Environmental Assessment, based on the *Approved Layout*, which is discussed further in the impact assessments in the following section.

### 5.1.4. Impact Assessments and Discussions for Schedule 2 Streams

It is unlikely that the Schedule 2 streams would experience any adverse impacts as the result of mining, as the proposed shortwalls, longwalls and thin seam pillar extraction panels have been setback so that no more than 20 mm of subsidence is predicted within the 40 metre buffer zones from the banks of these streams.

It is possible, that minor and isolated fracturing could occur in the exposed sandstone beds in the upper reaches of these creeks, due to the small upsidence and closure movements, but this is not expected to result in any adverse impacts on the ephemeral surface water flows.

It has been assessed, therefore, that no adverse impacts on the Schedule 2 streams would occur as a result of the extraction of the proposed shortwalls, longwalls and thin seam pillar extraction panels, based on the *Modified Layout*.

### 5.1.5. Impact Assessments and Discussions for Schedule 1 Streams

The Schedule 1 streams are likely to experience increased levels of ponding, flooding and scouring of the banks due to the changes in stream grade resulting from the proposed mining. For example, the natural and predicted post-mining levels and grades along Four Mile Creek and a Tributary to Blue Gum Creek (BGC1) are provided in Fig. 5.4 and Fig. 5.5, respectively.

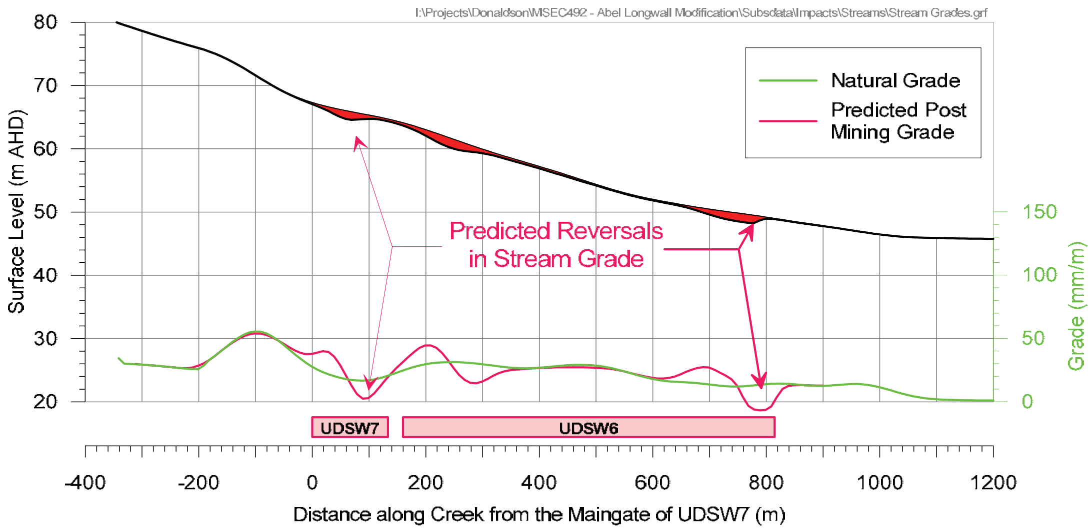


**Fig. 5.4 Natural and Predicted Post-Mining Levels and Grades along Four Mile Creek**

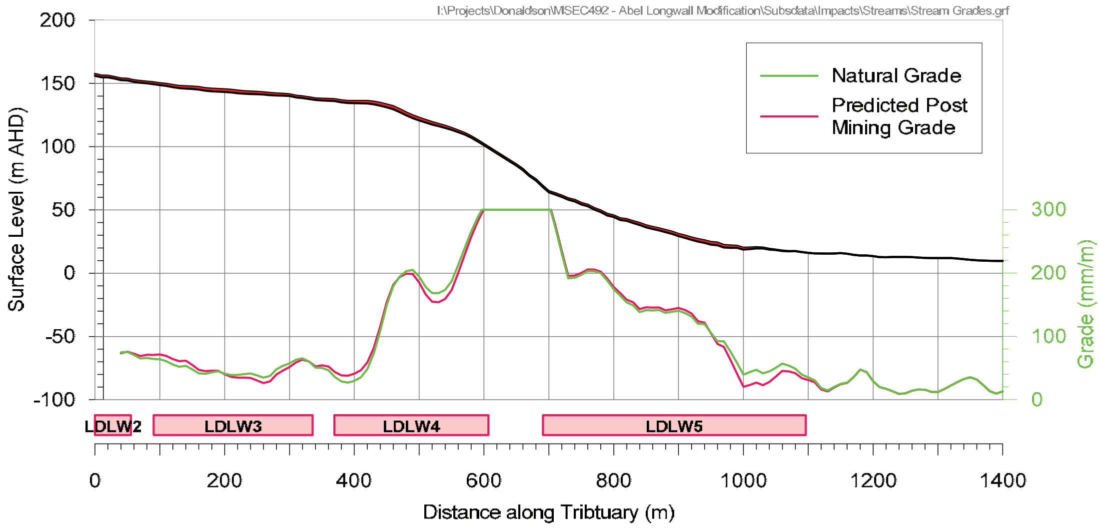


**Fig. 5.5 Natural and Predicted Post-Mining Levels and Grades along Tributary BGC1**

It can be seen from Fig. 5.4, that there are predicted reversals of grade along Four Mile Creek immediately upstream of the northern end of the proposed UDSW6 and, possibly, upstream of the tailgate of the proposed UDSW7. It is predicted that locally increased ponding will occur in these locations, having depths less than 0.3 metres and lengths less than 100 metres. Elsewhere, the predicted post-mining grades are similar to the natural grades along this creek. It can also be seen from Fig. 5.5, that there are no predicted reversals of grade along Tributary BGC1.

It is expected, therefore, that increased levels of ponding will occur along the Schedule 1 streams in the flatter areas above the proposed shortwalls in the Upper Donaldson Seam. The ponding will develop where the streams exit the extents of the modified mining areas, having depths up to approximately 0.5 metres and lengths up to approximately 100 metres. Smaller more isolated ponding is also expected to develop in the flatter areas above the proposed shortwalls and longwalls in the Lower Donaldson Seam.

The levels and extents of ponding are similar to or less than those assessed in the Part 3A Environmental Assessment, based on the *Approved Layout*, which states that "*potential ponding depths of 0.1 to 0.5 m estimated for the majority of these [Schedule 1] creeks*" with "*ponding depths ranging between 0.4 and 1.0 m*" for two tributaries (SE, 2006).

As described in Sections 3.8.2, 4.2.3 and 4.2.4, it is possible that the actual subsidence above the proposed thin seam pillar extraction panels and proposed longwalls could be greater than that predicted, due to the presence of the historic workings in the overlying Borehole Seam, if the existing stooks have remained stable or any of these workings are found to be only partially extracted. For this reason, the predicted post-mining levels and grades along the Tributary to Blue Gum Creek (BGC1) have been determined based on an upperbound subsidence of 3700 mm from the proposed mining, which is provided in Fig. 5.6.

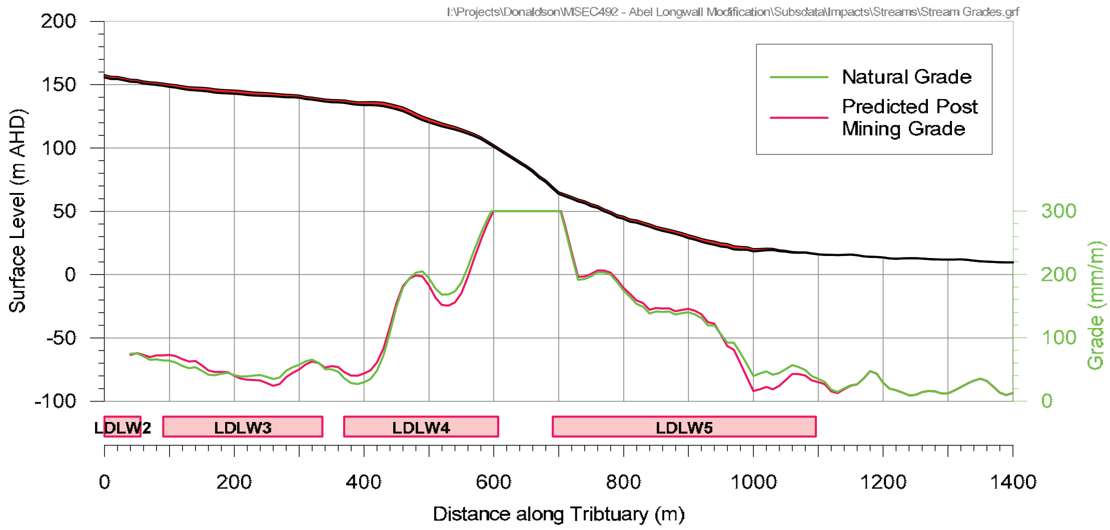


**Fig. 5.6 Natural and Predicted Post-Mining Levels and Grades along Tributary BGC1 Based on the Upperbound Subsidence Developing Above Proposed LDLW1 to LDLW5**

It can be seen from the above figure, that there are no predicted reversals of grade along Tributary BGC1, even if the upperbound subsidence of 3700 mm develops as a result of the extraction of the proposed thin seam pillar extraction panels and proposed longwalls.

It is expected, that fracturing, buckling and dilation of the uppermost bedrock will occur along the Schedule 1 streams where the proposed shortwalls and longwalls are mined directly beneath them. It has been observed in the past, that the depth of fracturing, buckling and dilation of the uppermost bedrock is generally less than 10 metres to 15 metres (SCT, 2003 and Mills and Huuskes, 2004).

In the upper reaches of the Schedule 1 streams, fracturing and buckling will be visible at the surface where the bedrock is exposed. In some cases, there may be some diversion of surface water flows into the dilated strata beneath the beds and the draining of any pooled water within the stream alignments. It is unlikely that there would be any net loss of water from the catchment, however, as any diverted surface water is likely to re-emerge further downstream.

In the lower reaches of the Schedule 1 streams, the fracturing and buckling of the bedrock may not be visible at the surface where there are sufficient depths of soil deposits above the bedrock. Fractures in the bedrock in these locations are likely to be filled with the deposits during subsequent flow events.

As described in Section 4.3, the maximum predicted curvatures for the proposed shortwalls and longwalls, based on the *Modified Layout*, are similar to or less than the range of predicted maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*. If the upperbound subsidence of 3700 mm were to develop above the proposed thin seam pillar extraction panels and proposed longwalls, as described in Sections 3.8.2, 4.2.3 and 4.2.4, the predicted curvatures and strains would still be no greater than those provided in the Part 3A Environmental Assessment, above the shallower bord and pillar mining in the Upper Donaldson Seam, based on the *Approved Layout*.

Consequently, the expected levels and extents of fracturing, buckling and dilation along the Schedule 1 streams above the proposed shortwalls and longwalls, based on the *Modified Layout*, are no greater than those assessed in the Part 3A Environmental Assessment, based on the *Approved Layout*.

The impact assessments and the proposed management strategies for the Schedule 1 streams do not change as a result of the proposed modifications.

## 5.2. Aquifers or Known Groundwater Resources

The alluvium along Blue Gum Creek provides a groundwater resource for stock and domestic use. The descriptions, predictions and impact assessments for the alluvium are provided in Section 5.6.

## 5.3. Cliffs and Rock Outcrops

### 5.3.1. Descriptions of the Cliffs and Rock Outcrops

For the purposes of this report, cliffs have been defined as continuous rockfaces, having heights greater than 10 metres and minimum slopes of 2 to 1 (i.e. greater than 63°). Rock outcrops have been defined as discontinuous rockfaces, having heights less than 10 metres or slopes less than 2 to 1 (i.e. less than 63°).

The cliffs and rock outcrops were identified from the Light Detection and Ranging (LiDAR) survey, the orthophotograph of the area and from site investigations. The locations of the cliffs within the Study Area are shown in Drawing No. MSEC492-14.

Cliffs have been identified along the upper reaches of Long Gully and Blue Gum Creek and along their tributaries. The sandstone cliffs have heights up to 20 metres and lengths ranging between 10 metres and 100 metres. Photographs of the cliffs along the upper reaches of Long Gully and tributaries are provided in Fig. 5.7 (after Fig. 6.8 of SE, 2006).

**Fig. 5.7 Photographs of the Cliffs along the Upper Reaches of Long Gully (after Fig. 6.8 of SE, 2006)**

The Part 3A Environmental Assessment stated that "*the sandstone exposures are fine to course grained, grey to yellow / brown and have medium to high strength. Orthogonal joint sets were observed on the rock outcrops striking sub-parallel and normal to the 025º and 130º striking cliff lines*" (SE, 2006).

Extensive rock outcropping has also been identified above the shortwalls and longwalls in the Lower Donaldson Seam. It is noted, that some of these areas were defined as "*cliffs*" in the Part 3A Environmental Assessment, however, the site investigations found that the exposed rock was discontinuous, generally less than 10 metres in height or had slopes generally less than 2 to 1. The surface level contours generated from the LiDAR survey also confirmed that the heights and slopes were less than those which have been used to define a "*cliff*". Photographs of the rock outcropping is provided in Fig. 5.8.

**Fig. 5.8 Photographs of the Rock Outcropping above the Proposed Shortwalls in the Lower Donaldson Seam**

Project Approval 05-0136 requires Donaldson Coal to ensure that "*not more than 60% of the coal seam is extracted beneath the cliff areas*". The definition of what constitutes a cliff, therefore has an implication on the extent of mining in the Lower Donaldson Seam.

