APPENDIX I
SUBSIDENCE IMPACT ASSESSMENT




Moolarben Coal Mines Pty Ltd

Moolarben Coal Project
Stage 2

REPORT
on
THE PREDICTION OF SUBSIDENCE PARAMETERS AND THE ASSESSMENT OF MINE SUBSIDENCE IMPACTS ON NATURAL FEATURES AND SURFACE INFRASTRUCTURE RESULTING FROM THE PROPOSED EXTRACTION OF LONGWALLS 1 TO 13 IN SUPPORT OF A PART 3A APPLICATION

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EXECUTIVE SUMMARY

Moolarben Coal Mines Pty Ltd (MCM) proposes to develop two new underground coal mines and an open cut mine as part of a new development called Stage 2 of the Moolarben Coal Project, which is located 35 to 40kms to the north east of Mudgee and is located immediately adjacent to the approved Moolarben Coal Project. Approval to Stage 1 of the Moolarben Coal Project was granted by the Minister for Planning on 6 September 2007 as a Major Project under Part 3A of the Environmental Planning & Assessment Act 1979.

The locations of Stage 1 and Stage 2 of the Moolarben Coal Project are shown in Drawing No. MSEC353-01, which together with all other drawings is included in Appendix E.

MCM proposes to extract coal from 13 new longwalls in Stage 2 of the Moolarben Coal Project using longwall mining methods from the Ulan Seam. As shown in the attached drawings, these proposed longwalls are surrounded to a large extent by the approved open cut mine areas in Stage 1 and the proposed new open cut mine areas in Stage 2 of the Moolarben Coal Project. The entries to the proposed longwalls will be accessed from the approved Stage 1 open cut highwalls.

The proposed Longwalls 1 to 9 are to be extracted from an area known as Underground 1 (UG1) and proposed Longwalls 10 to 13 are to be extracted from an area known as Underground 2 (UG2). A potential future underground mining area that is known as Underground 3 (UG3) is located at the eastern side. No longwall layouts have been planned for UG3 and, hence, further studies are to be carried out to assess the viability of longwall mining in this area. The location of this block and the overall layout of all the proposed longwalls are shown in Drawing No. MSEC353-01.

Mine Subsidence Engineering Consultants (MSEC) was commissioned by Wells Environmental Services in October 2007, on behalf of MCM;

- To study the mining proposals;
- To identify all major natural features and items of surface infrastructure above the proposed longwalls;
- To provide subsidence predictions for the proposed Longwalls 1 to 13 UG1 and UG2; and
- To provide detailed subsidence impact assessments for all the major natural features and items of surface infrastructure above the proposed longwalls, in support of a Part 3A application.

On completion of the above study, a detailed subsidence assessment report, MSEC353 Revision B, was prepared and this report formed part of the Stage 2 Environmental Assessment (2009) (Stage 2 EA). Subsequently the Department of Planning requested Galvin and Associates to peer review the Subsidence Report supplied as part of the Stage 2 EA. The Galvin and Associates comments along with other issues raised during submissions were incorporated into the report, which was then updated to Revision C.

MCM has since developed a Preferred Project for Stage 2 of the Moolarben Coal Project and this report, Revision E, now incorporates the changes from Stage 2 and supports the Preferred Project Report (PPR).

The widths of the proposed longwall panels vary from approximately 270 metres to 305 metres and the lengths of the longwall panels vary from 1695 metres to 2870 metres. The cover in the area varies from 35 metres to 165 metres. The underground workings will extract coal from the Ulan Seam and the extracted seam thickness will vary from approximately 2.1 metres to 3.2 metres.

The General 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 extraction of the proposed Longwalls 1 to 13. The extent of the General Study Area is shown in a solid black line in Drawing No. MSEC353-01. The Study Area is made up of the General Study Area plus additional areas that lie outside the General Study Area that may be subjected to valley related or far-field horizontal movements and could be sensitive to such movements. A number of natural features and items of surface infrastructure have been identified in the Study Area.

Barriers of unmined coal have been provided to protect various surface infrastructure and natural features from the effects of mine subsidence in a manner that is consistent with previously approved projects in this region. A barrier has been proposed against the Gulgong to Sandy Hollow rail-line, which is located to the north and east of the proposed longwall panels, and at the Munghorn Gap Nature Reserve, which is located to the south and east of the proposed longwall panels. A further barrier has been proposed to protect an archaeological site that is located at cliff line site C7. A Subsidence Management Plan will be prepared to manage and control the effects of mine subsidence on all these features.

The maximum predicted total systematic subsidence due to the extraction of the proposed Longwalls 1 to 13 is 1980 mm and is expected over Longwall 3. At this location the depth of cover is 143 metres and the proposed extracted seam thickness is 3.2 metres. This predicted total subsidence of 1980 mm represents 62% of the extracted seam thickness.

The maximum predicted total systematic tilt due to Longwalls 1 to 13 of 95 mm/m is expected near the maingate of Longwall 9. The maximum predicted total systematic tensile and compressive strains resulting from the extraction of the proposed longwalls, are both greater than 50 mm/m and the associated minimum radii of curvatures are both less than 0.3 kilometres. The maximum predicted total systematic tensile and compressive strain both occur near the maingate of Longwall 9.

A number of natural features and items of surface infrastructure have been identified in the vicinity of the proposed longwall and these are described in Chapter 2 of this report. The natural features and items of surface infrastructure that are located over the proposed longwalls include critically endangered ecological communities (CEECs), threatened species, cliffs and overhangs, archaeological sites, power lines, several tracks, and farm dams.

The height of the fractured strata zone above the seam is predicted to extend up to the existing ground surface level, however, it is unlikely that cracking will be continuous from the seam up to the surface. Surface cracking will be more visible where the depths of cover are less than 100 metres. There are some basalt intrusions above the proposed longwalls which may be of sufficient strength to prevent fracturing from reaching the surface in some locations.

A number of small drainage lines have been identified within the Study Area. After the Open Cuts have been formed most of these drainage lines will flow into the Open Cut Pit. Some of the drainage lines are located within the proposed northern out of pit emplacement areas and these will be filled by the out of pit emplacement prior to longwall extraction. The predicted movements have been determined along seven drainage lines, which have been called DL1 to DL7 inclusive, and these drainage lines are shown in Drawing No. MSEC353-06. Drainage Lines 4 and 5 are within the northern out of pit emplacement area. The predicted changes in grade along the drainage lines are generally less than the natural grades which vary from approximately 20 mm/m to 500 mm/m, with the shallower grades being located along Drainage Lines 5, 6 and 7. It is expected, therefore, that some ponding may occur along the drainage lines resulting from the extraction of the proposed longwalls, particularly along Drainage Lines 6, and 7.

Ten cliff sites have been identified and the total length of cliff lines in the Study Area is 570 metres. Three of these cliffs are located within the northern out of pit emplacement footprint and will be covered prior to longwall extraction. Cliff site C7, which comprises rock art and is approximately 100 metres long, will be protected by the provision of an unmined block of coal immediately below this cliff. The remaining cliff sites will experience a range of mine subsidence ground movements and rock falls may occur at some of these sites. Considering the shallow depths of cover, the magnitude of the predicted subsidence movements and the shape and position of these cliff sites, the total length of potential rock falls along these cliffs and overhangs, resulting from the extraction of Longwalls 1 to 13, is expected to be up to 15 % of the lengths of these cliffs and overhangs. As there is a possibility of rock falls, it is recommended that appropriate management strategies are put in place to ensure the safety of people that may be within the vicinity of these cliffs during the mining period. The conditions of all the cliffs should be monitored throughout the mining period and until such time that the mine subsidence movements have ceased.

It has been observed that down slope movements occur on slopes that are located over or near extracted longwalls. Where such movements occur on steep slopes, there is a higher likelihood that surface tension cracking can occur near the tops of the slopes.

There are records of threatened bat species occurring within the Study Area; namely, the Large-eared Pied Bat (*Chalinolobus dwyeri*) and the Greater Long-eared Bat (*Noctophilus timoriensis*). The Large-eared Pied Bat resides predominantly in caves and rock overhangs, which are likely to be impacted by the proposed Longwalls 1 to 13. It is expected that the impacts, particularly if rock falls should occur, could damage the habitats and affect some of the bats. Habitats located within the out of pit emplacement footprint will be affected by the emplacement operations.

The predicted systematic tilts at the vegetation communities are likely to result in some reduced and some increased grades within the critically endangered ecological communities (CEECs). These changes in grade may result in ponding of surface water runoff where existing natural grades are relatively shallow, such as over proposed Longwalls 3, 4, and 5. It is expected that fracturing and dilation of the bedrock would occur as a result of the extraction of the proposed longwalls, and would result in some surface cracking of soils. It is possible that, below some of the CEECs, the massive basalt layers that are present could resist the surface cracking. The surface cracking can be remediated, where necessary, by infilling with soil or other suitable materials, or by locally regrading and compacting the surface. One CEEC is partially located within the northern out of pit emplacement footprint and will subsequently be covered during the emplacement operations.

The Gulgong to Sandy Hollow Railway line is outside the General Study Area and is approximately 330 metres from the nearest edge of Longwall 5. At this location the rail track will not be subjected to measurable systematic mine subsidence ground movements; however, it would experience small far field horizontal movements and upsidence and closure movements. The effects of the differential far field movements and upsidence and closure movements are small and are unlikely to adversely impact on the railway line.

There are no sealed roads within the Study Area. Murragamba Road is the only public access road within the Study Area and it is located over the north east part of the Proposed Longwalls 4 and 5. It is expected that increased levels of ponding could occur along the road and that considerable cracking and rippling of the road surfaces would occur as a result of the extraction of the proposed longwalls. The roads are unsealed and can be regraded, repaired and reconstructed using standard road maintenance techniques as mining proceeds.

There is one low voltage electricity power line within the Study Area, passing over the commencing end of proposed Longwalls 6 and 7 and the commencing end of Longwall 5. It is likely that the maximum predicted systematic tilts at the power lines would be of sufficient magnitude to result in impacts on the power lines. It is recommended that these power lines are inspected by a suitably qualified person, prior to the proposed longwalls mining beneath them, to assess the existing conditions of the powerlines and to determine whether any preventive measures are required, such as the installation of cable sheaves and guy ropes.

The main copper telecommunications cables within the Study Area generally follow the alignment of Murragamba Road. It is possible that the predicted systematic strains at the copper telecommunications cable within the Study Area are of sufficient magnitudes to result in impact. The copper telecommunications cables within the Study Area are local cables and if any impacts occur, as a result of the extraction of the proposed longwalls, the cables can be easily repaired.

There is an optical fibre cable located along the northern side of Ulan-Wollar Road. The closest point of the cable to the proposed longwalls is approximately 240 metres from the north east end of Longwall 5. At this location the optical fibre cable will not be subjected to measurable systematic mine subsidence ground movements; however, it may experience small far field horizontal movements and possibly negligible upsidence and closure movements. The effects of differential far field movements due to the proposed longwalls on the optical fibre cable are small and are unlikely to adversely impact on the optical fibre cable.