The proposed shortwalls in the Lower Donaldson Seam have overall void widths of 120 metres and solid chain pillar widths of 25 metres and, therefore, will extract around 83 % of the coal, assuming that the full seam thickness is mined. The proposed longwalls in the Lower Donaldson Seam have overall void widths of 230 metres and solid chain pillar widths of 35 metres and, therefore, will extract around 87 % of the coal, assuming that the full seam thickness is mined.

Based on "*cliffs*" as defined in the Part 3A Environmental Assessment, the proposed shortwalls and longwalls in the Lower Donaldson Seam would not be permitted to mine beneath the areas defined as rock outcropping in this report (based on the LiDAR survey and site investigations), as these mining methods would extract more than 60 % of the coal seam.

The condition for "*no more than 60 % of the coal seam extracted beneath the cliff areas*" seems to be a condition tailored for bord and pillar mining, where partial extraction can be used to locally reduce the proportion of coal extracted directly beneath these areas. This condition is much more difficult to achieve with shortwall and longwall mining, as it is much more labour intensive and expensive to stop and start these types of mining around these areas.

It is argued, if the rock outcropping areas were to be defined as "*cliff*s" as per the Part 3A Environmental Assessment, that the shortwalls and longwalls should be permitted to mine beneath these areas, as similar discontinuous and low level rock outcropping has been approved to be directly mined beneath elsewhere in the NSW Coalfields, including at Airly, Angus Place, Appin, Baal Bone, Clarence, Dendrobium, Metropolitan, Tower, Ulan, West Cliff and West Wallsend Collieries. Also, the rock outcropping is located on land that is owned by Coal and Allied and is not readily visible from public vantage points.

It has been recommended, that Donaldson Coal seek approval, as part of the S75W modification, for the proposed shortwalls and longwalls in the Lower Donaldson Seam be permitted to mine directly beneath the rock outcropping (i.e. extract more than 60 % of the coal beneath these areas). It is not proposed to mine directly beneath the cliffs located along the upper reaches of Long Gully and Blue Gum Creek, as these are located within the rainforest areas.

There are also two quarries located within the Study Area which are described in Section 6.11.

### 5.3.2. Predictions for the Cliffs and Rock Outcrops

The cliffs located along the upper reaches of Long Gully and Blue Gum Creek are located within the rainforest areas. The proposed shortwalls and longwalls have been setback so that no more than 20 mm of subsidence is predicted within these rainforest areas and, hence, these cliffs.

The rock outcropping is located above the proposed shortwalls and longwalls in the Lower Donaldson Seam and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements for the proposed mining in the Lower Donaldson Seam is provided in Chapter 4.

### 5.3.3. Comparison of the Predictions for the Cliffs and Rock Outcrops with those Provided in the Part 3A Environmental Assessment

The cliffs located along the upper reaches of Long Gully and Blue Gum Creeks are located within the rainforest areas. Both the proposed shortwalls and longwalls, based on the *Modified Layout*, and the bord and pillar mining, based on the *Approved Layout*, have been setback such than no more than 20 mm of subsidence is predicted within these rainforest areas. The predicted mine subsidence parameters for these cliffs, based on the *Modified Layout*, are the same as those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

There were no specific subsidence predictions provided in the Part 3A Environmental Assessment for the areas which have been defined as rock outcropping in this report. Whilst the bord and pillar mining adopted in the Part 3A Environmental Assessment limited the recovery to 60 % of the coal beneath these areas, the *Approved Layout* comprised 160 metre wide extraction panels, whereas, the proposed shortwalls adopted for the *Modified Layout* have 120 metre wide voids.

### 5.3.4. Impact Assessments and Discussions for the Cliffs

The predicted subsidence for the cliffs along the upper reaches of Long Gully and Blue Gum Creeks is less than 20 mm. While it is possible that these cliffs could experience subsidence slightly greater than 20 mm, they would not be expected to experience any significant conventional tilts, curvatures or strains. It is unlikely, therefore, that the cliffs along the upper reaches of Long Gully and Blue Gum Creeks would experience any adverse impacts resulting from the extraction of the proposed shortwalls and longwalls.

### 5.3.5. Impact Assessments and Discussions for the Rock Outcrops

The magnitudes of the predicted mine subsidence movements are likely to be sufficient to result in some fracturing of the rock outcrops and, where the rock is marginally stable, could then result in an instability. Previous experience in the NSW Coalfields indicates that the percentage of rock outcrops that are likely to be impacted by mining is very small, because they are generally discontinuous and have smaller heights.

The impacts on discontinuous and relatively low level rock outcropping is far less than that observed for larger continuous clifflines, which has found to be in the order of 5 % to 10 % of the length of the cliffline, where the depths of cover are around 200 metres to 300 metres. It is expected, therefore, that less than 5 % of the extents of the rock outcropping located above the proposed shortwalls and longwalls in the Lower Donaldson Seam would be impacted by the proposed mining.

The main risk associated with isolated rock falls is public safety. It is recommended that persons who enter the mining lease are made aware of the potential for rockfalls resulting from the extraction of the proposed mining. The conditions of the rock outcropping should be monitored throughout the mining period until such time that the mine subsidence movements have ceased, as may be required, which will be addressed with the future Public Safety Management Plans.

As described in Sections 3.8.2, 4.2.3 and 4.2.4, it is possible that the actual subsidence above the proposed thins seam pillar extraction panels and proposed longwalls could be greater than that predicted, due to the presence of the historic workings in the overlying Borehole Seam, if the existing stooks have remained stable or any of these historic workings are found to be only partially extracted. Whilst the extents of impacts on the rock outcrops would increase, if the maximum upperbound subsidence of 3700 mm developed above the proposed mining, it would still be expected that the potential impacts could be managed using the methods described above.

## 5.4. Steep Slopes

### 5.4.1. Descriptions of the Steep Slopes

For the purposes of this report, steep slopes have been defined as areas of land having natural gradients greater than 1 in 3 (i.e. 33 %, or an angle to the horizontal of 18°). The locations of the steep slopes within the Study Area were determined using the surface level contours generated from a LiDAR survey of the area. The areas identified as having steep slopes within the Study Area are shown in Drawing No. MSEC492-14.

The surface is steepest along *Black Hill* which is a ridgeline located near the centre of the mining lease. The natural grades in this area typically vary up to 1 in 2 (i.e. 27º, or 50 %), with isolated areas have natural grades up to 1 in 1 (i.e. 45º, or 100 %).

A photograph of the steep slopes within the Study Area is provided in Fig. 5.9.

**Fig. 5.9 Photograph of the Steep Slopes within the Study Area**

The surface soils along steep slopes have developed from the Boolaroo (Pnb), Adamstown (Pna), and Lambton (Pnl) Subgroups of the Newcastle Coal Measures, as indicated in Fig. 1.4. The majority of the steep slopes are stabilised by natural bushland.

### 5.4.2. Predictions for the Steep Slopes

The steep slopes are located across the proposed shortwalls and longwalls in the Lower Donaldson Seam and, therefore, are expected to experience the full range of predicted subsidence movements resulting from the extraction of these panels. A summary of the maximum predicted conventional subsidence movements due to the extraction of the shortwalls and longwalls in the Lower Donaldson Seam is provided in Chapter 4.

### 5.4.3. Comparison of the Predictions for the Steep Slopes with those Provided in the Part 3A Environmental Assessment

The steep slopes are expected to experience the full range of predicted subsidence movements. It can be seen from Section 4.3, that the predicted mine subsidence parameters, based on the *Modified Layout*, are generally similar to or less than the range of predicted maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

The maximum predicted subsidence above the proposed LDLW1 to LDLW5 is greater than the maximum predicted in the Part 3A Environmental Assessment, based on the *Approved Layout*, which is discussed further in the impact assessments in the following section.

### 5.4.4. Impact Assessments and Discussions for the Steep Slopes

The maximum predicted tilt for the steep slopes is 30 mm/m (i.e. 3.0 %), which represents a change in grade of 1 in 35. The predicted changes in grade are small when compared to the natural grades of the steep slopes, which are greater than 1 in 3 and, therefore, the tilts are unlikely to result in any significant impact on the stability of the steep slopes.

The steep slopes are more likely to be impacted by ground curvatures and strains. The potential impacts would generally result from the down slope movement of the soil, causing tension cracks to appear at the tops of the slopes and compression ridges to form at the bottoms of the slopes.

The steep slopes are located above the proposed shortwalls and longwalls in the Lower Donaldson Seam, where the depths of cover typically vary between 250 metres and 370 metres. The width-to-depth ratios for these panels, therefore, vary between 0.4 and 0.5 for the proposed shortwalls, and vary between 0.6 and 0.9, for the proposed longwalls.

Whilst the depths of cover for the steep slopes within the Study Area are shallower than those typically in the Southern Coalfield, the width-to-depth ratios for the proposed shortwalls are similar to those for typical longwall mining in the Southern Coalfield. Also, the depths of cover and width-to-depth ratios for the proposed longwalls are similar to those from the longwalls at Dendrobium Mine.

There is extensive experience of mining beneath steep slopes at Dendrobium Mine and elsewhere in the Southern Coalfield, including along the Cataract, Nepean, Bargo and Georges Rivers. No large-scale slope failures have been observed along these slopes, even where longwalls have been mined directly beneath them. Although no large-scale slope failures have been observed in the Southern Coalfield, tension cracking has been observed at the tops of steep slopes as the result of downslope movements.

It is expected, that the maximum size and extent of surface cracking for the steep slopes located above the proposed LDLW1 to LDLW5 will be similar to those observed during the extraction of the Longwalls 1 and 2 at Dendrobium Mine, which had similar depths of cover, similar panel width-to-depth ratios and also included some multi-seam mining. The surface cracking for the steep slopes located above the shortwalls are expected to be smaller than those observed at in Area 1 at Dendrobium Mine.

Dendrobium Longwalls 1 and 2 have void widths of 245 metres and a solid chain pillar width of 50 metres and were extracted from the Wongawilli Seam at a depth of cover ranging between 170 metres and 320 metres. These longwalls partially mined beneath previous bord and pillar workings in the overlying Bulli Seam, having an interburden thickness of approximately 20 metres to 30 metres. The maximum predicted conventional curvatures, resulting from the extraction of Dendrobium Longwalls 1 and 2, were 0.35 $km^{-1}$ hogging and 0.75 $km^{-1}$ sagging, which are similar orders of magnitude to the maxima predicted for the proposed longwalls.

The larger surface cracks observed in Area 1 at Dendrobium Mine were associated with the slippage of soils adjacent to the ridgeline and down the steep slopes, resulting in large tension cracks at the tops of the slopes and compressive ridges at the bottom of slopes. The widths of the observed surface cracks at the tops of the ridgeline and steep slopes varied up to 400 mm wide. Additional surface cracks, typically in the order of 100 mm to 150 mm in width, were also observed further down the ridgeline and steep slopes.

If tension cracks were to develop, as the result of the extraction of the proposed shortwalls and longwalls in the Lower Donaldson Seam, it is possible that soil erosion could occur if these cracks were left untreated. It is possible, therefore, that some remediation might be required, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the slopes in the longer term.

The requirement and methodology for any erosion and sediment control and remediation techniques would be determined in consideration of:- potential impacts when unmitigated, including potential risks to public safety and the potential for self-healing or long-term degradation; potential impacts of the control/remediation technique, including site accessibility; and consultation with relevant stakeholders.

As described in Sections 3.8.2, 4.2.3 and 4.2.4, it is possible that the actual subsidence above the proposed thin seam pillar extraction panels and proposed longwalls could be greater than that predicted, due to the presence of the historic workings in the overlying Borehole Seam, if the existing stooks have remained stable or any of these historic workings are found to be only partially extracted. Whilst the extents of impacts on the steep slopes would increase, if the maximum upperbound subsidence of 3700 mm developed above the proposed mining, it would still be expected that any impacts could be repaired using the methods described above.

## 5.5. Land Prone to Flooding or Inundation

The lower reaches of the Schedule 2 streams comprise wide flat areas which could be prone to flooding and inundation. The descriptions, predictions and impact assessments for the streams are provided in Section 5.1, which includes setbacks so that no more than 20 mm of subsidence is predicted within the 40 metre buffer zones from the banks of the Schedule 2 streams. Blue Gum Creek drains into the *Pambalong Nature Reserve*, which includes a swamp area, and the descriptions, predictions and impact assessments are provided in Section 5.6.

## 5.6. Swamps and Wetlands

### 5.6.1. Descriptions of the Swamps and Wetlands

There are a number of swamps which have been identified along the lower reaches of Blue Gum Creek. The *Pambalong Nature Reserve* is also located on the eastern part of the mining lease and comprises a swamp area and RAMSAR wetlands. The locations of the swamps and wetlands within the Study Area are shown in Drawing No. MSEC492-13. A photograph of the *Pambalong Nature Reserve* is provided in Fig. 5.10.


**Fig. 5.10 Photograph of the Pambalong Nature Reserve (after Fig. 6.7 of SE, 2006)**

#### 5.6.2. Predictions for the Swamps and Wetland

The swamps along Blue Gum Creek are located within the limit of alluvium of this stream, as shown in shown in Drawing No. MSEC492-13. The proposed shortwalls and longwalls have been setback from the stream so that no more than 20 mm of subsidence is predicted within the limit of alluvium and, hence, the swamps. There is no mining proposed in the vicinity of the *Pambalong Nature Reserve*.

Project Approval 05-0136 requires Donaldson Coal to "*ensure that the project does not result in any subsidence impacts on the Pambalong Nature Reserve*" and "*limit mining operations to first workings beneath, and ensure that mining subsidence impacts requiring mitigation works*" on the Blue Gum Creek alluvium.

The swamps and the *Pambalong Nature Reserve*, therefore, are predicted to experience less than 20 mm of subsidence as a result of the extraction of the proposed shortwalls and longwalls. Whilst it is possible that the swamps could experience subsidence slightly greater than 20 mm, they would not be expected to experience any significant conventional tilts, curvatures or strains.

#### 5.6.3. Comparison of the Predictions for the Swamps and Wetland with those Provided in the Part 3A Environmental Assessment

The *Approved Layout* adopted in the Part 3A Environmental Assessment used the same subsidence control zones for the alluvium and wetland, with the bord and pillar mining setback so that no more than 20 mm of subsidence was predicted within these zones. The predicted subsidence parameters for the swamps and wetland, based on the *Modified Layout*, therefore, are similar to those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

#### 5.6.4. Impact Assessments and Discussions for Swamps and Wetland

It is unlikely that the swamps or the *Pambalong Nature Reserve* would experience any adverse impacts as the result of mining, as the proposed shortwalls and longwalls have been setback so that no more than 20 mm of subsidence is predicted within these subsidence control zones.

### 5.7. Water Related Ecosystems

There are water related ecosystems within the Study Area associated with the streams, which are discussed in Section 5.1, and with the *Pambalong Nature Reserve*, which is discussed in Section 5.6.

### 5.8. Threatened and Protected Species

#### 5.8.1. Descriptions of the Rainforest Communities

Rainforest communities have been identified along the upper reaches of Long Gully and Blue Gum Creek. The locations of the rainforest communities are shown in Drawing No. MSEC492-13 and a photograph is provided in Fig. 5.11.

**Fig. 5.11 Photograph of the Rainforest Community along the Upper Reaches of Long Gully (after Fig. 6.6 of SE, 2006)**

Subsidence control zones will be applied to the rainforest communities within the Study Area.

#### 5.8.2. Predictions for the Rainforest Communities

The proposed shortwalls and longwalls have been setback from the rainforest communities so that no more than 20 mm of subsidence is predicted within the mapped extents of these areas. Whilst it is possible that the rainforest communities could experience subsidence slightly greater than 20 mm, they would not be expected to experience any significant conventional tilts, curvatures or strains.

#### 5.8.3. Comparison of the Predictions for the Rainforest Communities with those Provided in the Part 3A Environmental Assessment

The *Approved Layout* adopted in the Part 3A Environmental Assessment used the same subsidence control zones for the rainforest communities, with the bord and pillar mining setback so that no more than 20 mm of subsidence was predicted within these zones. The predicted subsidence parameters for the rainforest communities, based on the *Modified Layout*, therefore, are similar to those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

#### 5.8.4. Impact Assessments and Discussions for the Critical Habitat

It is unlikely that the rainforest communities would experience any adverse impacts as the result of mining, as the proposed shortwalls and longwalls have been setback so that no more than 20 mm of subsidence is predicted within these rainforest communities.

### 5.9. Natural Vegetation

The vegetation within the Study Area generally consists of undisturbed native bush. The Part 3A Environmental Assessment describes that the "*vegetation on the site comprises dry schlerophyll woodland and semi-cleared rural land use areas with riparian vegetation along the creeks. Pockets of cool, temperate rainforest exist along the protected areas of Long Gully below the cliff lines*" (SE, 2006). The extent of natural vegetation can be seen from the aerial photograph provided in Fig. 5.12.

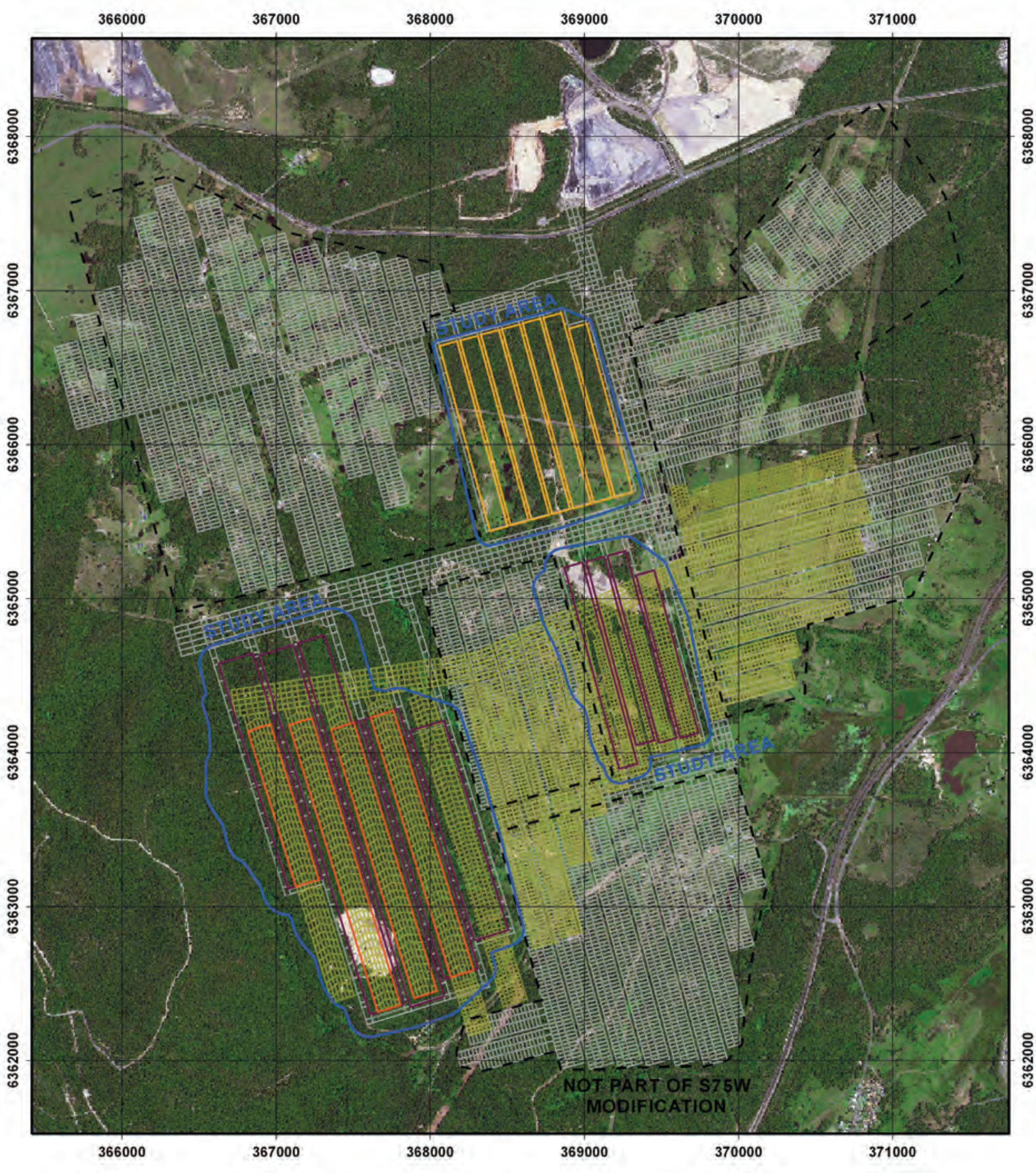


**Fig. 5.12 Aerial Photograph showing the Extent of Natural Vegetation**

The descriptions, predictions and impact assessments for the *Pambalong Nature Reserve* are provided in Section 5.6. The descriptions, predictions and impact assessments for the rainforest communities are provided in Section 5.8.

The following sections provide the descriptions, predictions and impact assessments for the surface infrastructure identified within the Study Area. Comparisons of the predictions, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, are also provided in this chapter.

All significant items of surface infrastructure located outside the Study Area, which may be subjected to valley related or far-field horizontal movements and may be sensitive to these movements, have also been included as part of these assessments.

## 6.1. Railways

There are no operating railways in the Study Area. The disused Richmond Vale Railway corridor crosses the southern part of the Study Area, which is shown in Drawing No.MSEC492-15. The corridor is located outside the proposed panels, as it generally follows Blue Gum Creek and, therefore, is located within the subsidence control zone.

There are no tracks or other railway infrastructure within the corridor identified within the Study Area. A photograph of the railway corridor is provided in Fig. 6.1. It is understood that the railway is listed as a heritage item with the Cessnock City Council (SE, 2006).

**Fig. 6.1 Photograph of the Disused Railway Corridor**

The railway corridor is predicted to experience less than 20 mm of subsidence as the result of mining. While it is possible that the corridor could experience subsidence slightly greater than 20 mm, it would not be expected to experience any significant conventional tilts, curvatures or strains. As there is no railway infrastructure associated with the disused corridor, no impacts are anticipated.

The disused Richmond Vale No. 1 Tunnel is located approximately 1 kilometres south-west of LDLW2, at its closest point to the proposed panels. The tunnel could experience small far-field horizontal movements as a result of the proposed mining. At this distance, the far-field horizontal movements are expected to be small bodily movements which are not associated with any measurable strains. It is unlikely, therefore, that the tunnel would experience any adverse impacts as the result of mining.

## 6.2. Local Roads, Bridges and Culverts

### 6.2.1. Description of the Local Roads and Tracks

The public roads and tracks within the Study Area are shown in Drawing No. MSEC492-15. Black Hill Road is the only public road located above the proposed shortwalls in the Upper Donaldson Seam, with a total length of road of approximately 1.1 kilometres located directly above the proposed second workings. Photographs of Black Hill Road (SE, 2006) are provided in Fig. 6.2.

**Fig. 6.2 Photographs of Black Hill Road (after Figs. 6.28 and 6.29 of SE, 2006)**

Taylors and Meredith Roads are located above the proposed shortwalls in the Lower Donaldson Seam, with a total length of road of approximately 1 kilometre located directly above the proposed second workings.

The public roads have bitumen seals and have been constructed with several cuttings, embankments and drainage culverts. There are also other unsealed roads and tracks located across the Study Area. The roads located west of the 330 kV transmission line are maintained by the Cessnock Council and the roads located east of the transmission line are maintained by the Newcastle City Council.

### 6.2.2. Predictions for the Local Roads and Tracks

Black Hill Road is located near the central part of the shortwalls in the Upper Donaldson Seam, where the depths of cover are greater than those in the north-eastern corner of these panels. The predicted mine subsidence parameters for this road, therefore, are less than the maxima for the shortwalls in the Upper Donaldson Seam. The predicted profiles of subsidence, tilt and curvature along this road are similar to those for Prediction Line 1, which are shown in Fig. C.01, in Appendix C.

The roads and tracks located above the shortwalls and longwalls in the Lower Donaldson Seam are located across the mining areas and, therefore, are expected to experience the full range of predicted subsidence movements for these areas.

A summary of the maximum predicted subsidence, tilt and curvatures for the roads and tracks within the Study Area is provided in Table 6.1.

**Table 6.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Roads and Tracks**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Black Hill Road Above Shortwalls in Upper Donaldson Seam | 1500 | 30 | 1.5 | 2.0 |
| Taylors and Meredith Roads Above Shortwalls in Lower Donaldson Seam | 1700 | 10 | 0.5 | 1.0 |
| Unsealed Tracks Above Shortwalls and Longwalls in Lower Donaldson Seam | 3100 | 30 | 1.0 | 1.0 |

The maximum predicted conventional curvature for Black Hill Road, above the proposed shortwalls in the Upper Donaldson Seam, is 1.5 $km^{-1}$ hogging and 2.0 $km^{-1}$ sagging, which represent minimum radii of curvature of 0.7 kilometres and 0.5 kilometres, respectively. The maximum predicted conventional curvature for the roads and tracks above the proposed shortwalls and longwalls in the Lower Donaldson Seam are 1.0 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvatures of 1 kilometre.

The maximum predicted conventional strains for Black Hill Road, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 15 mm/m tensile and 20 mm/m compressive. The maximum predicted conventional strains for the roads and tracks above the shortwalls and longwalls in the Lower Donaldson Seam are 10 mm/m tensile and compressive. The analysis of strains measured in the NSW Coalfields, for previously extracted panels having similar width-to-depth ratios as the proposed shortwalls, is provided in Section 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements and downslope movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

### 6.2.3. Comparison of the Predictions for the Local Roads and Tracks with those Provided in the Part 3A Environmental Assessment

The comparison between the maximum predicted subsidence parameters for the roads and tracks, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, is provided in Table 6.2.

**Table 6.2 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the Roads and Tracks Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 1100 ~ 1300 (Above Panels)<br>310 ~ 530 (Above Pillars) | 28 ~ 32 | 1.17 ~ 1.31 | 1.48 ~ 1.66 |
| Modified Layout (MSEC492) | 1700 (Sealed roads)<br>3100 (Unsealed tracks) | 30 | 1.5 | 2.0 |

It can be seen from the above table, that the maximum predicted subsidence for the roads and tracks of 3100 mm, based on the *Modified Layout*, is greater than the maximum provided in the Part 3A Environmental Assessment, based on the *Approved Layout*. It is noted, that the maximum predicted subsidence of 3100 mm occurs for the unsealed tracks above the proposed LDLW1 to LDLW5. The maximum predicted subsidence for the local roads and tracks located above the proposed shortwalls, based on the *Modified Layout*, is 1700 mm.