There are a number of fences within the Study Area that could be affected by tilting of the fence posts and changes of tension in the fence wires due to strain as mining occurs. It is likely that some sections of the fences would be impacted by the predicted subsidence movements and would require repair or replacement. Impacted fences are relatively easy to rectify by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

There are 13 farms dams that have been identified within the Study Area. Six of the farm dams are located within or adjacent to the footprint of the northern out of pit emplacement and will be covered prior to longwall extraction. The maximum predicted changes in freeboard at the farm dams, resulting from the extraction of the proposed longwalls, vary between a minimum of less than 50 mm and a maximum of greater than 100 mm. The direction of the maximum predicted tilt at Dams Refs. A02d03 and A03d01 are such that the freeboards at the dam walls could slightly decrease (i.e. water levels slightly increase) by approximately 100 mm. This change in level is not expected to have any appreciable impact of the normal functioning of the dam. It is expected, that cracking and leakage of water could occur in the farm dams which are subjected to the greater strains, though, any cracking or leakages can be easily identified and repaired. Any loss of water from the farm dams would flow into the drainage line in which the dam was formed.

A northern out of pit emplacement, created from the open cut operations, will be located above Longwalls 3 to 8 as is shown in Drawing No. MSEC353-18. This northern out of pit emplacement has side slopes with grades of up to 1 in 4 and slope heights up to 85 metres. As these proposed longwalls are mined, a maximum subsidence of approximately 1900 mm has been predicted at the base of the northern out of pit emplacement area and the potential additional settlement of the northern out of pit emplacement, resulting from extraction of the proposed longwalls, is up to 3000 mm. The maximum predicted total subsidence plus potential additional settlement of the northern out of pit emplacement area is therefore 4900 mm. The predicted subsidence at the natural ground surface and additional settlement of the northern out of pit emplacement area can initiate downhill slumping of the soils in this location. The areas of greatest concern are the possible failure of the northern out of pit emplacement slopes above and close to the proposed work areas of the haul roads, the conveyors and the Stage 2 ROM facilities that are located close to the south western corner of Longwall 5. It is recommended, therefore, that detailed monitoring, site remediation strategies and safety management precautions are developed. Consideration could be given to restricting access to areas near slopes, particularly during the active subsidence period, until the monitored subsidence movements cease or the risk of slope failure is determined to be very low.

There are 21 Aboriginal archaeological sites located within the Study Area. One overhang site with rock art, Site ID S2MC236, that is located at Cliff C7, will be protected by leaving by a block of unmined coal below the site. One of these sites is located within the northern out of pit emplacement footprint and will be covered prior to longwall extraction. Open sites containing artefact scatters and isolated finds can potentially be affected by cracking of the surface soils as a result of mine subsidence movements. It is unlikely, however, that the scattered artefacts or isolated finds themselves would be impacted by surface cracking. Care should be taken to prevent impacts to the open sites through any surface remediation activities. Sites located in overhangs will be subject to similar impacts as described for the cliffs and overhangs and artefact scatters and isolated finds can potentially be affected by rock falls. Any artefacts that require protection from potential impacts would either need to be removed from the overhangs or would need to be protected by minimising the risk of rock falls at the relevant overhang.

There is one heritage item of moderate local significance located near the finishing end of Longwall 6. The item is a dry stone wall that formed part of the Mudgee to Wollar road that ran via Moolarben. The dry stone wall is unlikely to be subjected to any significant impact resulting from the extraction of the proposed longwalls. Potential impacts would most likely include loose stones that may become dislodged during mining. It is recommended that a detailed photographic record of the pre mining condition of the dry stone wall be prepared so that if any stones become dislodged during mining, they can be identified and replaced in the correct positions following the completion of mining.

One survey mark, known as Murragamba Trig Station, is located above the proposed longwalls and it will be subjected to mine subsidence movements. When the ground has stabilised it will be necessary to re-establish this mark in consultation with the Department of Lands.

The assessments in this report indicate that the levels of impact on the natural features and items of surface infrastructure can be managed by the preparation and implementation of management strategies. It should be noted, however, that more detailed assessments of some natural features and items of surface infrastructure have been undertaken by other consultants, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

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Fig. C.02	Predicted Profiles of Systematic Subsidence, Tilt and Strain along Prediction Line 2 Resulting from the Extraction of Longwalls 1 to 13 ....Appendix C
Fig. C.03	Predicted Profiles of Systematic Subsidence, Tilt and Strain along Prediction Line 3 Resulting from the Extraction of Longwalls 1 to 13 ....Appendix C
Fig. C.04	Predicted Profiles of Systematic Subsidence, Tilt and Strain along Prediction Line 4 Resulting from the Extraction of Longwalls 1 to 13 ....Appendix C
Fig. C.05	Profiles of Initial and subsided Surface Level and Predicted Subsidence Drainage Line DL1........Appendix C

Fig. C.06 Profiles of Initial and subsided Surface Level and Predicted Subsidence Drainage Line DL2 .... Appendix C
Fig. C.07 Profiles of Initial and subsided Surface Level and Predicted Subsidence Drainage Line DL3 .... Appendix C
Fig. C.08 Profiles of Initial and subsided Surface Level and Predicted Subsidence Drainage Line DL4 .... Appendix C
Fig. C.09 Profiles of Initial and subsided Surface Level and Predicted Subsidence Drainage Line DL5 .... Appendix C
Fig. C.10 Profiles of Initial and subsided Surface Level and Predicted Subsidence Drainage Line DL6 .... Appendix C
Fig. C.11 Profiles of Initial and subsided Surface Level and Predicted Subsidence Drainage Line DL7 .... Appendix C
Fig. C.12 Predicted Profiles of Systematic Subsidence, Tilt Along and Tilt Across the Alignment of the Powerline through UG1 .... Appendix C
Fig. C.13 Predicted Profiles of Systematic Subsidence, Tilt and Strain along the Alignment of Murragamba Road .... Appendix C

Drawings

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

Drawing No. ***Description***
MSEC353 – 01 General Layout .... Appendix E
MSEC353 – 02 Surface Level Contours .... Appendix E
MSEC353 – 03 Seam Floor Contours .... Appendix E
MSEC353 – 04 Seam Thickness Contours .... Appendix E
MSEC353 – 05 Depth of Cover Contours .... Appendix E
MSEC353 – 06 Watercourses and Vegetation .... Appendix E
MSEC353 – 07 Cliffs and Steep Slopes .... Appendix E
MSEC353 – 08 Roads and Railway .... Appendix E
MSEC353 – 09 Surface Infrastructure and Key Plan .... Appendix E
MSEC353 – 10 Surface Infrastructure Map 1 .... Appendix E
MSEC353 – 11 Surface Infrastructure Map 2 .... Appendix E
MSEC353 – 12 Surface Infrastructure Map 3 .... Appendix E
MSEC353 – 13 Surface Infrastructure Map 4 .... Appendix E
MSEC353 – 14 Surface Infrastructure Map 5 .... Appendix E
MSEC353 – 15 Archaeological Sites and Survey Marks .... Appendix E
MSEC353 – 16 Prediction Lines .... Appendix E
MSEC353 – 17 Predicted Total Subsidence Contours after Longwall 13 .... Appendix E
MSEC353 – 18 Northern Out of Pit Emplacement .... Appendix E

CHAPTER 1. BACKGROUND

1.1. Introduction

Moolarben Coal Mines Pty Ltd (MCM) proposes to develop two new underground coal mines and an open cut coal mine as part of Stage 2 of the Moolarben Coal Project, with associated infrastructure, which is located 40 km to the north east of Mudgee and is located immediately adjacent to the approved Stage 1 of the Moolarben Coal Project. Approval for Stage 1 of the Moolarben Coal Project was granted by the Minister for Planning on 6 September 2007 as a Major Project under Part 3A of the *Environmental Planning & Assessment Act 1979*.

MCM proposes to extract coal from 13 new longwalls in Stage 2 of the Moolarben Coal Project from the Ulan Seam using longwall mining methods. The proposed longwalls are surrounded to a large extent by the approved open cut mine areas in Stage 1 and the proposed new open cut mine area in Stage 2 of the Moolarben Coal Project. The entry to the proposed longwalls will be from the approved Stage 1 open cut highwalls.

The proposed Longwalls 1 to 9 are to be extracted from an area known as Underground 1 (UG1) and proposed Longwalls 10 to 13 are to be extracted from an area known as Underground 2 (UG2). A potential future underground mining area that is known as Underground 3 (UG3) is located to the east. No longwall layouts have been planned for UG3 and, hence, further studies are to be carried out to assess the viability of longwall mining in this area. The location of this block and the overall layout of all the proposed longwalls are shown in Drawing No. MSEC353-01, which together with all other drawings is included in Appendix E.

The widths of the proposed longwall panels vary from approximately 270 metres to 305 metres and the lengths of the longwall panels vary from 1695 metres to 2870 metres. The cover in the area varies from 35 metres to 165 metres. The underground workings will extract coal from the Ulan Seam and the extracted seam thickness will vary from approximately 2.1 metres to 3.2 metres.

Barriers of unmined coal have been provided to protect various surface infrastructure and natural features from the effects of mine subsidence in a manner that is consistent with previously approved projects in this region. A barrier has been proposed against the Gulgong to Sandy Hollow rail-line, which is located to the north and east of the proposed longwall panels, and at the Munghorn Gap Nature Reserve, which is located to the south and east of the proposed longwall panels. A further barrier has been proposed to protect an archaeological site that is located at cliff line site C7. A Subsidence Management Plan will be prepared to manage and control the effects of mine subsidence on all these features.

Mine Subsidence Engineering Consultants (MSEC) was commissioned by Wells Environmental Services in October 2007, on behalf of MCM;

- To study the mining proposals;
- To identify all major natural features and items of surface infrastructure above the proposed longwalls;
- To provide subsidence predictions for the proposed Longwalls 1 to 13 in UG1 and UG2; and
- To provide detailed subsidence impact assessments for all the major natural features and items of surface infrastructure above the proposed longwalls, in support of a Part 3A application.

On completion of the above study, a detailed subsidence assessment report, MSEC353 Revision B, was prepared and this report formed part of the Stage 2 Environmental Assessment (2009) (Stage 2 EA). Subsequently, the Department of Planning requested Galvin and Associates to peer review the Subsidence Report supplied as part of the Stage 2 EA. The Galvin and Associates comments along with other issues raised during submissions were incorporated into the report, which was then updated to Revision C.

MCM has since developed a Preferred Project for Stage 2 of the Moolarben Coal Project and this report, Revision E, now incorporates the changes from Stage 2 and supports the Preferred Project Report (PPR).

A number of natural features and items of surface infrastructure have been identified in the vicinity of the proposed longwall and these are described in Chapter 2 of this report. The proposed longwalls and the

Study Area, which is defined in Section 2.1, have been overlaid on an orthophoto and topographic map of the area, which are shown in Fig. 1.1 and Fig. 1.2 respectively. The major natural features and items of surface infrastructure within the Study Area can be seen in these figures.

Chapter 3 includes a brief overview of longwall mining, the development of mine subsidence and the method that has been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls.

Chapter 4 provides a general overview of the maximum predicted systematic subsidence parameters resulting from the extraction of the proposed longwalls.

Chapter 5 provides the site-specific predicted subsidence parameters for each natural feature and item of surface infrastructure described in Chapter 2. The impact assessments and recommendations for each of these features have been made based on the predicted subsidence parameters.

This report has been provided to support the Preferred Project Report for the proposed Study Area for UG1 and UG2.