The potential for impacts on the roads and tracks are dependent on the differential subsidence (i.e. tilt, curvature and strain), rather than the magnitude of vertical subsidence. It can be seen from the above table, that the predicted tilts and curvatures, based on the *Modified Layout*, are similar to or slightly greater than the range of predicted maxima provided in the Part 3A Environmental Assessment based on the *Approved Layout*.

As described in Sections 3.8.2, 4.2.3 and 4.2.4, it is possible that the actual subsidence above the proposed thin seam pillar extraction panels, proposed longwalls and the northern ends of the proposed shortwalls in the Lower Donaldson Seam could be greater than that predicted, due to the presence of the historic workings in the overlying Borehole Seam, if the existing stooks have remained stable or any of these historic workings are found to be only partially extracted. The discussions on the potential impacts on the unsealed tracks, for the predicted and upperbound subsidence parameters based on the *Modified Layout*, are provided in the following section.

### 6.2.4. Impact Assessments and Discussions for the Local Roads above the Proposed Shortwalls in the Upper Donaldson Seam

The predicted vertical subsidence along Black Hill Road could potentially affect the surface water drainage along this road. As described in the Part 3A Environmental Assessment, this road could potentially be "*impacted by ponding, where the road crosses Four Mile and Viney Creeks*" (SE, 2006).

The existing and predicted post-mining levels and grades along Black Hill Road are provided in Fig. 6.3. It can be seen from this figure, that the predicted changes in grade are small when compared with the existing gradients along the alignment of the road. It is expected, therefore, that any increase in the levels of ponding or flooding at the stream crossings would be minor.

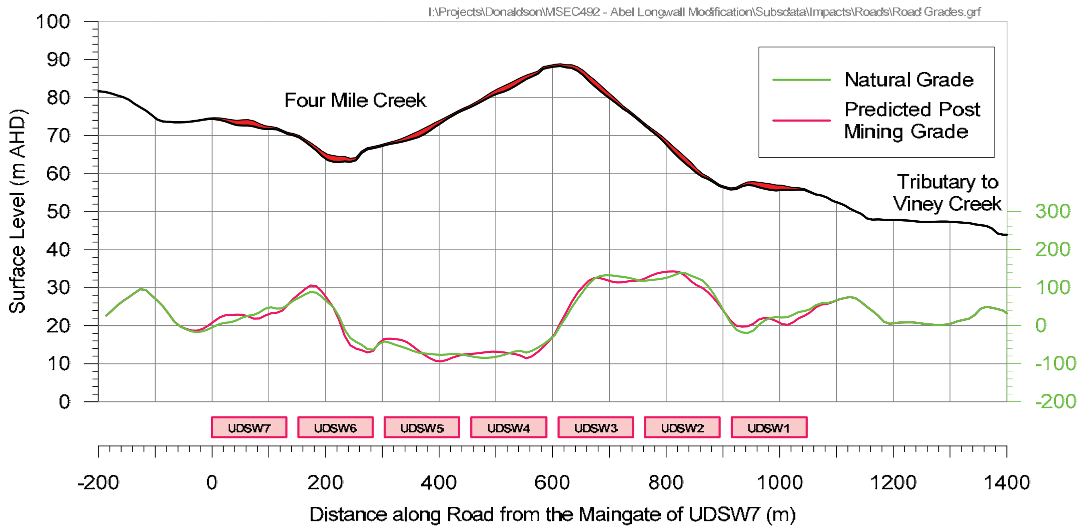


**Fig. 6.3 Existing and Predicted Post-Mining Levels and Grades along Black Hill Road**

The maximum predicted conventional tilts and curvatures for Black Hill Road, based on the *Modified Layout*, are similar to the range of maximum provided in the Part 3A Environmental Assessment, based on the *Approved Layout*. The impact assessment and proposed management strategies for the road, therefore, are the same as those provided in the Part 3A Environmental Assessment.

The Part 3A Environmental Assessment states that the impacts to Black Hill Road "*will be significant, in that cracking and buckling or shear failures are likely to occur above and during the extraction of each panel mined. Maximum tensile crack widths are estimated to range between 60 and 95 mm based on the CWC tensile strain predictions*" (SE, 2006).

The minimum depth of cover along Black Hill Road, above the proposed shortwalls in the Upper Donaldson Seam, is around 100 metres. The minimum depth of cover along this road is similar to that where Beltana Longwalls 1 to 10 mined directly beneath Charlton Road, which varied between 80 metres and 115 metres. The impacts to Black Hill Road are expected to be less than those observed along Charlton Road, as the width-to-depth ratio of the proposed shortwalls, of 1.2, is less than those for the longwalls at Beltana, which were greater than 2.0.

The crack widths observed along Charlton Road, due to the extraction of Beltana Longwalls 1 to 10, typically varied between 50 mm and 100 mm, with a maximum observed crack width around 380 mm. The heave and step heights observed along the road were typically in the order of 25 mm. Examples of the impacts observed along Charlton Road at Beltana is provided in Fig. 6.4.

**Fig. 6.4 Examples of Impacts Observed along Charlton Road at Beltana**

It is expected, that Black Hill Road could be maintained in a safe and serviceable condition throughout the mining period using visual monitoring and normal road maintenance techniques. It is expected, that the impacts would develop gradually as the extraction face of each shortwall mined directly beneath the road.

It is recommended that management plans are developed, in consultation with the Cessnock and Newcastle City Councils as part of the Extraction Plan process. With the implementation of these management strategies, it would be expected that Black Hill Road could be maintained in safe and serviceable conditions throughout the mining period.

### 6.2.5. Impact Assessments and Discussions for the Public Roads above the Proposed Shortwalls in the Lower Donaldson Seam

The maximum predicted conventional tilt for the public roads above the proposed shortwalls in the Lower Donaldson Seam is 10 mm/m (i.e. 1 %), which represents a change in grade of 1 in 100. The predicted changes in grade are small, in the order of 1 % and, therefore, the potential changes in the surface water drainage are expected to be minor.

The maximum predicted conventional hogging and sagging curvatures for the public roads above the proposed shortwalls in the Lower Donaldson Seam are 0.3 $km^{-1}$ hogging and 0.6 $km^{-1}$ sagging, which represent minimum radii of curvature of 3 kilometres and 2 kilometres, respectively. The predicted conventional strains for these roads, based on applying a factor of 10 to the predicted maximum conventional curvatures, are 3 mm/m tensile and 6 mm/m compressive.

It is expected, at these magnitudes of predicted curvatures and strains, that cracking and rippling of the road surfaces would occur as each of the proposed shortwalls mine beneath them. The depths of cover along the public roads, above the proposed shortwalls in the Lower Donaldson Seam, typically vary between 160 metres and 300 metres, which equate to panel width-to-depth ratios of 0.4 to 0.8.

Previous experience of mining directly beneath roads in the NSW Coalfields, having similar depths of cover and panel width-to-depth ratios, indicates that cracks widths are typically between 10 mm and 25 mm and heaving heights are typically up to 25 mm. It is expected, that the public roads above the proposed shortwalls in the Lower Donaldson Seam could be maintained in safe and serviceable condition throughout the mining period using normal road maintenance techniques.

### 6.2.6. Impact Assessments and Discussions for the Unsealed Tracks above the Proposed Shortwalls and Longwalls in the Lower Donaldson Seam

It is expected, at the magnitudes of predicted curvatures and strains, that cracking and heaving of the unsealed road surfaces would occur as the result of the extraction of the proposed shortwalls and longwalls in the Lower Donaldson Seam. The unsealed tracks could also experience increased ponding in the locations of maximum tilt. It is expected, that the unsealed tracks could be maintained in safe and serviceable conditions by regrading and recompacting the road surfaces during mining.

As described in Sections 3.8.2, 4.2.3 and 4.2.4, it is possible that the actual subsidence above the proposed thin seam pillar extraction panels and proposed longwalls could be greater than that predicted, due to the presence of the historic workings in the overlying Borehole Seam, if the existing stooks have remained stable or any of these historic workings are found to be only partially extracted. Whilst the extents of impacts on the unsealed tracks would increase, if the maximum upperbound subsidence of 3700 mm developed above the proposed longwalls, it would still be expected that any impacts could be repaired using the methods described above.

The potential impacts resulting from the destabilisation of the historic workings in the Borehole Seam could develop more rapidly than impacts resulting from single-seam mining. Only unsealed tracks are located above the historic workings, in the locations of the proposed thin seam pillar extraction panels and proposed longwalls, and Meredith Road (also unsealed) is located above the historic workings, in the location of the proposed shortwalls in the Lower Donaldson Seam. It is recommended, therefore, that strategies are developed as part of the Extraction Plan process to manage these potential impacts, which may include visual and ground monitoring, as well as the development of the appropriate remediation measures.

## 6.3. The F3 Freeway, Hunter Expressway and Bridges

The Sydney-Newcastle (F3) Freeway is located outside the Study Area, which is shown in Drawing No. MSEC492-15. The freeway is located around 1.1 kilometres south-east of the shortwalls in the Lower Donaldson Seam, at its closest point to the proposed mining. At this distance, the highway is not predicted to experience any significant conventional subsidence movements.

The F3 Freeway could experience far-field horizontal movements, which are described in Sections 3.5 and 4.6. It can be seen from Fig. 4.3, that incremental far-field horizontal movements up to around 50 mm have been observed at distances of 1.1 kilometres from previous underground mining. These movements tend to be bodily movements, towards the extracted goaf area, which are accompanied by very low levels of strain, generally less than the order of survey tolerance.

It is unlikely, therefore, that the freeway pavement would experience any adverse impacts resulting from the proposed mining. Similarly, it is not expected that the drainage culverts, cuttings, embankments, emergency phone system and road signage would experience any adverse impacts resulting of the proposed mining.

It is recommended that the movements are monitored at the freeway bridges closest to the proposed mining, which includes the Stockrington Road overpass. It is also recommended that a Trigger Action Response Plan (TARP) is developed for these bridges, as part of the Extraction Plan process, in consultation with the Roads and Maritime Services (RMS).

The Hunter Expressway is currently being constructed to the south of the Study Area, which is shown in Drawing No. MSEC492-15. The expressway is located around 1.2 kilometres south of the longwalls in the Lower Donaldson Seam, at its closest point to the proposed mining. At this distance, the expressway is not predicted to experience any significant conventional subsidence movements.

The Hunter Expressway is being constructed above the historic workings in the Borehole Seam. It is unlikely that the proposed mining would reactivate the historic workings beneath the expressway due to the distance from the proposed mining. The potential for pillar run is also limited due to the discontinuous nature of the historic workings between the expressway and the proposed mining.

## 6.4. Electrical Infrastructure

### 6.4.1. Description of the Electrical Infrastructure

A single circuit 330 kV transmission line owned by *TransGrid* is located south of the proposed shortwalls and longwalls in the Lower Donaldson Seam. The location of the transmission line is shown in Drawing No. MSEC492-16. The tower numbers are also indicated in this drawing.

The towers are located outside the proposed panels, as the easement generally follows Blue Gum Creek and, therefore, is located within the subsidence control zone. There are three tension towers located within the Study Area, being Towers 10B, 11B and 13B. The tension towers are supported on inclined piles. A number of the suspension towers have been constructed with cruciform bases.

A photograph of the transmission line is provided in Fig. 6.5.

**Fig. 6.5 Photograph of the 330 kV Transmission Line**

A 132 kV powerline owned by *Ausgrid* crosses the eastern part of the Study Area. The three phase conductors are supported by dual poles, with the locations indicated in Drawing No. MSEC459-16. There are eight pole-pairs which are located directly above the proposed panels in the Lower Donaldson Seam, north and south of West Mains 2. A photograph of the 132 kV powerline is provided in Fig. 6.6.

**Fig. 6.6 Photograph of the 132 kV Power Line**

There is also a network of 66 kV and low voltage powerlines owned by *Ausgrid* located across the Study Area. These powerlines service the residential properties within the Study Area.

### 6.4.2. Predictions for the Electrical Infrastructure

The predicted profiles of conventional subsidence, tilt along and tilt across the alignment of the 330 kV transmission line are shown in Fig. C.03, in Appendix C. A summary of the maximum predicted subsidence, tilt and curvatures anywhere along the transmission line, within the Study Area, is provided in Table 6.3.

**Table 6.3 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures Anywhere Along the 330 kV Transmission Line within the Study Area**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| 330 kV Transmission Line | < 20 | < 0.5 | < 0.01 | < 0.01 |

It is noted, that the predicted subsidence parameters provided in the above table are the maxima resulting from the proposed mining and, therefore, do not include the subsidence parameters resulting from the approved bord and pillar mining which are not being modified as part of this Section 75W Modification.

The maximum predicted tilt for the transmission line is less than 0.5 mm/m (i.e. < 0.1 %), which represents a change in grade of less than 1 in 2,000. The maximum predicted conventional curvatures for the transmission towers are less 0.01 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvature greater than 100 kilometres.

The maximum predicted conventional strains for the transmission towers, based on applying a factor of 10 to the maximum predicted conventional curvatures, are less than survey tolerance (i.e. less than 0.3 mm/m tensile and compressive).