Fig. 1.1 Aerial Photograph Showing Proposed Longwalls 1 to 13 and the Study Area

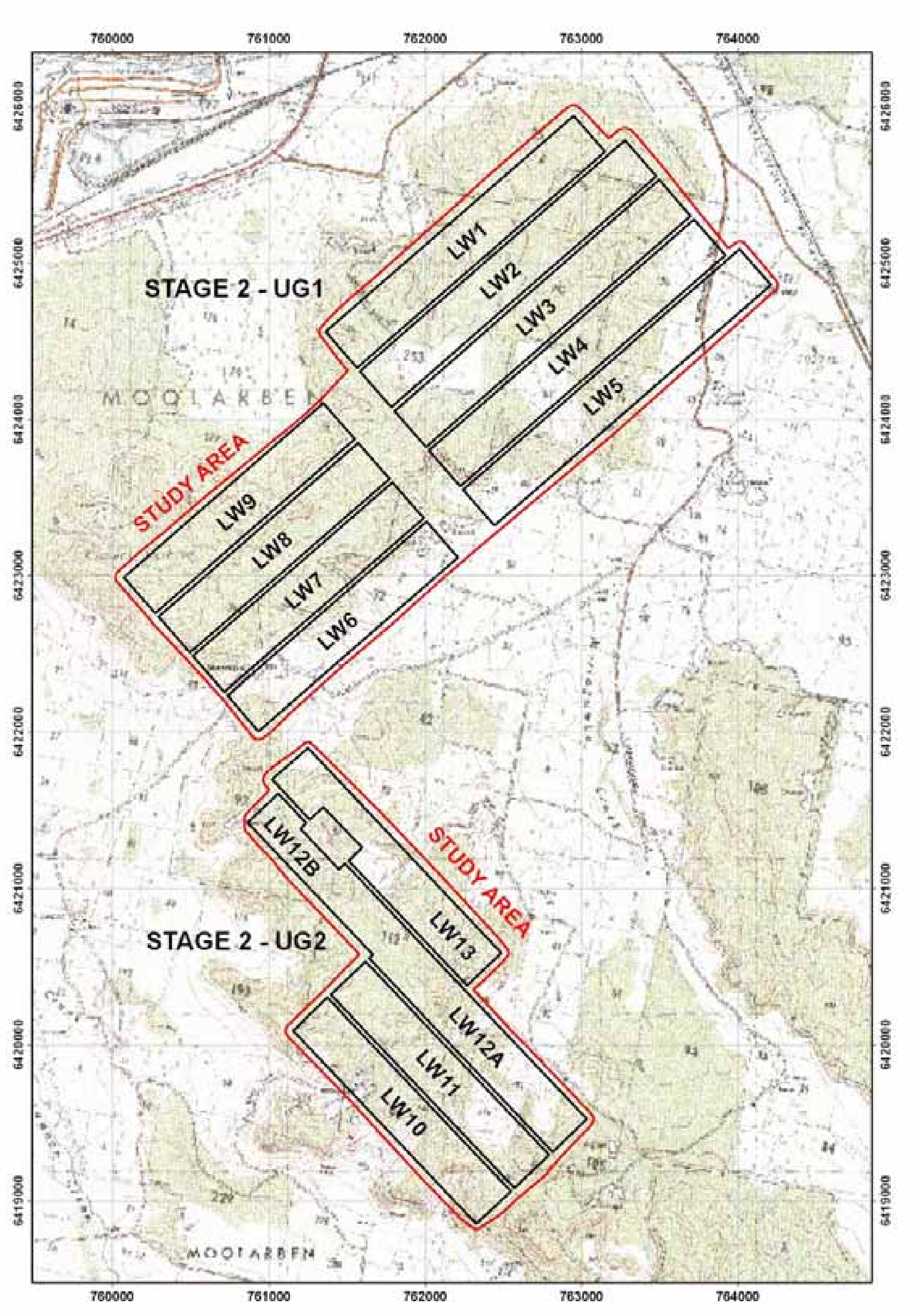

Fig. 1.2 Topographic Map Showing Proposed Longwalls 1 to 13 and the Study Area

1.2. Mining Geometry

The proposed layout of Longwalls 1 to 13 is shown in Drawing No. MSEC353-01. The proposed Longwalls 1 to 13 have a general void width of 305 metres, although Longwall 12B has been narrowed to a void width of 270 metres beyond the finishing end of Longwall 11.

The proposed longwalls have pillar widths of 30 metres.

A barrier of coal has been left in place between proposed Longwalls 12B and 13 in order to protect an important Aboriginal archaeological rock art site, Site ID S2MC236, which is discussed further in Section 2.8 and Cliff site C7, which is further discussed in Section 2.3.8 . The coal barrier has been based on an approximate 55 metre buffer around the rock outcrop containing the archaeological site as this distance is equivalent to half the depth of cover under this rock art site.

A summary of the proposed longwall dimensions is provided in Table 1.1.

Table 1.1 Proposed Longwall Dimensions within the Study Area

Longwall Number	Total Void Width (m)	Width of Pillar Preceding Longwall Maingate (m)	Overall Longwall Length (m)
LW1	305	30	2103
LW2	305	30	2249
LW3	305	30	2249
LW4	305	30	2249
LW5	305	30	2345
LW6	305	30	1694
LW7	305	30	1694
LW8	305	30	1694
LW9	305	30	1694
LW10	305	30	1706
LW11	305	30	1706
LW12A	270	30	1706
LW12B	305	30	1163
LW13	305	30	1806

The proposed longwalls are surrounded to a large extent by the approved open cut mine areas in Stage 1 and proposed new open cut mine areas in Stage 2 of the Moolarben Coal Project and the entry to the proposed longwalls will be accessed from the approved open cut 1 highwalls. The depth of cover to the Ulan Seam above the proposed longwalls varies between a minimum of about 35 metres over the proposed Longwall 10, and a maximum of 165 metres over the proposed Longwall 2. The seam floor generally dips from the south-west down to the north-east over the entire mining area.

The seam thickness within the goaf areas of the proposed longwalls varies from a minimum of 2.1 metres over Longwall 10, to a maximum of 3.2 metres over Longwalls 1 to 4. MCM proposes to extract all of the available seam thickness in this Stage 2 area. The limit of the longwall shearer is currently proposed to be 4.5 m high to suit the UG4 area.

The surface level contours, seam floor contours, seam thickness contours, and depth of cover contours are shown in Drawings Nos. MSEC353-02, MSEC353-03, MSEC353-04 and MSEC353-05, respectively. The depth of cover has been presented on Drawing No. MSEC353-05 in three zones, of less than 50 metres, 50 to 100 metres and greater than 100 m. These zones are also shown on the drawings that present the surface features.

1.3. Geological Details

The surface geological features in the vicinity of the proposed longwalls are shown in Fig 1.3. This figure was produced from a geological coalfield map that was downloaded from the Geological Survey of the Department of Primary Industries' website called Western Coalfield Regional Geology (Northern Part) Geological Sheet 1 1998 -1:100000 Western Coalfield Map.

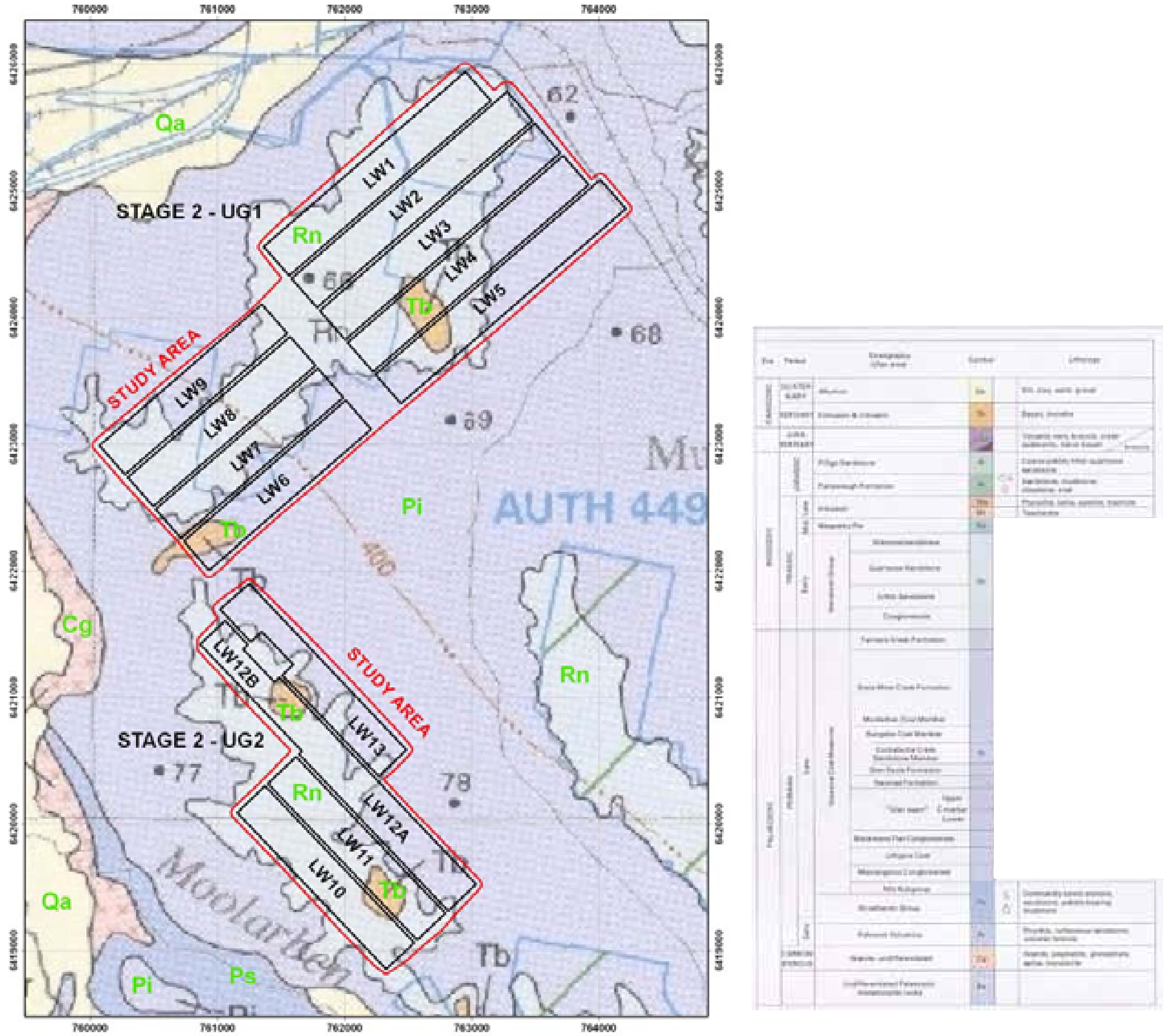

Fig. 1.3 Surface Geological Map Showing Proposed Longwalls 1 to 13 and the Study Area
(Source-1:100000 Western Coalfield Map)

As can be seen in this figure the surface geology of most of the areas over the proposed longwalls is predominantly units from the Narrabeen Group Sandstones and Conglomerates, (Rn), which are coloured in a light blue hatching, as well as areas of Basalt, (Tb). These units overlie areas, which are hatched in a violet colour, that indicates the surface geology around the longwalls are from the Illawarra Coal Measures (Pi). Other surface geological units that are shown in this figure, but are not within the General Study Area are areas of Alluvials (Qa), Shoalhaven Group deposits (Ps) and Granite (Cg).