The predicted profiles of conventional subsidence, tilt along and tilt across the alignment of the 132 kV powerline are shown in Fig. C.04, in Appendix C. A summary of the maximum predicted subsidence and tilt at the powerpole locations, within the Study Area, is provided in Table 6.4. The parameters provide in this table are the maximum values within a 20 metre radius of the powerpoles. The tilt is the maximum at any time during or after the completion of mining.

**Table 6.4 Maximum Predicted Total Conventional Subsidence and Tilt for the 132 kV Powerline**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| 132 kV Powerline | 950 | 10 | 0.5 | 0.5 |

It is noted, that the predicted subsidence parameters provided in the above table are the maxima within the Study Area and, therefore, do not include the subsidence parameters resulting from the approved bord and pillar mining which are not being modified as part of this Section 75W Modification.

The 66 kV powerlines and consumer lines are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

### 6.4.3. Comparison of the Predictions for the Electrical Infrastructure with those Provided in the Part 3A Environmental Assessment

The comparison between the maximum predicted subsidence parameters for the 330 kV transmission line, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, is provided in Table 6.5. It is noted, that the parameters provided in the table below are the maxima anywhere along the transmission line, not just at the tower locations.

**Table 6.5 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the 330 kV Transmission Line Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 820 ~ 1820 (Above Panel)<br>100 ~ 820 (Above Pillar) | 8 ~ 46 | 0.33 ~ 2.39 | 0.42 ~ 4.3 |
| Modified Layout (MSEC492) | < 20 | < 0.5 | < 0.01 | < 0.01 |

It is noted, that the predicted subsidence parameters provided in the above table for the *Modified Layout* are the maxima resulting from the proposed shortwalls and longwalls and, therefore, do not include the subsidence parameters resulting from the approved bord and pillar mining which are not being modified as part of this Section 75W Modification.

It can be seen from the above table, that the maximum predicted mine subsidence parameters for the 330 kV transmission line, resulting from the extraction of the proposed shortwalls and longwalls based on the *Modified Layout*, are substantially less than those provided in the Part 3A Environmental Assessment based on the *Approved Layout*.

The comparison between the maximum predicted subsidence parameters for the 132 kV powerline, based on the *Approved Layout* and the *Modified Layout*, is provided in Table 6.6.

**Table 6.6 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the 132 kV Powerline Based on the Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 690 ~ 1330 (Above Panel)<br>350 ~ 1020 (Above Pillar) | 10 ~ 66 | 0.33 ~ 3.4 | 0.42 ~ 4.3 |
| Modified Layout (MSEC492) | 950 | 10 | 0.5 | 0.5 |

It is noted, that the predicted subsidence parameters provided in the above table for the *Modified Layout* are the maxima resulting from the proposed shortwalls and longwalls and, therefore, do not include the subsidence parameters resulting from the approved bord and pillar mining which are not being modified as part of this Section 75W Modification.

It can be seen from the above table, that the maximum predicted mine subsidence parameters for the 132 kV powerline, resulting from the extraction of the proposed shortwalls and longwalls based on the *Modified Layout*, are similar to the range of predicted maxima provided in the Part 3A Environmental Assessment based on the *Approved Layout*.

### 6.4.4. Impact Assessments and Recommendations for the 330 kV Transmission Line

The potential impacts on the 330 kV transmission line are less than those assessed in the Part 3A Environmental Assessment as the predicted mine subsidence parameters, based on the *Modified Layout*, are substantially less than those based on the *Approved Layout*. It is noted, that the predicted subsidence parameters for the *Modified Layout* are the maxima within the Study Area and, therefore, do not include the subsidence parameters resulting from the approved bord and pillar mining which are not part of this Section 75W Modification.

The 330 kV transmission towers are located outside the extents of the proposed shortwalls. The maximum predicted subsidence at the towers is less than 20 mm. Whilst it is still possible that the transmission towers could experience subsidence slightly greater than 20 mm, the towers would not be expected to experience any significant conventional tilts, curvatures or strains.

It is unlikely, therefore, that the 330 kV Transmission Line would experience any adverse impacts as a result of the proposed mining. It is recommended, that the predicted movements for the transmission line are provided to TransGrid, so that a review can be undertaken and confirm the structural integrity and stability of the towers.

### 6.4.5. Impact Assessments and Recommendations for the 132 kV and 66 kV Powerlines

The potential impacts on the 132 kV and 66 kV powerlines are similar to those assessed in the Part 3A Environmental Assessment as the predicted mine subsidence parameters, based on the *Modified Layout*, are within the range of those based on the *Approved Layout*. It is noted, that the predicted subsidence parameters provided for the 132 kV powerline are the maxima within the Study Area and, therefore, do not include the subsidence parameters resulting from the approved bord and pillar mining which are not being modified as part of this Section 75W Modification.

As described in the Part 3A Environmental Assessment, that "*a rule of thumb used by Energy Australia engineers is that the top of the poles may displace up to 2 diameters horizontally before intervention or mitigation works are considered necessary. Based on 15 m high power pole that has a diameter of 250 mm, the maximum tolerable tilt at a power pole is in the order of 33 mm/m*" (SE, 2006).

The 132 kV powerline crosses the proposed shortwalls in Lower Donaldson Seam. There is one powerpole pair located directly above the proposed shortwalls, where the maximum predicted tilt is 10 mm/m. It is unlikely, therefore, that the 132 kV powerline would experience any adverse impacts as a result of the proposed mining.

The 66 kV powerlines cross the proposed shortwalls in the Upper and Lower Donaldson Seam. These powerlines are predicted to experience tilts up to 30 mm/m. It is possible, that the powerlines located directly above the proposed shortwalls in the Upper Donaldson Seam may require some preventive or remedial measures.

Extensive experience of mining beneath powerlines in the NSW Coalfields, where the mine subsidence movements were similar to those predicted for the proposed mining, indicates that incidences of impacts is very low and of a minor nature. Some remedial measures have been required, in the past, which included adjustments to cable catenaries, pole tilts and to consumer cables which connect between the powerlines and houses.

It is recommended that the predicted movements, based on the *Modified Layout*, are provided to *Ausgrid* so that the necessary preventive measures can be developed, which may include the installation of guy wires or cable sheaves. It is also recommended, as described in the Part 3A Environmental Assessment, that a TARP is developed, in consultation with *Ausgrid*, as part of the Extraction Plan process.

## 6.5. Telecommunications Infrastructure

### 6.5.1. Description of the Telecommunications Infrastructure

A direct buried optical fibre cable owned by *Telstra* crosses the proposed shortwalls in the Upper Donaldson Seam. The cable branches off John Renshaw Drive and connects with a local distribution frame located off Black Hill Road.

A direct buried optical fibre cable owned by *Optus* is also located south of the proposed shortwalls in the Lower Donaldson Seam. This section of cable is proposed to be re-routed, as shown in Drawing No. MSEC492-17. The existing and new alignments of the cable are located 240 metres and 700 metres, respectively, from LDSW4, at their closest point to the proposed mining.

There are also direct buried copper telecommunications cables owned by *Telstra* located across the Study Area. These cables service the residential properties within the Study Area. The copper cable network is shown in Drawing No. MSEC492-17.

### 6.5.2. Predictions for the Telecommunications Infrastructure

The predicted profiles of conventional subsidence, tilt and curvature along the alignment of the Telstra optical fibre cable are shown in Figs. C.05, in Appendix C. A summary of the maximum predicted subsidence and curvatures for this cable is provided in Table 6.7.

**Table 6.7 Maximum Predicted Total Conventional Subsidence and Curvatures for the Telstra Optical Fibre Cable**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Telstra Optical Fibre Cable | 1600 | 30 | 1.5 | 2.5 |

The parameters provided in the above table are the maxima along the alignment of the optical fibre cable. The tilt and curvatures are the maxima at any time during or after the completion of mining.

The maximum predicted ground curvature for the Telstra optical fibre cable are 1.5 $km^{-1}$ hogging and 2.5 $km^{-1}$ sagging, which represent minimum radii of curvature of 0.7 kilometres and 0.4 kilometres. The maximum predicted conventional strains for the optical fibre cable, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 15 mm/m tensile and 25 mm/m compressive. The analysis of strains measured in the NSW Coalfields, for previously extracted panels having similar width-to-depth ratios as the proposed shortwalls, is provided in Section 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements and downslope movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The existing and re-aligned Optus optical fibre cables are predicted to experience less than 20 mm subsidence as a result of the proposed shortwalls, longwalls and thin seam pillar extraction panels. It is unlikely, therefore, that these optical fibre cables would experience any measureable conventional subsidence movements resulting from the extraction of the proposed shortwalls, longwalls and thin seam pillar extraction panels, based on the *Modified Layout*.

The copper telecommunications cables are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

### 6.5.3. Comparison of the Predictions for the Telecommunications Infrastructure with those Provided in the Part 3A Environmental Assessment

The comparisons of the maximum predicted subsidence parameters for the Telstra optical fibre cable, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, are provided in Table 6.8.

**Table 6.8 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the Telstra OFC Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 690 ~ 1330 (Above Panel)<br>350 ~ 1020 (Above Pillar) | 10 ~ 66 | 0.33 ~ 3.4 | 0.42 ~ 4.3 |
| Modified Layout (MSEC492) | 1600 | 30 | 1.5 | 2.5 |

It can be seen from Table 6.8, that the maximum predicted subsidence for the Telstra optical fibre cable, based on the *Modified Layout*, is greater than the maximum provided in the Part 3A Environmental Assessment, based on the *Approved Layout*. It should be noted, however, that the potential for impacts on the cable are dependent on differential subsidence (i.e. curvature and strain), rather than the magnitude of vertical subsidence. The maximum predicted tilt, curvatures and conventional strains for this cable, based on the *Modified Layout*, are similar to the range of predicted maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

The comparison of the maximum predicted subsidence parameters for the copper telecommunications cables, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, is provided in Table 6.9.

**Table 6.9 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the Copper Cables Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 750 ~ 1330 (Above Panel)<br>300 ~ 900 (Above Pillar) | 16 ~ 33 | 0.58 ~ 1.31 | 0.73 ~ 1.66 |
| Modified Layout (MSEC492) | 1500 | 30 | 1.5 | 2.0 |

It can be seen from the above table, that the maximum predicted subsidence for the copper telecommunications cables, based on the *Modified Layout*, is greater than the maximum provided in the Part 3A Environmental Assessment, based on the *Approved Layout*. It should be noted, however, that the potential for impacts on the cable are dependent on differential subsidence (i.e. curvature and strain), rather than the magnitude of vertical subsidence. The maximum predicted tilt, curvatures and conventional strains for these cables, based on the *Modified Layout*, are similar to but slightly greater than the range of predicted maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

### 6.5.4. Impact Assessments and Discussions for the Optical Fibre Cable

The potential impacts on the Telstra optical fibre cable are similar to those assessed in the Part 3A Environmental Assessment as the predicted mine subsidence parameters, based on the *Modified Layout*, are similar to the range of predicted maxima based on the *Approved Layout*. The predicted strains for the Telstra optical fibre cable are likely to be of sufficient magnitude to impact on the serviceability of the cable.

The optical fibre cable could also potentially be affected by elevated strains, resulting from non-conventional ground movements or where the cables connect to the support structures, which may act as anchor points, preventing any differential movements that may have been allowed to occur in the ground. Tree roots have also been known to anchor cables to the ground. The extent to which the anchor points affect the ability of the cables to tolerate the mine subsidence movements depends on the cable size, type, age, installation method and ground conditions.

In addition to this, optical fibre cables contain additional fibre lengths over the sheath lengths, where the individual fibres are loosely contained within tubes. Compression of the sheaths can transfer to the loose tubes and fibres and result in “micro-bending” of the fibres constrained within the tubes, leading to higher attenuation of the transmitted signal. If the maximum predicted compressive strains were to be fully transferred into the optical fibre cables, the strains could be of sufficient magnitude to result in the reduction in capacities of the cables or transmission loss.

It is likely that preventive measures would be required for this cable, such as that described in the Part 3A Environmental Assessment, by “*temporarily remov[ing] the cables from the trenches and place them in significantly larger diameter PVC conduit before placing the cable back in the trench. The conduit would then prevent direct transfer of ground strain into the cables during undermining*” (SE, 2006). Similar preventive measures have been successfully undertaken at South Bulga and Beltana Collieries.

The strains transferred into the optical fibre cables can be monitored using Optical Time Domain Reflectometer (OTDR), which can be used to detect elevated strains resulting from non-conventional ground movements. If elevated strains are detected along the cable, they can be relieved by exposing and then reburying the affected section of cable.

It is recommended that the predicted movements along the optical fibre cables, based on the *Modified Layout*, are provided to Telstra so that the necessary management plans can be developed. It is also recommended, as described in the Part 3A Environmental Assessment, that a TARP is developed, in consultation with Telstra, as part of the Extraction Plan process.

### 6.5.5. Impact Assessments and Discussions for the Copper Cables

The potential impacts on the copper telecommunications cables are similar to those assessed in the Part 3A Environmental Assessment as the maximum predicted tilts, curvatures and strains, based on the *Modified Layout*, are similar to but slightly greater than the range of predicted maxima based on the *Approved Layout*.

As described in the Part 3A Environmental Assessment, “*as a ‘rule-of-thumb’, normal copper telecommunications cables can generally accommodate tensile strains of up to 20 mm/m*” (SE, 2006). Extensive experience of mining beneath copper telecommunications cables in the NSW Coalfields, where the mine subsidence movements were similar to those predicted for the proposed mining, indicates that incidences of impacts is extremely low and of a minor nature.

For example, copper telecommunications cables were previously mined beneath by the Whybrow Seam longwalls at South Bulga and Beltana and there were no reported impacts. The maximum observed strains, where Beltana Longwalls 1 to 10 mined directly beneath the copper cables, were 26 mm/m tensile and 24 mm/m compressive.

Based on this experience, it is unlikely that the proposed mining would result in any significant impacts on the direct buried or aerial copper telecommunications cables within the Study Area. Any minor impacts on these cables would be expected to be relatively infrequent and easily repaired.

## 6.6. Agriculture Utilisation and Agriculture Improvements

The land above the proposed shortwalls has been partially cleared and is used for residential and light agricultural purposes, including orchards and some grazing. The agricultural utilisation could be affected by surface cracking, which is discussed in Section 4.8. The predictions, impact assessments and discussions for the rural building structures, fences and farm dams are provided in Sections 6.7, 6.8 and 6.9, respectively.

## 6.7. Rural Building Structures

### 6.7.1. Description of the Rural Building Structures

There are 15 rural building structures which have been identified within the Study Area, of which, 6 structures are located directly above the proposed shortwalls in the Upper Donaldson Seam and none are located directly above the proposed shortwalls in the Lower Donaldson Seam. There are no rural building structures located above the proposed longwalls.

The rural building structures include sheds, garages, gazebos, pergolas, greenhouses, playhouses, shade structures and other non-residential building structures. The locations of these structures are shown in Drawing No. MSEC492-18.

### 6.7.2. Predictions for the Rural Building Structures

A summary of the maximum predicted subsidence, tilt and curvatures at the rural building structures is provided in Table 6.10. The parameters provide in the table are the maximum values within a 20 metre radius of the perimeters of the structures. The tilt and curvatures are the maxima at any time during or after the completion of mining.

**Table 6.10 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Rural Building Structures**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Above Shortwalls in the Upper Donaldson Seam | 1400 | 30 | 1.0 | 2.5 |
| Above Shortwalls in the Lower Seam | 50 | 1 | 0.02 | < 0.01 |

The maximum predicted conventional curvatures for the rural building structures located above the proposed shortwalls in the Upper Donaldson Seam are 1.0 $km^{-1}$ hogging and 2.5 $km^{-1}$ sagging, which represent minimum radii of curvature of 1.0 kilometre and 0.4 kilometres, respectively. The maximum predicted conventional curvatures for the rural building structures located above the shortwalls in the Lower Donaldson Seam are 0.02 $km^{-1}$ hogging and less than 0.01 $km^{-1}$ sagging, which represent minimum radii of curvatures of 50 kilometres and greater than 100 kilometres, respectively.

The maximum predicted conventional strains for rural building structures located above the proposed shortwalls in the Upper Donaldson Seam, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 10 mm/m tensile and 25 mm/m compressive. The maximum predicted conventional strains for rural building structures located above the proposed shortwalls in the Lower Donaldson Seam, based on applying a factor of 10 to the maximum predicted conventional curvatures, are in the order of survey tolerance (i.e. less than 0.3 mm/m tensile and compressive). The analysis of strains measured in the NSW Coalfields, for previously extracted panels having similar width-to-depth ratios as the proposed shortwalls, is provided in Section 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements and downslope movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

### 6.7.3. Comparison of the Predictions for the Rural Building Structures with those Provided in the Part 3A Environmental Assessment

There were no specific subsidence predictions provided for the rural building structures in the Part 3A Environmental Assessment. As the rural building structures are located across the extents of the approved mining in ML1618, the comparisons have been made using the maximum predicted subsidence parameters provided in the Part 3A Environmental Assessment.

The comparison between the maximum predicted subsidence parameters for the rural building structures, based on the *Modified Layout*, with the maximum predicted subsidence provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, is provided in Table 6.11.

**Table 6.11 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the Rural Building Structures Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout* (Part 3A) | 1820 | 66 | 3.38 | 4.29 |
| Modified Layout (MSEC492) | 1400 | 30 | 1.0 | 2.5 |

Note: * denotes that the subsidence parameters based on the Approved Layout are the maximum predicted anywhere above the proposed mining areas.

It can be seen from the above table, that the maximum predicted subsidence parameters for the rural building structures, based on the *Modified Layout*, are less than the range of the predicted maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

### 6.7.4. Impact Assessments and Discussions for the Rural Building Structures

The maximum predicted tilt for the rural building structures is 30 mm/m (i.e. 3 %), which represents a change in grade of 1 in 33, and occurs for the rural structures located above the proposed shortwalls in the Upper Donaldson Seam. The maximum predicted tilt for the rural structures located above the proposed shortwalls in the Lower Donaldson Seam is 1 mm/m (i.e. 0.1 %), which represents a change in grade of 1 in 1000.

The building structures are generally of light-weight construction and, therefore, it is unlikely that these structures would become unstable as the result of mining induced tilt. It is possible, that serviceability impacts could occur at the higher levels of predicted tilt, including door swings and issues with roof and pavement drainage, all of which can be remediated using normal building maintenance techniques.

It is also expected, at the predicted magnitudes of curvature and strain, that impacts could occur to the rural building structures located directly above the proposed shortwalls in the Upper Donaldson Seam, including cracking or differential movement of the wall claddings and flexing or distortion of the structural frames. It is unlikely that any of these structures would become unstable due to the more flexible types of constructions. It has been found, from past mining experience, that the incidence of impacts on rural building structures is low and that any impacts can generally be remediated using normal building maintenance techniques.

In any case, it is recommended, that the rural building structures located above the proposed shortwalls are inspected by a Structural Engineer, as part of the Extraction Plan process, to confirm the existing conditions and to determine whether any preventive measures are required, prior to mining beneath these structures.

## 6.8. Fences

The fences are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence parameters within the Study Area is provided in Chapter 4.

Wire fences can be affected by tilting of the fence posts and by changes of tension in the fence wires due to strain as mining occurs. These types of fences are generally flexible in construction and can usually tolerate tilts of up to 10 mm/m and strains of up to 5 mm/m without significant impacts.

It is likely, therefore, that some of the wire fences within the Study Area would be impacted as the result of the extraction of the proposed shortwalls and longwalls. Any impacts on the wire fences could be remediated by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

## 6.9. Farm Dams

### 6.9.1. Description of the Farm Dams

There are 33 farm dams which have been identified within the Study Area, of which, 11 dams are located directly above the proposed shortwalls in the Upper Donaldson Seam and around 7 dams are located directly above the proposed shortwalls in the Lower Donaldson Seam. There are no farm dams located above the proposed longwalls.

The locations of the farm dams are shown in Drawing No. MSEC492-18. A photograph of typical farm dams is provided in Fig. 6.7.

**Fig. 6.7 Photograph of the Typical Farm Dams**

The farm dams are typically of earthen construction and have been established by localised cut and fill operations within the natural drainage lines. The dams located directly above the proposed shortwalls in the Upper Donaldson Seam range in size between 100 $m^2$ and 8,200 $m^2$ and range in maximum dimension between 10 metres and 150 metres. The dams located directly above the proposed shortwalls in the Lower Donaldson Seam range in size between 75 $m^2$ and 1,900 $m^2$ and range in maximum dimension between 15 metres and 75 metres.

### 6.9.2. Predictions for the Farm Dams

A summary of the maximum predicted subsidence, tilt and curvatures for the farm dams is provided in Table 6.12. The parameters provide in the table are the maximum values within a 20 metre radius of the perimeter of the dams. The tilt and curvatures are the maxima at any time during or after the completion of mining.

**Table 6.12 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Farm Dams**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Above Shortwalls in the Upper Donaldson Seam | 1400 | 35 | 1.5 | 2.5 |
| Above Shortwalls in the Lower Donaldson Seam | 1500 | 20 | 0.6 | 0.6 |

The maximum predicted conventional curvatures for the farm dams located above the shortwalls in the Upper Donaldson Seam are 1.5 $km^{-1}$ hogging and 2.5 $km^{-1}$ sagging, which represent minimum radii of curvature of 0.7 kilometres and 0.4 kilometres, respectively. The maximum predicted conventional curvatures for the farm dams located above the shortwalls in the Lower Donaldson Seam are 0.6 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvature of 1.7 kilometres.

The maximum predicted conventional strains for the farm dams located above the shortwalls in the Upper Donaldson Seam, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 15 mm/m tensile and 25 mm/m compressive. The maximum predicted conventional strains for the farm dams located above the shortwalls in the Lower Donaldson Seam, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 6 mm/m tensile and compressive. The analysis of strains measured in the NSW Coalfields, for previously extracted panels having similar width-to-depth ratios as the proposed shortwalls, is provided in Section 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

### 6.9.3. Comparison of the Predictions for the Farm Dams with those Provided in the Part 3A Environmental Assessment

The comparison of the maximum predicted subsidence parameters for the farm dams, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, is provided in Table 6.13.

**Table 6.13 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the Farm Dams Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 830 ~ 1820 (Above Panel)<br>300 ~ 1020 (Above Pillar) | 8 ~ 51 | 0.8 ~ 1.8 | 1.0 ~ 12.1 |
| Modified Layout (MSEC492) | 1500 | 35 | 1.5 | 2.5 |

It can be seen from the above table, that the maximum predicted mine subsidence parameters for the farm dams, based on the *Modified Layout*, are similar to the range of predicted maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

### 6.9.4. Impact Assessments and Discussions for the Farm Dams

The maximum predicted tilt for the farm dams is 35 mm/m (i.e. 3.5 %), which represents a change in grade of 1 in 30. Mining induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side and decreasing on the other. Tilt can potentially reduce the storage capacity of farm dams by causing them to overflow. If the storage capacity of any farm dams were adversely affected as a result of mining, these could be re-instated by raising the earthen walls of the affected dams.

The farm dams could also be affected by surface cracking, heaving or stepping. It is expected, at the magnitudes of the predicted curvatures and strains, that fracturing and buckling would occur in the uppermost bedrock above the proposed shortwalls in the Upper Donaldson Seam. The size and extent of fracturing and buckling of the uppermost bedrock reduces above the proposed shortwalls in the Lower Donaldson Seam, as the depths of cover increase. Surface cracking or stepping in the base of the farm dams would be visible, especially where the depths of the bedrock are relatively shallow.

The potential impacts on the farm dams located above the proposed shortwalls in the Upper Donaldson Seam are similar to those assessed in the Part 3A Environmental Assessment, as the predicted mine subsidence parameters, based on the *Modified Layout*, are within the range of those predicted for the dams based on the *Approved Layout*. The potential impacts on the farm dams located above the proposed shortwalls in the Lower Donaldson Seam are similar to or less than those assessed in the Part 3A Environmental Assessment, as the predicted mine subsidence parameters, based on the *Modified Layout*, are similar to or less than those predicted for the farm dams based on the *Approved Layout*.

In the Part 3A Environmental Assessment, it was assessed that that "*a high proportion of the dams would be subject to significant cracking of the dams and storage areas that could ultimately drain the dams. Maximum crack widths are estimated to range from 60 mm to 200 mm, to depths of 5 m to 7 m based on the possible range of tensile strain estimates over 10 m. Loss or increased of storage areas due to tilt may also occur if relatively large cracks develop beneath the dams*" (SE, 2006).

It has been found that the incidence of impacts to farm dams in the Hunter Coalfield is relatively low where there is a reasonable depth of cover, say greater than 150 metres to 200 metres, such as the case for the majority of the farm dams within the Study Area. Any surface cracking or leakages in the farm dams could be identified by visual inspections and remediated by re-instating the bases on the dams with cohesive materials. Any loss of water from the farm dams would flow into the drainage line in which the dam was formed.

It is recommended that the farm dams are visually monitored, as the proposed shortwalls mine directly beneath them, such that any impacts can be identified and remediated accordingly. In this way the farm dams can be maintained in serviceable conditions throughout the mining period. As part of Donaldson Coal's commitments for the Abel Underground Mine, Donaldson Coal will develop a Dam Monitoring and Management Strategy (DMMS) for dams prior to any mining which will potentially impact on the dam.

## 6.10. Groundwater Bores

The locations of the registered groundwater bores within the Study Area are shown in Drawing No. MSEC492-19. The locations and details of the registered groundwater bores were obtained from the Department of Natural Resources using the *Natural Resource Atlas* website (NRAtlas, 2011). There is only one registered groundwater bore in the Study Area, being GW078127, which is a Donaldson Coal monitoring bore.

It is likely that groundwater bores will experience some impacts as the result of mining of the proposed shortwalls, particularly those located directly above the proposed mining. Impacts may include temporary lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality. Such impacts on the groundwater bores can be readily managed and, where required, repaired by the Mine Subsidence Board.

## 6.11. Quarries

### 6.11.1. Description of the Quarries

There are two quarries located within the Study Area, being Black Hill Quarry and Stockrington Quarry, the locations of which are shown in Drawing No. MSEC492-14.

Black Hill Quarry is located on privately owned land and is operated by *Woodbury's Haulage and Earthmoving* and is located directly above the proposed shortwalls in the Lower Donaldson Seam. The quarry has "*severely steeply dipping (i.e. 60 to 70º) benched batters that are up to 40 m high and are cut into medium to thickly bedded, high strength sandstone and siltstone*" (SE, 2006). A photograph of Black Hill Quarry is provided in Fig. 6.8.