A typical stratigraphic section for the Study Area, which was provided by Minerva Geological Services Pty Ltd, is shown in Fig. 1.4. A discussion of the geological units is provided below in Section 1.3.1.

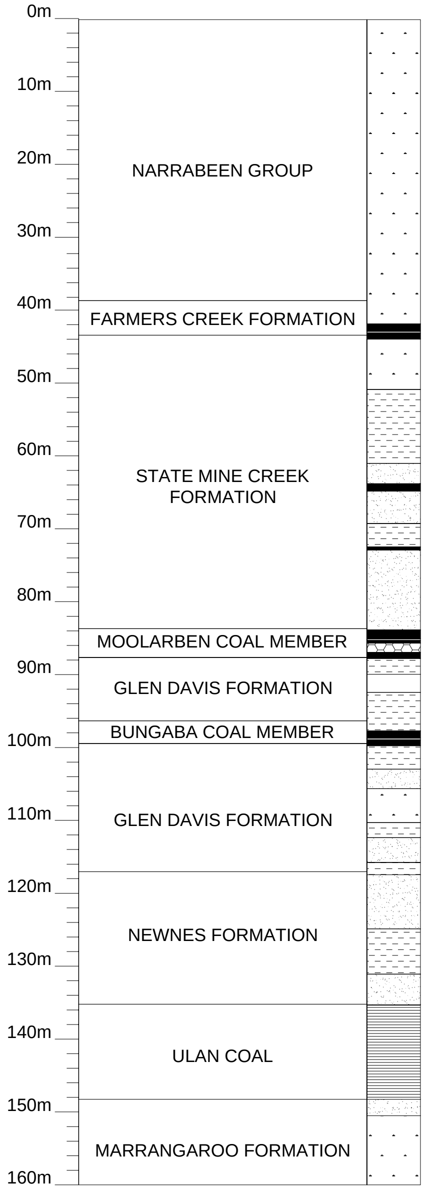

Fig. 1.4 Stratigraphic Column (based on WMLB117)

1.3.1. Lithology

The major geological units in the Study Area are, from the top down:-

- Tertiary basalt intrusions;
- Triassic sandstones and conglomerates of the Narrabeen Group;
- Permian Illawarra Coal Measures, including the Ulan Seam; and
- Carboniferous Ulan Granite.

The tertiary intrusions consist mainly of small plugs and remnant basalt flows of Tertiary age. The approximate surface location of the tertiary basalt within the Study Area, known as basalt caps, is shown on Fig. 1.3. These basalt caps provide soils that are suited to the endangered ecological community the *White Box Yellow Box Blakely's Redgum Woodland and derived Grasslands* which are further discussed in Section 2.3.13 with the approximate locations of these communities shown on Drawing No. MSEC353-06.

The Triassic sandstone, known as Wollar Sandstone, is part of the Narrabeen Group of sandstones and conglomerates and the Wollar Sandstone is the main outcropping rock formation in the Study Area. The sandstones are between 14 metres and 70 metres thick and commonly about 60 metres thick with both massive and strongly cross-bedded units of individual thickness in the range of 1.5 metres to 3 metres.

Permian Illawarra Coal Measures consist of up to six formations that include conglomerate, claystone, mudstone, siltstone, tuff, sandstone and coal with a general northwest strike direction and dip of 1 to 2 degrees to the northeast. A brief description of each formation, provided in Minerva Geological Services, (February 2007), is as follows;

- Farmers Creek Formation: between 6 metres to 10 metres of siltstone, sandstone, and white cherty claystone;
- State Mine Creek Formation: up to 30 metres of interbedded sandstone, siltstone and claystone. The Moolarben Coal Member occurs at the base of the State Mine Creek Formation and is between 2 metres and 4 metres thick, consisting of tuffaceous mudstone and claystone. The Middle River Coal Member occurs at the top of the State Mine Creek Formation and is generally less than 2 metres thick, consisting of stony coal and claystone;
- Cockabutta Creek Sandstone Member: up to 9 metres of predominantly medium to very coarse-grained quartzose sandstone, similar to the Marrangaroo Conglomerate;
- Newnes and Glen Davis Formations: up to 20 metres thickness of laminated mudstones, siltstones and find-grained sandstones;
- Ulan Coal: the major coal development in the licence area. The seam thickness varies from approximately 6 metres to 15 metres and is divided into 2 units – Upper (comprising, from top down, ULA, UB1, UB2, UC1, UC2) and Lower (comprising from top down, UCL, DTP, DWS, ETP, EBT and ELR). CMK defines the boundary between upper and lower units; and
- Marrangaroo Conglomerate: Generally between 2 metres and 6 metres thick. The conglomerate is quartzose, commonly porous, and has a “gritty” sucrosic texture.

The Carboniferous Ulan Granite forms the basement below the Illawarra Coal Measures.

There are four regional structural features, none of which intersect the proposed underground mining areas. The four regional structural features are the Spring Gully Fault Zone, Curra and Greenhill’s Fault, Flat Dip Domain, and Ulan Hinge Line.

A detailed description of the surface and subsurface geological features in the lease area is contained in a report by Minerva Geological Services, (February 2007).

CHAPTER 2. IDENTIFICATION OF SURFACE FEATURES

2.1. The Study Area

The Study Areas for UG1 and UG2 are defined as the surface area that is likely to be affected by the proposed mining of Longwalls 1 to 13 in the Ulan Seam by MCM. 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,
- The predicted vertical limit of subsidence, taken as the 20 mm subsidence contour, and
- Features sensitive to far-field movements.

As the depth of cover above the proposed longwall varies between 35 and 165 metres, the 26.5 degree angle of draw line has been conservatively determined by drawing a line around the outer edge of the proposed longwall voids at a horizontal distance that varies between 18 and 88 metres.

The predicted limit of vertical subsidence has been taken as the predicted incremental 20 mm subsidence contour as determined using the Incremental Profile Method, which is described in further detail in Section 3.4. A detailed discussion of the Incremental Profile Method can also be found at http://www.minesubsidence.com in Background Reports in the report titled 'General Discussion of Mine Subsidence Ground Movements'.

A thick black line has been drawn, therefore, defining the General Study Area, and it was based upon the combined 26.5 degree angle of draw line and the 20 mm subsidence contour line, whichever was furthest from the proposed longwalls, and this line is shown in Drawing No. MSEC353-01. The predicted incremental 20 mm subsidence contour line resulting from the extraction of proposed Longwalls 1 to 13 was found to be located entirely within the area bounded by the 26.5 degree angle of draw line.

There are additional areas that lie outside the General Study Area that are expected to experience either far-field movements, or valley related upsidence and closure movements. The surface features which may be sensitive to such movements have been identified in this report and, hence, these features, which are listed below, have been included as part of the Study Area.

- Gulgong to Sandy Hollow Railway Line;
- Survey Control Marks;
- Various cliff lines in the Munghorn Gap Nature Reserve; and
- Highwalls of the proposed open cut mines and the underground mine entries from these highwalls.

2.2. General Description of the Natural Features and Items of Surface Infrastructure

The major natural features and items of surface infrastructure within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), Sheet Number 8833-2-N, an extract of which is included above as Fig. 1.2. The following sections in this chapter identify and describe all of the major natural features and items of surface infrastructure that lie within the Study Area. The natural features and items of surface infrastructure, which are further defined in specific studies, are illustrated in Drawings Nos. MSEC353-06 to MSEC353-15.

Table 2.1 lists the types of natural features and surface improvements that have been identified within the Study Area and indicates the sections of this report that provide further descriptions and details of these features. This list follows the format of the list included in Appendix B of the DPI SMP Guideline 2003. Further details of areas of environmental sensitivity, are provided in subsequent sections of this report.

Table 2.1 Natural Features and Surface Improvements

Item	Within Study Area	Environmentally Sensitive Area	Section Number Reference
NATURAL FEATURES			
Catchment Areas or Declared Special Areas			
Rivers or Creeks			
Aquifers or Known Groundwater Resources	✓		2.3.3
Springs			
Sea or Lakes			
Shorelines			
Natural Dams			
Cliffs or Pagodas	✓	✓	2.3.8
Steep Slopes	✓		2.3.9
Escarpments			
Land Prone to Flooding or Inundation			
Swamps, Wetlands or Water Related Ecosystems			
Threatened, Protected Species or Critical Habitats	✓		2.3.13
National Parks or Wilderness Areas	✓		2.3.14
State Recreational or Conservation Areas			
State Forests			
Natural Vegetation	✓		2.3.17
Areas of Significant Geological Interest			
Any Other Natural Feature Considered Significant			
PUBLIC UTILITIES			
Railways	✓		2.4.1
Roads (All Types)	✓		2.4.2
Bridges			
Tunnels			
Culverts	✓		2.4.1
Water, Gas or Sewerage Pipelines	✓		2.4.6
Liquid Fuel Pipelines			
Electricity Transmission Lines or Associated Plants	✓		2.4.7
Telecommunication Lines or Associated Plants	✓		2.4.8
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	Environmentally Sensitive Area	Section Number Reference
FARM LAND AND FACILITIES			
Agricultural Utilisation, Agricultural Improvements or Agricultural Suitability of Farm Land			
Farm Buildings or Sheds			
Gas or Fuel Storages			
Poultry Sheds			
Glass Houses or Green Houses			
Hydroponic Systems			
Irrigation Systems			
Fences	✓		2.6.4
Farm Dams	✓		2.6.5
Wells or Bores			
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 and Associated Plants			
Buildings, Equipment or Operations that are Sensitive to Surface Movements			
Surface Mining (Open Cut) Voids and Rehabilitated Areas			
Mine Infrastructure Including Tailings Dams or Emplacement Areas	✓		2.7
Any Other Industrial, Commercial or Business Features			
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓		2.8
ITEMS OF ARCHITECTURAL SIGNIFICANCE			
PERMANENT SURVEY CONTROL MARKS	✓		2.11
RESIDENTIAL ESTABLISHMENTS			
Houses			
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			
Any Other Residential Features			
ANY OTHER ITEM OF SIGNIFICANCE			

2.3. Natural Features

2.3.1. Drinking Water Catchment Areas or Declared Special Areas

There are no drinking water catchment areas or declared special areas within the Study Area.

2.3.2. Rivers or Creeks

There are no rivers or creeks within the Study Area.

The nearest river is the Goulburn River, which is located at least 1.5 kilometres north west of the proposed longwalls. Murragamba Creek is located approximately 300 metres to the south east of proposed Longwall 5.

A number of other small drainage lines have been identified within the Study Area, as shown in Drawing No. MSEC353-06.

It should be noted that open cut areas surround a majority of the proposed UG1 and UG2 areas and a high proportion of the surface flows from the Study Area will flow into the open cut areas. The position of some of these small drainage lines that flow across the proposed northern out of pit emplacement may change as a result of clearing and placement of fill in this area.

2.3.3. Aquifers and Known Ground Water Resources

The aquifers and groundwater resources within the vicinity of the proposed longwalls have been investigated and are described in the report by Aquaterra (2011).

2.3.4. Springs

No natural springs have been identified within the Study Area.

Groundwater resources within the Study Area are described in the report by Aquaterra (2011).

2.3.5. Seas or Lakes

There are no seas or lakes within the Study Area.

2.3.6. Shorelines

There are no shorelines within the Study Area.

2.3.7. Natural Dams

There are no natural dams within the Study Area.

2.3.8. Cliffs and Natural Rock Formations

For the purposes of this report, a cliff has been defined as a continuous rockface having a minimum height of 10 metres and a minimum slope of 2 to 1, i.e. having a minimum angle to the horizontal of 63°. The locations of the cliffs were determined from site inspections and from the 2 metre surface contours of the area.

The locations of cliffs identified within the Study Area are shown in Drawing No. MSEC353-07 as presented within Appendix E. The cliffs and overhangs have formed from sandstone. Details of the cliffs and overhangs are provided in Table 2.2.

Table 2.2 Details of the Cliffs identified within the Study Area

ID	Approximate Overall Length (m)	Approximate Maximum Height (m)	Approximate Maximum Overhang (m)
C1	20	10	0
C2	20	15	0
C3	20	12	4
C4	20	15	5
C5	20	15	0
C6	20	10	0
C7	2 @ 50	10	6
C8	50	20	5
C9	100	20	7
C10	200	40	10

The cliffs have been defined as an area of environmental sensitivity for the purposes of this report.

Typical photographs of the cliffs are provided in Fig. 2.1 to Fig. 2.4. There may be other cliffs within the Study Area, however, their position cannot be determined from the 2 metre contour lines and they may be located in less accessible areas within the Study Area. Cliffs C2, C3 and C4 will be covered by the northern out of pit emplacement.

There are also a number of overhangs and smaller cliffs, which have been called rock ledges in this report. The overhangs and rock ledges are located across the Study Area. A photograph of a typical overhang is shown in Fig. 2.5.