**Fig. 6.8 Photograph of the Black Hill Quarry**

Stockrington Quarry is located on land owned by Coal and Allied and is operated by *Daracon Quarries* and is located directly above the proposed longwalls in the Lower Donaldson Seam. The quarry produces "*gravel road base and concrete aggregate products*" (SE, 2006). A photograph of Stockrington Quarry is provided in Fig. 6.9.

**Fig. 6.9 Photograph of Stockrington Quarry**

### 6.11.2. Predictions for the Quarries

A summary of the maximum predicted subsidence, tilt and curvatures for Black Hill and Stockrington Quarries is provided in Table 6.14. The parameters provide in the table are the maximum values within a 20 metre radius of the perimeter of the quarries. The tilt and curvatures are the maxima at any time during or after the completion of mining.

**Table 6.14 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Quarries**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Black Hill Quarry | 1700 | 15 | 0.5 | 0.5 |
| Stockrington Quarry | 2300 | 20 | 0.3 | 0.3 |

The maximum predicted conventional curvatures for Black Hill Quarry are 0.5 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvature of 2 kilometres. The maximum predicted conventional curvatures for Stockrington Quarry are 0.3 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvature of 3 kilometres.

The maximum predicted conventional strains for Black Hill Quarry, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 5 mm/m tensile and compressive. The maximum predicted conventional strains for Stockrington Quarry, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 3 mm/m tensile and compressive. The analysis of strains measured in the NSW Coalfields, for previously extracted panels having similar width-to-depth ratios as the proposed shortwalls, is provided in Section 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements and downslope movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

### 6.11.3. Comparison of the Predictions for the Quarries with those Provided in the Part 3A Environmental Assessment

The comparisons of the maximum predicted subsidence parameters for Black Hill and Stockrington Quarries, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, are provided in Table 6.15 and Table 6.16, respectively.

**Table 6.15 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for Black Hill Quarry Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 790 ~ 1220 (Above Panel)<br>680 ~ 900 (Above Pillar) | 15 ~ 22 | 0.64 ~ 0.96 | 0.8 ~ 1.26 |
| Modified Layout (MSEC492) | 1700 | 15 | 0.5 | 0.5 |

**Table 6.16 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for Stockrington Quarry Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 420 ~ 650 (Above Panel)<br>420 ~ 530 (Above Pillar) | 5.7 ~ 7.8 | 0.46 ~ 0.47 | 0.58 ~ 0.68 |
| Modified Layout (MSEC492) | 2300 | 20 | 0.3 | 0.3 |

It can be seen from the above tables, that the maximum predicted subsidence for the quarries, based on the *Modified Layout*, are greater than the maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*. It is then noted, that the potential for impacts on the quarries are dependent on the differential subsidence (i.e. tilt, curvature and strain), rather than the magnitude of vertical subsidence.

It can be seen from Table 6.15, that the maximum predicted tilt and curvatures for Black Hill Quarry, based on the *Modified Layout*, are similar to or less than the range of maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

It can be seen from Table 6.16, that the maximum predicted curvatures for Stockrington Quarry, based on the *Modified Layout*, are less than the range of maxima provided in the Part 3A Environmental Assessment based on the *Approved Layout*. It can also be seen from this table, however, that the maximum predicted tilt, based on the *Modified Layout*, is greater than the range of maxima provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

#### 6.11.4. Impact Assessments and Discussions for the Quarries

The mine subsidence movements resulting from the extraction of the proposed longwalls could dislodge marginally stable rocks or loose boulders on the quarry faces. The potential for rock falls poses a safety risk for people beneath the quarry faces.

The potential impacts on Black Hill Quarry are less than those assessed in the Part 3A Environmental Assessment as the predicted mine subsidence parameters, based on the *Modified Layout*, are less than those based on the *Approved Layout*. The report by Strata Engineering states that "*The impacts may include tapered 50 to 160 mm wide cracks to depths of about 5 to 7 m depth (or possibly deeper where rock exposures exist), through the batters and haul roads*" (SE, 2006).

It is expected that these potential impacts could be managed by periodic visual inspections by a Geotechnical Engineer and the implementation of preventive measures, which may include the removal of unstable rocks or locally excavating adversely impacted sections of the quarry faces.

Surface cracking and heaving of the quarry haulage roads could occur during the extraction of the proposed longwalls. It would be expected, however, that these roads could be maintained in serviceable conditions using normal road maintenance techniques.

It is recommended, that management strategies are developed as part of the Extraction Plan process, in consultation with the quarry owners, so that work in the quarry can be undertaken safely during the mining period. It may be necessary to restrict access beneath some adversely affected sections of the quarry faces, until such time that the faces have been restabilised.

As described in Sections 3.8.2, 4.2.3 and 4.2.4, it is possible that the actual subsidence above the proposed thin seam pillar extraction panels, proposed longwalls and the northern ends of the proposed shortwalls in the Lower Donaldson Seam could be greater than that predicted, due to the presence of the historic workings in the overlying Borehole Seam, if the existing stooks have remained stable or any of these historic workings are found to be only partially extracted. Whilst the extents of impacts on the quarries would increase, if the maximum upperbound subsidence of 3700 mm developed above the proposed longwalls, it would still be expected that any impacts could be managed using the strategies described above.

The potential impacts resulting from the destabilisation of the historic workings in the Borehole Seam could develop more rapidly than impacts resulting from single-seam mining. The potential for pillar run beneath the Stockrington Quarry is reduced, however, as the record tracings indicate that total pillar extraction has occurred beneath this quarry. It is recommended, therefore, that strategies are developed as part of the Extraction Plan process to manage these potential impacts, which could include visual and ground monitoring, as well as the development of the appropriate remediation measures. Management strategies will need to be developed, in consultation with the quarry owners, so that safe working conditions can be maintained at the quarries.

## 6.12. Exploration Bores

The exploration bores are located directly above the proposed shortwalls and longwalls and, therefore, could experience the full range of predicted subsidence movements, which were described in Chapter 4. It is likely, therefore, that fracturing and shearing would occur in the boreholes as the result of mining. It is recommended that the exploration bores are sealed and capped prior to mining directly beneath them.

## 6.13. Archaeological Sites

### 6.13.1. Description of the Archaeological Sites

There are 18 archaeological sites which have been identified within or immediately adjacent to the Study Area, which are shown in Drawing No. MSEC492-19. A summary of these sites is provided in Table 6.17.

**Table 6.17 Archaeological Sites within or Immediately Adjacent to the Study Area**

| Site Name | Site ID | Type | Location |
|---|---|---|---|
| Abel 1 | 38-4-0985 | Grinding Grooves | Approx. 150 metres north of LDLW4 |
| Abel 2 | 38-4-0986 | Grinding Grooves | Approx. 50 metres east of LDLW3 |
| AMA2/A | *Pending* | Artefact Scatter | Directly above UDSW4 |
| AMA2/B | *Pending* | Artefact Scatter | Directly above UDSW3 |
| AMA2/C | *Pending* | Artefact Scatter | Directly above UDSW4 |
| AMB1/A | *Pending* | Grinding Grooves | Directly above LDSW2 |
| AMC10/A | *Pending* | Grinding Grooves | Approx. 110 metres west of LDLW1 |
| AMC12/A | *Pending* | Scarred Tree (Possible) | Directly above UDBP2 and LDLW2 |
| AMC16/A | *Pending* | Grinding Grooves | Directly above UDBP4 and LDLW4 |
| AMC2/A | *Pending* | Grinding Grooves | Directly above LDLW3 |
| AMC2/B | *Pending* | Rock Shelter | Directly above LDLW3 |
| AMC2/C | *Pending* | Grinding Grooves | Approx. 180 metres north of LDLW4 |
| AMC2/D | *Pending* | Scarred Tree (Possible) | Directly above LDLW3 |
| AMC5/A | *Pending* | Artefact Scatter | Above northern end of LDLW4 |
| Black Hill Quarry 1 | 38-4-0341 | Artefact Scatter | Directly above LDSW3 |
| CA6 | *Pending* | Artefact Scatter | Approx. 50 metres north of UDSW5 |
| F1/B | 38-4-0980 | Artefact Scatter | Approx. 70 metres north of UDSW5 |
| FMC6 Donaldson Mine | 38-4-0668 | Artefact Scatter | Directly above UDSW5 |

There are also three cultural places (i.e. areas of cultural sensitivity) identified within the Study Area, which are shown in Drawing No. MSEC492-19. A summary of these sites is provided in Table 6.18.

**Table 6.18 Cultural Places Identified within the Study Area**

<table>
<tr><th>Site Name</th><th>Type</th><th>Location</th></tr>
<tr><td>Black Hill Locality</td><td>Cultural Place</td><td rowspan="2">Partially above shortwalls in the Lower and Upper Donaldson Seams, thin seam workings in the Upper Donaldson Seam and longwalls in the Lower Donaldson Seam</td></tr>
<tr><td>Black Hill Pathway</td><td>Cultural Place</td></tr>
<tr><td>Ceremonial Area</td><td>Cultural Place</td><td>Partially above thin seam workings in the Upper Donaldson Seam and longwalls in the Lower Donaldson Seam</td></tr>
</table>

Further descriptions of the archaeological sites and cultural places are provided in the report prepared by South East Archaeology (SEA, 2012).

### 6.13.2. Predictions for the Archaeological Sites

A summary of the maximum predicted subsidence, tilt and curvatures for the archaeological sites is provided in Table 6.19. The parameters provide in the table are the maximum values within a 20 metre radius of the sites. The tilt and curvatures are the maxima at any time during or after the completion of mining.

**Table 6.19 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Archaeological Sites within or Immediately Adjacent to the Study Area**

| Site Name | Site ID | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|---|
| Abel 1 | 38-4-0985 | < 20 | < 0.5 | < 0.01 | < 0.01 |
| Abel 2 | 38-4-0986 | 200 | 3 | 0.06 | < 0.01 |
| AMA2/A | *Pending* | 1350 | 35 | 1.50 | 1.90 |
| AMA2/B | *Pending* | 1550 | 50 | 3.60 | 3.50 |
| AMA2/C | *Pending* | 800 | 45 | 1.50 | 1.10 |
| AMB1/A | *Pending* | 800 | 11 | 0.30 | 0.05 |
| AMC10/A | *Pending* | 100 | 2 | 0.02 | < 0.01 |
| AMC12/A | *Pending* | 1400 | 8 | 0.20 | 0.05 |
| AMC16/A | *Pending* | 2400 | 9 | 0.15 | 0.45 |
| AMC2/A | *Pending* | 1300 | 7 | 0.10 | 0.20 |
| AMC2/B | *Pending* | 400 | 8 | 0.10 | 0.04 |
| AMC2/C | *Pending* | 25 | < 0.5 | < 0.01 | < 0.01 |
| AMC2/D | *Pending* | 400 | 7 | 0.10 | 0.04 |
| AMC5/A | *Pending* | 350 | 6 | 0.15 | 0.04 |
| Black Hill Quarry 1 | 38-4-0341 | 1000 | 9 | 0.25 | 0.10 |
| CA6 | *Pending* | < 20 | < 0.5 | < 0.01 | < 0.01 |
| F1/B | 38-4-0980 | < 20 | < 0.5 | < 0.01 | < 0.01 |
| FMC6 Donaldson Mine | 38-4-0668 | 1450 | 35 | 1.60 | 2.40 |

The maximum predicted conventional curvatures for the archaeological sites are 3.6 $km^{-1}$ hogging and 3.5 $km^{-1}$ sagging for the artefact scatters, 0.30 $km^{-1}$ hogging and 0.45 $km^{-1}$ sagging for the grinding grooves, 0.10 $km^{-1}$ hogging and 0.04 $km^{-1}$ sagging for the rock shelter, and 0.20 $km^{-1}$ hogging and 0.05 $km^{-1}$ sagging for the scarred trees.

The maximum predicted conventional strains for the archaeological sites, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 36 mm/m tensile and 35 mm/m compressive for the artefact scatters, 3.0 mm/m tensile and 4.5 mm/m compressive for the grinding grooves, 1.0 mm/m tensile and 0.4 mm/m compressive for the rock shelter, and 2.0 mm/m tensile and 0.5 mm/m compressive for the scarred trees.

The analysis of strains measured in the NSW Coalfields, for previously extracted panels having similar width-to-depth ratios as the proposed shortwalls, is provided in Section 4.4. Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The cultural places are partially located above the proposed shortwalls in the Upper and Lower Donaldson Seams, the proposed thin seam workings in the Upper Donaldson Seam, and the proposed longwalls in the Lower Donaldson Seam. These places could experience the full range of predicted subsidence movements, which were described in Chapter 4.

### 6.13.3. Comparison of the Predictions for the Archaeological Sites with those Provided in the Part 3A Environmental Assessment

The comparisons of the maximum predicted subsidence parameters for the archaeological sites, based on the *Modified Layout*, with those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*, are provided in Table 6.20 to Table 6.22. It is noted, that comparisons have not been provided for the rock shelter, as none were identified at the time of the Part 3A Environmental Assessment.