Fig. 2.1 Photograph of Cliff C5

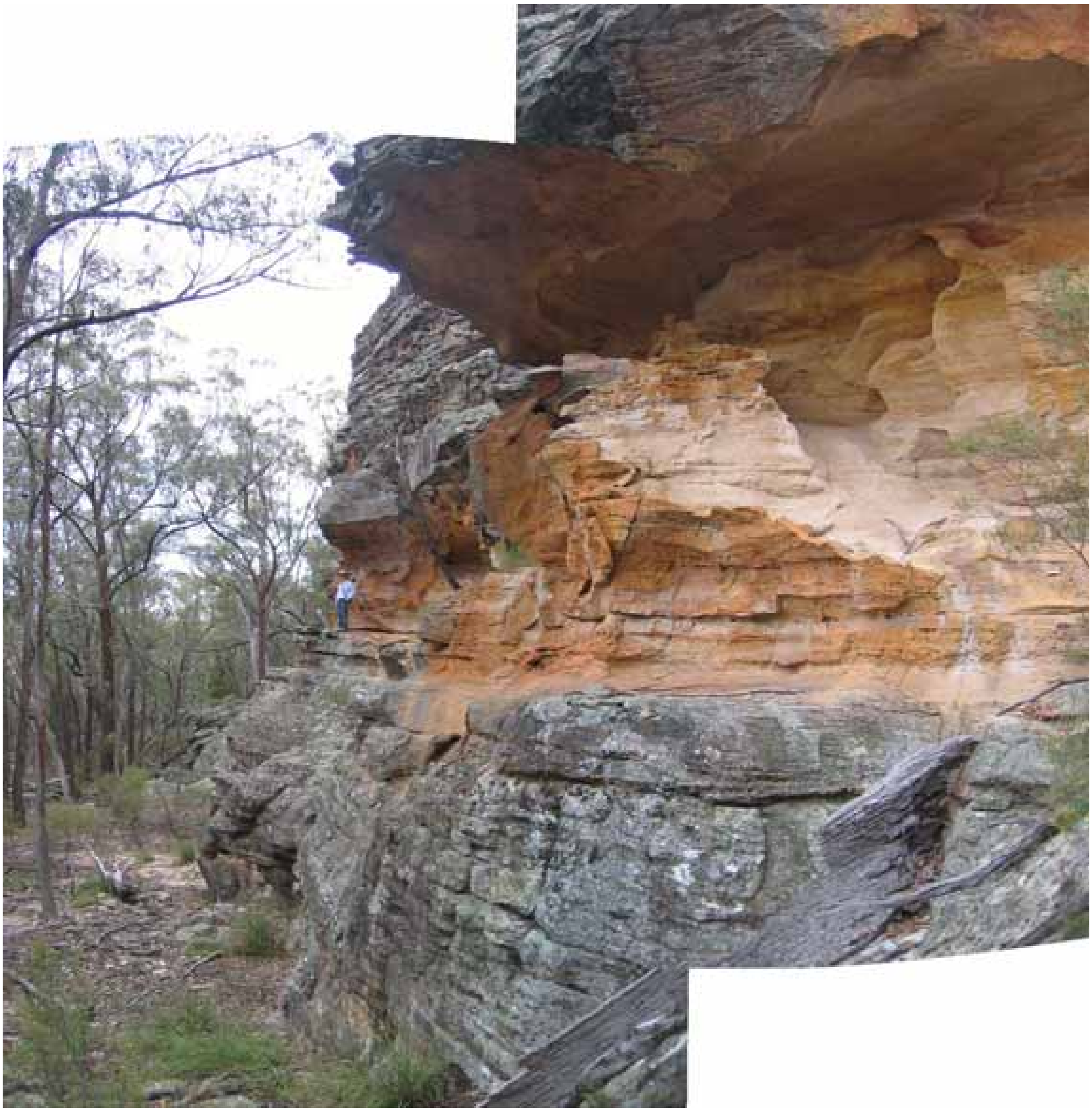

Fig. 2.2 Photograph of Cliff C8

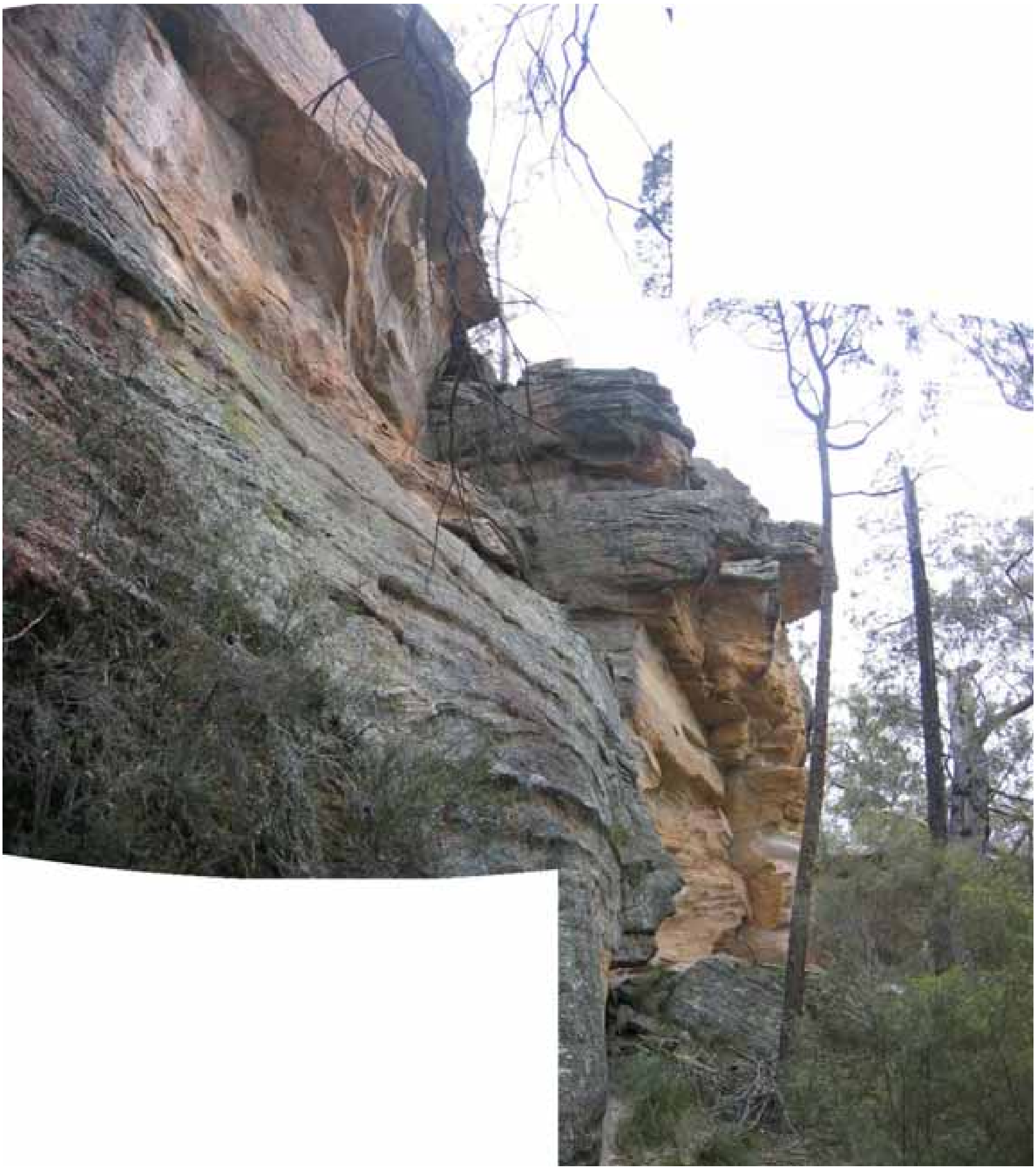

Fig. 2.3 Photograph of Cliff C9

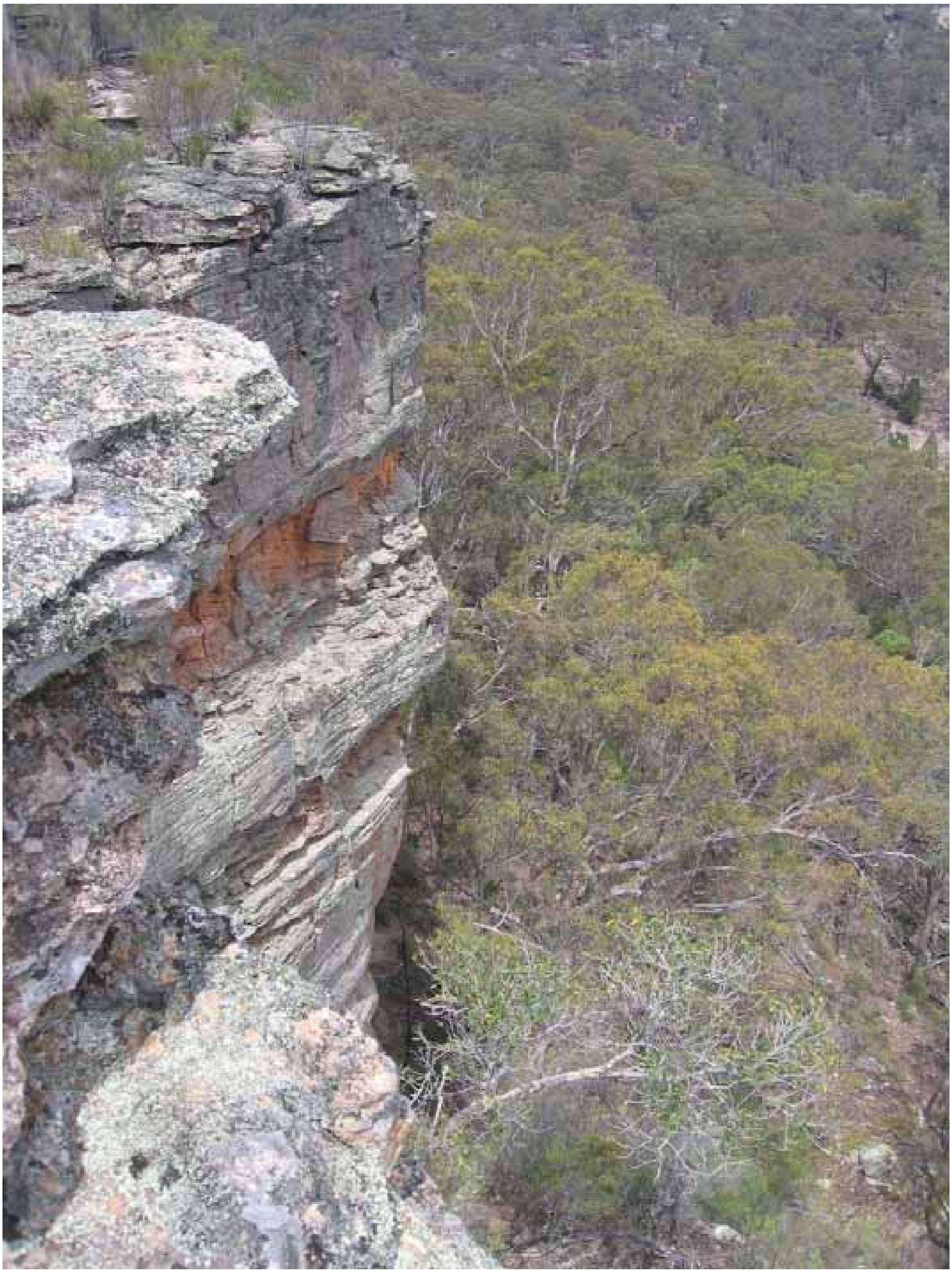

Fig. 2.4 Photograph of Cliff C10

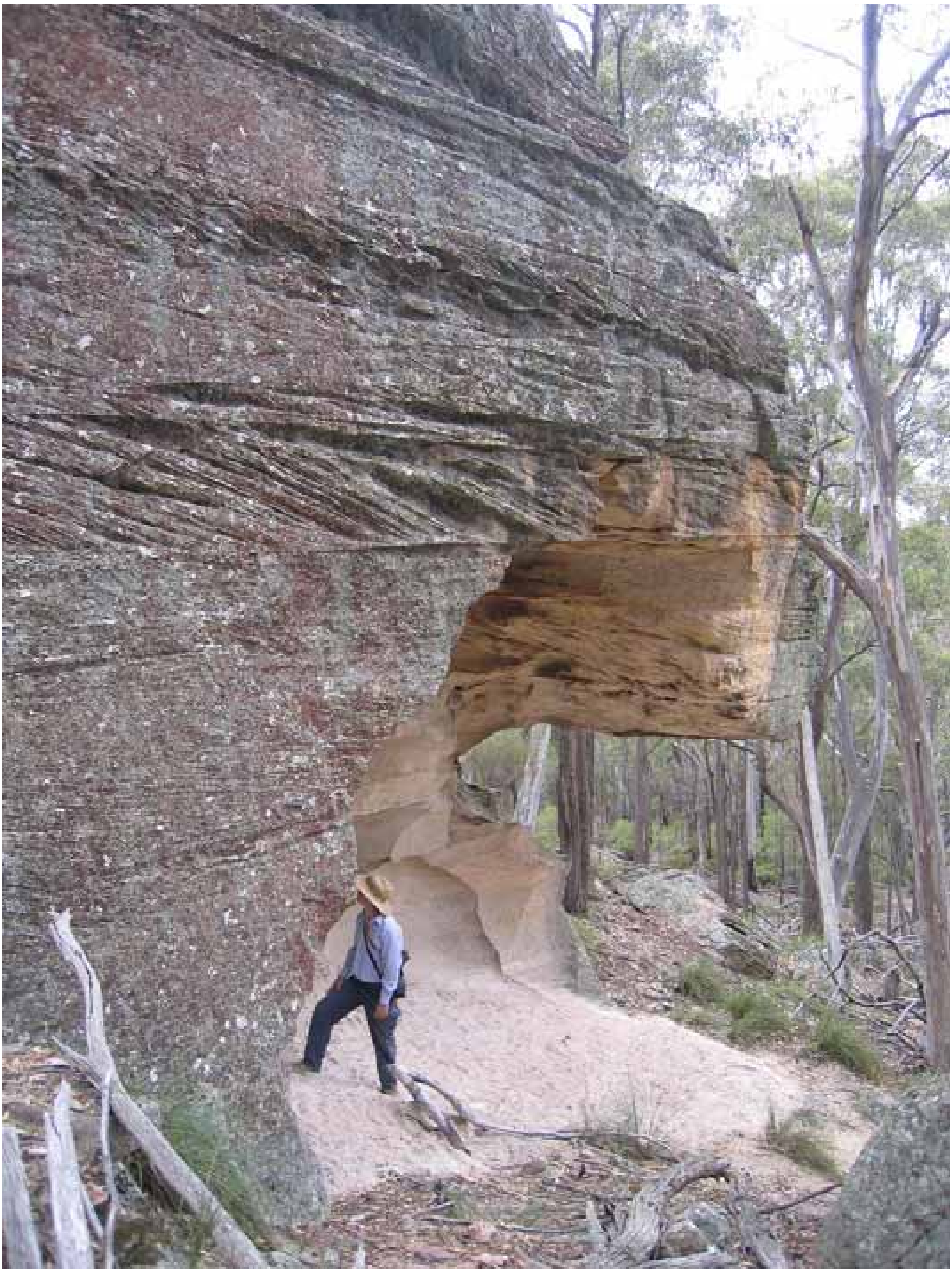

Fig. 2.5 Photograph of an overhang

2.3.9. Steep Slopes

A number of natural steep slopes have been identified within the Study Area. The reason for identifying the steep slopes is to highlight areas where existing ground slopes may be marginally stable. For the purposes of this report, a natural steep slope has been defined as an area of land having a natural gradient between 1 in 3 (i.e. a grade of 33 %, or an angle to the horizontal of 18°) and 2 in 1 (i.e. a grade of 200 %, or an angle to the horizontal of 63°).

The maximum slope of 2 to 1 represents the threshold adopted for defining a cliff. The minimum slope of 1 to 3 represents a slope that would generally be considered stable for slopes consisting of rocky soils or loose rock fragments. These natural steep slopes were identified from the surface level contours that were generated from the two metre surface contours of the area, and the locations of these steep slopes have been shown in Drawing No. MSEC353-07. The steep slopes located directly above the proposed longwalls within the Study Area typically have natural grades of up to 1 in 1, or a maximum angle to the horizontal of 45°.

The surface soils above the proposed longwalls generally consist of soils derived from sandstone, in varying stages of weathering and fracturing. The stability of these natural slopes varies depending on their soil or rock types, and in many cases, natural slopes can be stable at much higher gradients than 1 to 3, for example talus slopes in sandstone. The majority of these existing natural slopes have been stabilised, to some extent, by trees and other natural vegetation. Some steep slopes are located within the footprint of the proposed northern out of pit emplacement area as shown on Drawing No. MSEC 353-07 and these will therefore be covered before the extraction of the proposed longwalls.

2.3.10. Escarpments

The cliff line feature identified as Cliff C10 is up to 200 metres in length and may be viewed as being part of an escarpment. This escarpment is outside the General Study Area. A detailed discussion on this and the other cliff lines over and near the Study Area is presented in Section 2.3.8. There are no other escarpments within the Study Area.

2.3.11. Land Prone to Flooding or Inundation

There are no major natural flood prone areas identified within the Study Area.

2.3.12. Wetlands and Swamps

There are no swamps or wetlands within the Study Area.

2.3.13. Threatened, Protected Species or Critical Habitats

There are records of the following two threatened bat species occurring within the Study Area:

Large-eared Pied Bat (*Chalinolobus dwyeri*)

Greater Long-eared Bat (*Noctophilus timoriensis*)

The Large-eared Pied Bat resides predominantly in caves and rock overhangs. The Greater Long-eared Bat roosts in tree hollows in savannah type woodlands.

A vegetation community, known as the White Box - Yellow Box - Blakely's Red Gum Grassy Woodlands and Derived Native Grasslands, occurs at several locations within the Study Area and these ecological communities have been listed as Critically Endangered Ecological Communities (CEECs) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The occurrence of the CEECs appears to be related to the isolated tertiary basalt deposits above UG1 and UG2 as shown on Drawing No. MSEC353-06.

A discussion on flora and fauna within the Study Area, including the two threatened bat species and the CEECs, is included in a report by Ecovision Consulting and Marine Pollution Research (2008).

2.3.14. National Parks or Wilderness Areas

There are no National Parks or any land identified as wilderness under the *Wilderness Act 1987* within the Study Area.

There is a Nature Reserve and a National Park near the Study Area. The nearest edge of the Munghorn Gap Nature Reserve is approximately 140 metres from the starting end of Longwall 10 and the nearest edge of Goulburn River National Park is 1470 metres from the starting end of Longwall 5.

2.3.15. State Recreation Areas and State Conservation Areas

There are no State Recreation Areas or State Conservation Areas within the Study Area.

2.3.16. State Forests

There are no State Forests within the Study Area.

2.3.17. Natural Vegetation

The vegetation within the Study Area generally consists of disturbed land and undisturbed native bush. A detailed survey of the natural vegetation has been undertaken and is described in a report by Ecovision Consulting and Marine Pollution Research (2008).

2.3.18. Areas of Significant Geological Interest

There are no areas of significant geological interest within the Study Area. A brief description of the geology within the Study Area is provided in Section 1.3. A detailed description of the geology within the Study Area is provided in a report by Minerva Geological Services (2007).

2.3.19. Any Other Natural Feature Considered Significant

There are no other significant natural features within the Study Area.

2.4. Public Utilities

2.4.1. Railways

There are no railways within the Study Area, however, the Gulgong to Sandy Hollow Railway is located to the north east of the Study Area. The nearest point from the proposed longwalls to the railway line is approximately 330 metres from the nearest edge of Longwall 5. At this location the rail track will not be subjected to measurable systematic mine subsidence ground movements; however, it may experience small far field horizontal movements and the Gulgong to Sandy Hollow Railway has therefore been included in the assessment.

2.4.2. Roads

The locations of the roads, fire trails and four wheel drive tracks within and adjacent to the General Study Area are shown in Drawing No. MSEC353-08.

There is one public road in use that passes through the General Study Area. Murragamba Road is an unsealed road that passes over the north east part of the UG1 General Study Area over proposed Longwalls 4 and 5.

All other roads, including Carrs Gap Road, within the General Study Area are either unused roads or unsealed access roads that are used by local land owners.

2.4.3. Bridges

There are no bridges within the Study Area.

2.4.4. Tunnels

There are no tunnels within the Study Area.

2.4.5. Drainage Culverts

No drainage culverts were identified within the Study Area; however, drainage culverts are located along the Gulgong to Sandy Hollow Railway line, the largest of which is at the Murragamba Creek crossing. The nearest point from the proposed longwalls to the railway line is approximately 330 metres from the nearest edge of Longwall 5. At this location the rail track and culverts will not be subjected to measurable systematic mine subsidence ground movements; however, they may experience small far field horizontal movements and the Gulgong to Sandy Hollow Railway and culverts have therefore been included in the assessment.

2.4.6. Water, Gas or Sewer Pipelines

There is no public water infrastructure within the Study Area. Local, non operational water distribution pipelines may be present from connections between houses and local water storage tanks, which have been removed.

There are no public sewage pipelines or sewage treatment works within the Study Area. Local non operational site connections for septic tanks and disposal areas may be present at the locations where houses have been removed.

There are no gas or fuel pipelines within the Study Area.

2.4.7. Electrical Services

There is one low voltage powerline within the Study Area, passing over the commencing end of proposed Longwalls 6 and 7 and the commencing end of Longwall 5. The powerline is supported on timber poles. The route of the powerline is shown in Drawing No. MSEC353-09.

2.4.8. Telecommunications Services

The main underground copper cables within the Study Area are located along Murragamba Road. Underground consumer lines may be present at locations where houses have been removed, however these would have been disconnected.

There is an optical fibre cable located along the northern side of Ulan-Wollar Road and the closest point of the cable to the proposed longwalls is approximately 240 metres to the north east of Longwall 5.

2.4.9. Dams, Reservoirs and Associated Works

There are no dams located within the general Study Area.

2.4.10. Any Other Public Utilities

There are no other public utilities within the Study Area.

2.5. Public Amenities

There are no public amenities within the Study Area.

2.6. Farm Land or Facilities

2.6.1. On Site Waste Water Systems

Two demolished residences on the properties within the Study Area are likely to have had on-site waste water systems.

2.6.2. Rural Building Structures

There are no rural building structures within the Study Area.

2.6.3. Tanks

There are no tanks within the Study Area.

2.6.4. Fences

There are a number of fences within the Study Area which are constructed in a variety of ways, generally using either timber or metal materials. The fences are located across the Study Area.

2.6.5. Farm Dams

There are 13 farm dams (Structure Type D) that have been identified within the Study Area. The locations of the dams are shown in Drawings Nos. MSEC353-09 to 14.

2.6.6. Wells or Bores

Other than project specific bores there are no registered wells or water bores within the Study Area.

2.7. Industrial, Commercial and Business Establishments

2.7.1. Factories

There are no factories within the Study Area.

2.7.2. Workshops

There are no workshops within the Study Area.

2.7.3. Business or Commercial Establishments or Improvements

There are no businesses, commercial establishments or improvements within the Study Area.

2.7.4. Gas or Fuel Storages and Associated Plant

There are no known gas or fuel storages or associated plant within the Study Area.

2.7.5. Waste Storages and Associated Plant

There are no waste storages or associated plant within the General Study Area.

2.7.6. Buildings, Equipment or Operations that are Sensitive to Surface Movements

There are no known buildings, equipment or operations that are sensitive to surface movements within the Study Area.

2.7.7. Surface Mining (Open Cut) Voids and Rehabilitated Areas

Proposed open cut mining areas are located to the east and west of the proposed UG1 and UG2 areas as shown in Drawing No. MSEC353-01.

2.7.8. Mine Infrastructure Including Tailings Dams or Emplacement Areas

Some of the overburden materials from the Stage 2 Open Cut 4 Pit are proposed to be stockpiled in an out of pit emplacement area above portions of proposed UG1 Longwalls 3 to 8 (northern out of pit emplacement). The location of Open Cut 4 is shown in Drawing No. MSEC353-01. The proposed surface contours and the proposed location of the northern out of pit emplacement area that is proposed above Longwalls 3 to 8 in UG1 and the scheduled Project Years when each of the UG1 longwalls are proposed to be extracted are indicated on Drawing No. MSEC353-18.

Based on the provided surface contours, the northern out of pit emplacement area over UG1 will be formed by Year 7 and, based on the scheduled years of extraction for each longwall, the proposed Longwalls 3 to 8 will be extracted afterwards during Years 8 to 14.

Other mine infrastructure above UG1 includes Stage 2 ROM coal facilities, which are located at the south western end of Longwall 5, and conveyors between Stage 2 ROM coal facilities and Stage 1 ROM coal facilities.

The proposed final surface contours above and immediately to the south east of the UG1 longwalls will be those provided for Year 12, as re-presented in our Drawing No. MSEC353-18.

2.7.9. Any Other Industrial, Commercial or Business Features

There are no other industrial, commercial or businesses within the general Study Area.

2.8. Items of Archaeological Significance

There are 21 archaeological sites (identified in both Stage 1 and Stage 2 archaeological assessments) that have been identified within the Study Area, of which 17 are isolated finds or artefact scatters, and 4 have rock overhangs. The locations of the archaeological sites within the Study Area are shown in Drawing No. MSEC353-15.

Detailed descriptions of the archaeological sites are provided in the report by Heritas (2008).

2.9. Items of Historical or Heritage Significance

There is one item of moderate local significance located above proposed Longwall 6. The item is a dry stone wall that formed part of the Mudgee to Wollar road that ran via Moolarben. The item is known as Heritage Site No. 18 and is described in detail in a report by Archaeological Risk Assessment Services (2008). The location of the item is shown on Drawing No. MSEC353-15.

2.10. Items of Architectural Significance

There are no items of architectural significance within the Study Area.

2.11. Permanent Survey Control Marks

There is one survey mark, known as Murragamba Trig Station, included in the Study Area (MGA coordinates E 760942.064, N 6422386.932. The location of the survey control mark is shown in Drawing No. MSEC353-15.

2.12. Residential Establishments

2.12.1. Houses

There are no houses within the Study Area.

2.12.2. Swimming Pools

There are no swimming pools located within the Study Area.

2.12.3. Flats or Units

There are no flats or units within the Study Area.

2.12.4. Caravan Parks

There are no caravan parks within the Study Area.

2.12.5. Retirement or Aged Care Villages

There are no retirement or aged care villages within the Study Area.

2.12.6. Any Other Associated Structures

There are no other associated structures within the Study Area.

2.12.7. Any Other Residential Feature

There are no other major residential features within the Study Area.

2.13. Any Other Items

There are no other major items within the Study Area.

CHAPTER 3. OVERVIEW OF LONGWALL MINING, 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 longwall mining, the development of mine subsidence and the method that has been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls. More detailed descriptions of longwall mining and the development of subsidence are provided in a document titled "Introduction to Longwall Mining and Subsidence" which can be downloaded from the MSEC website at http://www.minesubsidence.com. Detailed descriptions of methods used to predict mine subsidence movements are provided in a document titled "General Discussion of Mine Subsidence Ground Movements" which can also be downloaded from the same website.

3.2. Overview of Longwall Mining

The coal within the Preferred Project will be extracted using longwall mining techniques. A cross-section along the length of a typical longwall at the coal face is shown in Fig. 3.1.

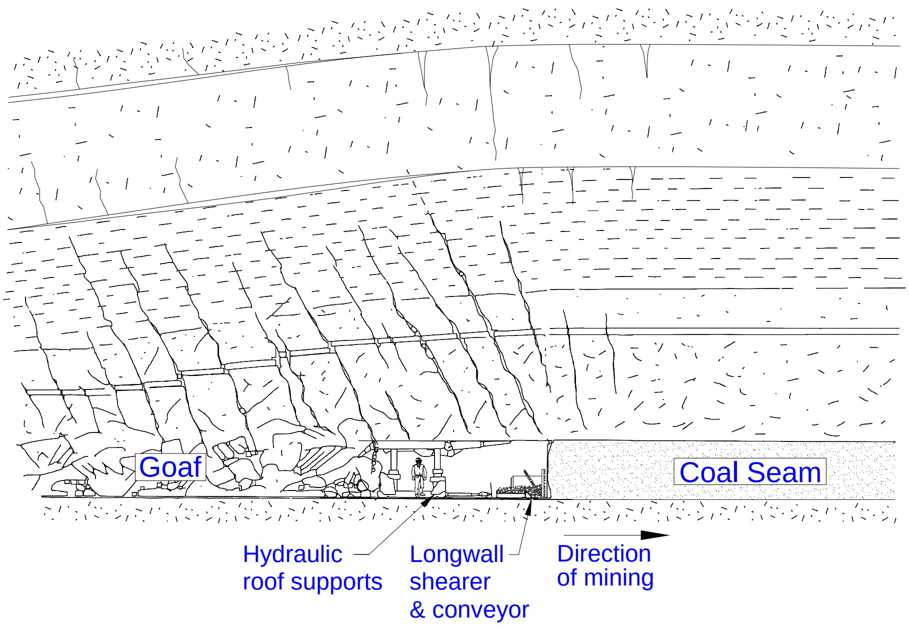

Fig. 3.1 Cross-section along the Length of a Typical Longwall at the Coal Face

The coal is removed by a shearer that cuts the coal from the coal face on each pass as it traverses the width of the longwall. The roof at the coal face is supported by a series of hydraulic roof supports, which temporarily hold up the roof strata, and provides a working space at the coal face. The coal is then transported by a face conveyor belt which is located behind 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 longwall.

The strata directly behind the hydraulic supports and immediately above the extracted coal seam, is allowed to collapse into the void that is left as the coal face retreats. The collapsed zone comprises of 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.

At the surface, the ground subsides vertically and also moves horizontally towards the centre of the mined goaf area. The maximum subsidence at the surface varies, depends on a number of factors including longwall geometry, depth of cover, extracted seam thickness, and geology. Based on observed data it is generally accepted that the maximum achievable subsidence in the Hunter and Western Coalfields is typically between 60 to 65 % of the extracted seam thickness.

3.3. Overview of Systematic Subsidence Movements

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

- **Subsidence** usually refers to vertical movement of a point, but subsidence of the ground actually includes both vertical and horizontal movement. These horizontal movements in some cases, where the subsidence is small, 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 %.

- **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 (1/km)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.

- **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 distance between two points increases and **Compressive Strains** occur where the distance 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.

A cross-section through a typical single longwall showing typical profiles of systematic subsidence, tilt, curvature and strain is provided in Fig. 3.2.