**Table 6.20 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the Artefact Scatter Sites Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 920 | 17 | Not Provided | Not Provided |
| Modified Layout (MSEC492) | 1550 | 50 | 3.6 | 3.5 |

**Table 6.21 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the Grinding Groove Sites Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 370 | 6 | Not Provided | Not Provided |
| Modified Layout (MSEC492) | 2400 | 11 | 0.30 | 0.45 |

**Table 6.22 Comparison between the Maximum Predicted Total Conventional Subsidence Parameters for the Scarred Trees Based on Approved and Modified Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Approved Layout (Part 3A) | 190 | 3 | Not Provided | Not Provided |
| Modified Layout (MSEC492) | 1400 | 7 | 0.20 | 0.05 |

It can be seen from the above tables, that the maximum predicted mine subsidence parameters for the archaeological sites, based on the *Modified Layout*, are greater than those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

The reason for this is partly due to additional sites being identified above the proposed mining areas. For example, only two grinding groove sites were identified within the current Study Area at the time of the Part 3A Environmental Assessment, which were Abel 1 and Abel 2. The maximum predicted subsidence parameters at these grinding groove sites, based on the *Modified Layout* (i.e. 200 mm subsidence and 3 mm/m tilt), are less than those provided for these sites in the Part 3A Environmental Assessment (i.e. 370 mm subsidence and 6 mm/m tilt).

The discussions on the potential impacts on the archaeological sites, based on the predicted subsidence parameters for the *Modified Layout*, are provided in the following sections.

### 6.13.4. Impact Assessments for the Artefact Scatter Sites

There are eight sites comprising artefact scatters or isolated finds within or immediately adjacent to the Study Area, being Sites AMA2/A, AMA2/B, AMA2/C, AMC5/A, Black Hill Quarry 1 (i.e. 38-4-0341), CA6, F1/B (i.e. 38-4-0980), and FMC6 Donaldson Mine (i.e. 38-4-0668).

These types of sites can potentially be affected by cracking of the surface soils as a result of mine subsidence movements. Discussions on the potential for surface deformations resulting from the proposed mining are provided in Section 4.8. It is unlikely, that these scattered artefacts or isolated finds themselves would be impacted by surface cracking.

Further discussions on the potential impacts on the artefact scatter sites, resulting from the proposed mining, are provided in the report prepared by South East Archaeology (SEA, 2012).

### 6.13.5. Impact Assessments for the Grinding Groove Sites

There are seven grinding groove sites within the Study Area, being Sites Abel 1 (i.e. 38-4-0985), Abel 2 (i.e. 38-4-0986), AMB1/A, AMC10/A, AMC16/A, AMC2/A, and AMC2/C.

The grinding groove sites Abel 1, Abel 2, AMC10/A and AMC2/C are located outside the extents of the proposed mining at distances 150 metres, 50 metres, 110 metres and 180 metres, respectively, at their closest points.

The maximum predicted conventional strains at Sites Abel 1 and Abel 2 are similar to uniform strains provided in the Part 3A Environmental Assessment. The potential impacts on these sites, therefore, are similar to those assessed in the Part 3A Environmental Assessment, which stated that "*Abel 1 grinding grooves are unlikely (i.e. a probability of $\leq$ 5%) to be cracked by the uniform tensile strains of <0.3 mm/m. It is possible (i.e. a probability of 10 - 50%) that the Abel 2 grinding groove site could be cracked by a CWC uniform strain of 0.5 mm/m. A maximum crack width of 3 to 5 mm is predicted for the site at this location*" (SE, 2006).

The maximum predicted conventional strains at Sites AMC10/A and AMC2/C are very small, less than the order of survey tolerance (i.e. less than 0.3 mm/m). It is unlikely, therefore, that these sites would be adversely impacted as a result of the proposed mining (i.e. a probability of less than 5 %).

The remaining grinding groove sites within the Study Area, being Sites AMB1/A, AMC16/A and AMC2/A, are located directly above the proposed mining. The predicted conventional strains at these sites vary between 1 mm/m to 3 mm/m tensile, and between 2 mm/m and 4.5 mm/m compressive. Fracturing in bedrock has been observed in the past, as a result of longwall mining, where tensile strains were greater than 0.5 mm/m or where compressive strains were greater than 2 mm/m. It is possible, therefore, that fracturing of the bedrock could occur in the vicinity of Sites AMB1/A, AMC16/A and AMC2/A.

Preventive measures could be implemented at the grinding grooves Sites AMB1/A, AMC16/A and AMC2/A, if required, including slotting of the bedrock around the sites to isolate them from the ground curvatures and strains. It is possible, however, that the preventive measures could result in greater impacts on these sites than those which would have occurred as a result of mine subsidence movements.

Further discussions on the potential impacts on the grinding groove sites, resulting from the proposed mining, are provided in the report prepared by South East Archaeology (SEA, 2012).

### 6.13.6. Impact Assessments for the Rock Shelter Site

There is one rock shelter within the Study Area, being Site AMC2/B, which is located directly above the maingate of proposed Longwall LDLW3 in the Lower Donaldson Seam. The maximum predicted tilt for the rock shelter is 8 mm/m (i.e. 0.8 %), which represents a change in grade of 1 in 125. It is unlikely that this site would experience any adverse impacts resulting from the mining induced tilt.

The maximum predicted curvatures for the rock shelter are 0.10 $km^{-1}$ hogging and 0.04 $km^{-1}$ sagging, which represent minimum radii of curvature of 10 kilometres and 25 kilometres, respectively. The maximum predicted conventional strains for this site, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 1 mm/m tensile and 0.4 mm/m compressive.

It is extremely difficult to assess the likelihood of instabilities for the rock shelter based upon predicted ground movements. The likelihood of the shelter becoming unstable is dependent on a number of factors which are difficult to fully quantify. These factors include jointing, inclusions, weaknesses within the rockmass, groundwater pressure and seepage flow behind the rockface. Even if these factors could be determined, it would still be difficult to quantify the extent to which these factors may influence the stability of the shelter naturally or when it is exposed to mine subsidence movements.

The predicted curvatures and conventional strains at the rock shelter are similar to those typically experienced in the Southern Coalfield, where these is extensive experience of mining beneath rock shelters. It has been reported that, where longwall mining has previously been carried out in the Southern Coalfield, beneath 52 shelters, that approximately 10 % of the shelters have been affected by fracturing of the strata or shear movements along bedding planes and that none of the shelters have collapsed (Sefton, 2000).

The rock shelter within the Study Area (Ref. AMC2/B) is an isolated boulder having a length less than 3 metres and a height less than 2 metres (SEA, 2012). This type of site is much less susceptible to mine subsidence impacts than the larger and continuous rock shelter sites which have been previously mined beneath in the Southern Coalfield. The potential impacts on this site, therefore, are expected to be much less than those previously observed in the Southern Coalfield.

It has been assessed, the likelihood of significant physical impacts on the rock shelter Site AMC2/B, resulting from the proposed mining, is relatively low (i.e. less than 5 %). Further discussions on the potential impacts on the rock shelter, resulting from the proposed mining, are provided in the report prepared by South East Archaeology (SEA, 2012).

#### 6.13.7. Impact Assessments for the Scarred Trees

There are two possible scarred trees within the Study Area. Site AMC12/A is located directly above the proposed thin seam workings in the Upper Donaldson Seam (i.e. UDBP2) and above the proposed longwalls in the Lower Donaldson Seam (i.e. LDLW2), and Site AMC2/D is located directly above the proposed longwalls in the Lower Donaldson Seam (i.e. LDLW3).

It has been found, from past longwall mining experience, that the incidence of impacts on trees is extremely rare. Impacts on trees have only been previously observed where the depths of cover were extremely shallow, in the order of 50 metres or less, or on very steeply sloping terrain, in the order of 1 in 1 or greater.

In the locations of the possible scarred trees, the depths of cover to the proposed thin seam workings and the proposed longwalls vary between 280 metres and 350 metres, and the depths of cover to the historic workings in the Borehole Seam vary between 80 metres and 120 metres. Also, the natural surface gradients in these locations are less than those which would be considered steep slopes (i.e. less than 1 in 3). It is unlikely, therefore, that the scarred trees would be adversely impacted by the proposed mining.

Further discussions on the potential impacts on the scarred trees, resulting from the proposed mining, are provided in the report prepared by South East Archaeology (SEA, 2012).

#### 6.13.8. Impact Assessments for the Cultural Places

The cultural places identified within the Study Area are the Black Hill Locality, Black Hill Pathway and the Ceremonial Area. These places could experience the full range of predicted subsidence movements, which were described in Chapter 4.

The potential impacts on the cultural places include surface cracking and deformations (refer to Sections 4.8 and 5.4) and changes in surface water drainage (refer to Sections 5.1, 5.6, 5.8 and 5.9). Further discussions on the potential impacts on the flora and fauna in these areas are provided in the report prepared by Hunter Eco (2012).

## 6.14. Heritage Sites

The only heritage site within the Study Area is the disused Richmond Vale Railway corridor, which crosses the southern part of the Study Area, and is shown in Drawing No.MSEC492-19. The descriptions, predictions and impact assessments for the corridor are provided in Section 6.1.

## 6.15. State Survey Control Marks

The locations of the state survey control marks in the vicinity of the proposed shortwalls and longwalls are shown in Drawing No. MSEC492-19. The survey control mark located directly above the proposed mining could experience the full range of predicted subsidence movements, which were described in Chapter 4. The survey control marks located in the immediate area could be affected by far-field horizontal movements, up to 3 kilometres outside the extents of the proposed longwalls. Far-field horizontal movements and the methods used to predict such movements are described further in Sections 3.5 and 4.6.

It will be necessary on the completion of the longwalls, when the ground has stabilised, to re-establish any survey control marks that are required for future use. Consultation between the Donaldson Coal and the Department of Lands will be required to ensure that these survey control marks are reinstated at the appropriate time, as required.

## 6.16. Houses

### 6.16.1. Description of the Houses

There are eight houses which have been identified within or immediately adjacent to the Study Area. The houses within the Study Area included both single and double storey structures and have been varying methods of construction, including slabs on ground or brick pier foundations, brick-veneer or timber framed construction with weatherboard or fibre cladding, and metal deck or tiled roofs.

### 6.16.2. Predictions for the Houses

The Project Approval 05-0136 requires Donaldson Coal to *"limit mining operations to first workings beneath, and ensure mining causes no subsidence requiring mitigation works"* for principal residences. Subsidence control zones have been established around each of the principal residences (i.e. houses), based on 26.5 degree angle of draw lines, which are shown in Drawing No. MSEC492-18.

There are two houses which are located directly above the proposed shortwalls in the Upper Donaldson Seam. It is noted, that these shortwalls will only be extracted within the subsidence control zones for these structures provided that compensation agreements can be established with the owners. In this case, the maximum predicted subsidence parameters for these two houses would be 1400 mm subsidence, 30 mm/m tilt, 1.0 $km^{-1}$ hogging curvature and 2.5 $km^{-1}$ sagging curvature.

The maximum predicted subsidence for the houses within the Study Area, based on the proposed shortwalls not mining within the subsidence control zones, is around 20 mm. Whilst it is still possible that the houses could experience subsidence slightly greater than 20 mm, the structures would not be expected to experience any significant conventional tilts, curvatures or strains.

### 6.16.3. Comparison of the Predictions for the Houses with those Provided in the Part 3A Environmental Assessment

There were no specific subsidence predictions provided for the houses in the Part 3A Environmental Assessment. Rather the application stated that the houses "*will be protected ('protected' means ensuring that the Principal Residence is not subject to a subsidence impact greater [than] that for which it is designed for without any works being required to it), from subsidence impacts by leaving barriers or long-term stable pillars beneath the residential structures, with an appropriate angle of draw*" (SE, 2006).

That is, the mine subsidence movements for the houses, based on the *Approved Layout*, were limited by excluding the bord and pillar mining within the subsidence control zones based on the 26.5 degree angle of draw around these structures.

If compensation agreements were to be established with the owners of the two houses located directly above the proposed shortwalls in the Upper Donaldson Seam, then the predicted subsidence parameters for these structures, based on the *Modified Layout*, would be greater than those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

Otherwise, the maximum predicted mine subsidence parameters for the houses within the Study Area, based on the *Modified Layout*, are similar to those provided in the Part 3A Environmental Assessment, based on the *Approved Layout*.

### 6.16.4. Impact Assessments for the Houses

If compensation agreements were to be established with the owners of the two houses located directly above the proposed shortwalls in the Upper Donaldson Seam and the houses were to be directly mined beneath, it would be expected that these structures would experience substantial impacts. The tilts would be expected to result in significant serviceability issues, including door swings and issues with roof gutter and wet area drainage, which could require the structures to be relevelled. The curvatures and strains would be expected to result in structural impacts, including substantial cracking in brickwork, plasterboard and finishes, or distortion of light-weight claddings and linings. It is possible, that the cost of repairs could exceed the cost of replacement and, in this case, the house may need to be rebuilt.

Otherwise, the predicted magnitudes of subsidence at the houses within the Study Area are small, around 20 mm, which are not expected to be associated with any significant tilts, curvatures or ground strains. It is unlikely, therefore, that these houses would experience any adverse impacts as a result of mining. It is possible, although unlikely, that some houses could experience extremely minor impacts, such as hairline cracking in the plasterboard, finishes or linings, however, these impacts could be readily repaired by the Mine Subsidence Board using normal building maintenance techniques.

### 6.16.5. Impact Assessments for Infrastructure Associated with the Houses

The properties within the Study Area also have other non-residential buildings and infrastructure. The descriptions, predictions and impact assessments for the rural structures, fences and farm dams are provided in Sections 6.7, 6.8 and 6.9, respectively.

Other infrastructure includes water tanks, septic tanks and driveways. The potential impacts on this infrastructure can managed with the implementation of Built Features Management Plans as part of the Extraction Plan process.