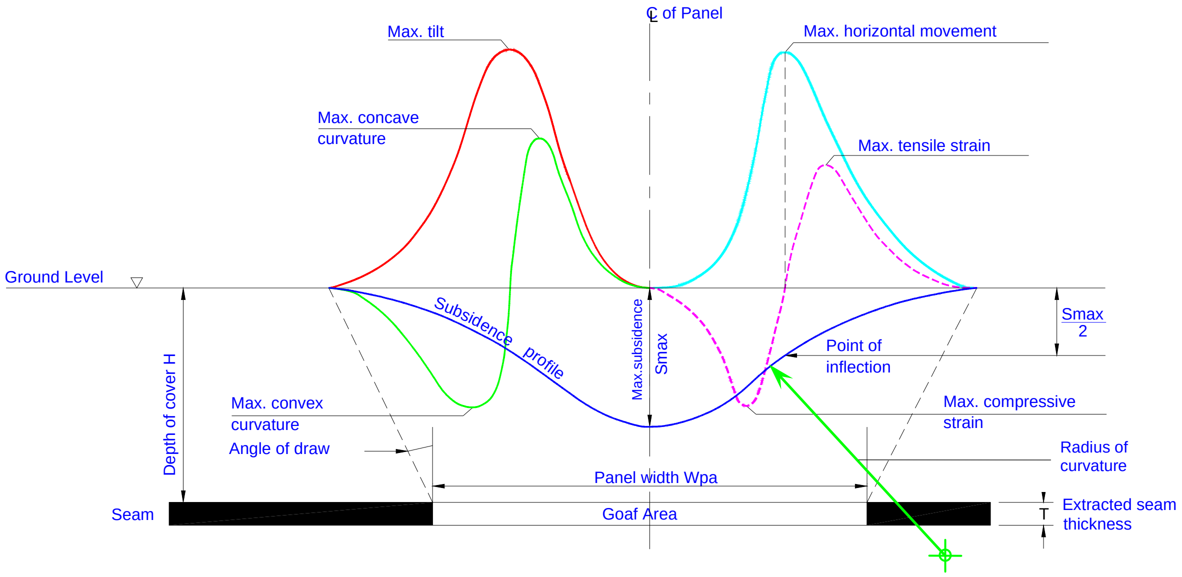

Fig. 3.2 Typical Profiles of Systematic Subsidence Parameters for a Single Longwall

The definitions of incremental, cumulative, total and travelling subsidence parameters are defined as follows:-

- **Incremental** subsidence parameters provided in this report, are the additional subsidence, tilts, curvatures, and strains which occur due to the extraction of a single longwall. Observed incremental subsidence profiles are determined by subtracting the observed subsidence profiles before from the observed subsidence profiles after the extraction of each longwall.
- **Cumulative** subsidence parameters provided in this report, are the accumulated subsidence, tilts, curvatures, and strains which occur due to the extraction of all proposed series of longwalls within a single seam.
- **Total** subsidence parameters provided in this report, are the accumulated subsidence, tilts, curvatures, and strains which occur after the extraction of all proposed series of longwalls within the current and preceding seams.
- **Travelling** subsidence parameters provided in this report, are the transient tilts, curvatures, and strains which occur as the longwall extraction faces passes directly beneath a point.

3.4. The Incremental Profile Method

The predicted systematic subsidence parameters for the proposed longwalls at the project were made using the Incremental Profile Method, which was developed by MSEC, formally known 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 including: Angus Place, Appin, Ashton, Baal Bone, Bellambi, Beltana, Bulli, Chain Valley, Clarence, Coalcliff, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Elouera, Fernbrook, Glennies Creek, Gretley, Invincible, John Darling, Kemira, Lambton, Liddell, Mandalong, Mannering, Metropolitan, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, 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 subsidence profiles, the proposed longwall geometries, local surface and seam information and geology. The method has a tendency to over-predict the systematic subsidence parameters (i.e. is slightly conservative) where the proposed 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 are available close to the proposed mining area.

The model uses the surface level contours, seam floor contours and seam thickness contours to make predictions. The surface level, seam floor and seam thickness contours were provided by MCM and are shown in Drawings Nos. MSEC353-02, MSEC353-03 and MSEC353-04, respectively.

The predicted systematic subsidence parameters for the proposed longwalls were determined using the standard Incremental Profile Model for the Hunter, Newcastle and Western Coalfields based on monitoring data from the Ulan Seam calibrated to local data. Modifications to the standard Incremental Profile Method have not been made for the presence of any thick massive strata units. A detailed description of the standard Incremental Profile Method is provided in the background reports that can be found on the website at http://www.minesubsidence.com.

Subsidence predictions have been made at points on regular grids orientated north-south and east-west across the General Study Area. A grid spacing of 10 metres in each direction was adopted, which provides sufficient resolution for the generation of subsidence, tilt, and strain contours.

The maximum predicted systematic subsidence parameters resulting from the extraction of the proposed longwalls at the project are provided in Chapter 4. The predicted systematic subsidence parameters at the natural features and items of surface infrastructure are provided in Chapter 5.

The standard Incremental Profile Method as used for the Hunter, Newcastle and Western Coalfields was calibrated to local data based on observed monitoring data available in the Upper Hunter Valley, for the nearby Ulan colliery and other collieries with similar panel width and cover geometries. The Standard incremental Profile Method for the Hunter, Newcastle and Western Coalfields assumes a maximum subsidence factor of 65% of the extracted seam thickness.

The model was adjusted to predict a maximum subsidence factor value of 60% of the extracted seam thickness due to the lower subsidence values that are commonly encountered in the Hunter, Newcastle and Western coalfields. This reduced subsidence is normally believed to be a result of the effect of thick layers of conglomerate or sandstone units in the material overlying the extracted coal seams.

3.5. Overview of Non-Systematic Subsidence Movements

Non-systematic subsidence movements include irregular subsidence movements and topography or valley related movements. They are also described as non-conventional subsidence movements. These movements are briefly described below and further details are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

3.5.1. Irregular Subsidence Movements

Irregular subsidence movements can result from near surface geological structures, including faults, dykes, and abrupt changes in geology. The presence of these features near the surface can result in a bump in the subsidence profile that is often accompanied by locally higher tilts and strains. Buckling of surface soils can also occur.

Irregular subsidence movements can also occur at shallow depths of cover, where the collapsed zone above the extracted longwalls extends near to the surface. In this situation, the resulting subsidence profile becomes very erratic, which is accompanied by higher tilts and strains.

In the Southern Coalfields the non-systematic tilts and strains resulting from irregular subsidence movements can be much greater than those resulting from the normal systematic subsidence movements, however, in the Western Coalfields, especially where the depths of cover are very low, the normal systematic subsidence movements can be higher than these non-systematic tilts and strains and hence these irregular subsidence movements can remain unnoticed..

Irregular subsidence movements, and the impacts resulting from such movements are described in Sections 5.22 of this report and Section 1.7 of the online document "General Discussion of Mine Subsidence Ground Movements" mentioned previously.

3.5.2. Valley Related Movements

The watercourses within the Study Area may be subjected to valley related movements, which are commonly observed along river and creek alignments in the Southern Coalfield, but less commonly observed in the Hunter Coalfield, which typically have much shallower depths of cover. The reason that valley related movements are less commonly observed in the Hunter Coalfield could be that the systematic subsidence movements are typically much larger than those observed in the Southern Coalfield, which tend to mask any smaller valley related movements which may occur.

Valley related movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.3.

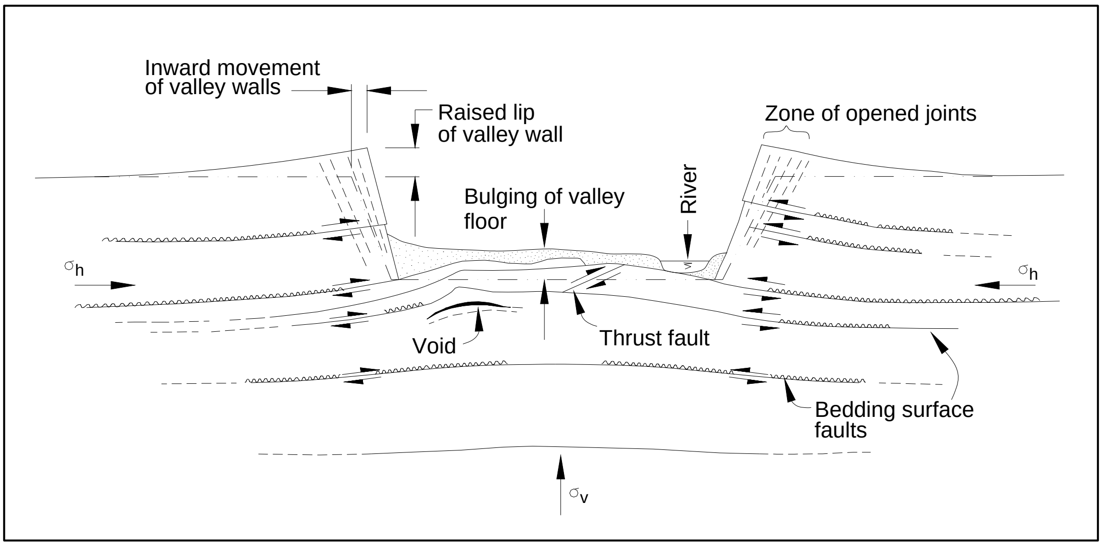

Fig. 3.3 Natural Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

These naturally occurring valley related movements can be accelerated by mine subsidence and are described using the following parameters:-

- **Upsidence** is the reduced subsidence, bulging, or net uplift movement within the base of a valley. It is typically expressed in units of *millimetres (mm)*. Upsidence predominantly results from the buckling of near surface strata in the base of the valley, where there is lower vertical confining stresses and increased horizontal stresses caused by a redistribution of insitu horizontal stresses around the collapsed zones above extracted longwalls. It follows that, whilst some strong bedrock layers are capable of accommodating an increase in horizontal stress, other valley floors, which may be weaker with thinner strata layers or with pre-existing natural joints, experience increased levels of upsidence. Upsidence can be measured by a comparison between the monitored survey data and an interpolated “flat terrain profile”. It is often easier to detect the magnitude and extent of the upsidence profile across a valley from the incremental subsidence profiles than from the total subsidence profiles.
  It is difficult to assess the full extent of upsidence from short monitoring lines located solely in the base of valleys as these short lines do not include the full upward thrust that extends beyond the cliff lines as is shown in the diagram above. Often incomplete assessments of upsidence are quoted because of short monitoring lines.
- **Closure** is the reduction in the horizontal distance between the valley sides, and is expressed in units of *millimetres (mm)*. Closure predominantly results from the above redistribution and increase in the horizontal stresses around the collapsed zones above extracted longwalls. Additional closure can result when downhill slumping of steeply sided talus slopes occurs, and/or from additional localised stress relaxation and slippage between bedding planes above the floor of the valley.
  The maximum measured closure along monitoring lines usually includes those survey bays across the bottom of the valley and it should be remembered that these observed movements include a component of the mining induced systematic ground movements.
- **Compressive Strains** occur within the valley as the result of valley closure movements and are calculated as the decrease in horizontal distance over a standard bay length, divided by the original bay length. **Tensile Strains** also occur adjacent to the valley as the result of valley closure movements, and are calculated as the increase in horizontal distance over a standard bay length, divided by the original bay length. So that ground strains can be compared between different locations within a colliery, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20. Compressive and tensile strains due to valley closure movements are typically expressed in units of *millimetres per metre (mm/m)*.

There are a number of factors which affect valley related movements (Kay, Barbato, Mills 2007), some of which include:

- Longwall geometry, such as panel width, panel length and pillar width;
- Depth of cover, seam extraction height and direction of mining;
- Position of longwall within a series of longwalls and previous adjacent mining;
- Magnitude of subsidence resulting from mining;
- Distance between the valley and the mined void, the orientation of the valley to mining and whether the valley is directly mined beneath;
- Height, width and shape of valleys, as well as the type of topography in the vicinity of valleys;
- Geology in the overburden and in the base of the valley, including the type of strata, bedding, jointing and geomechanical properties; and
- Composition of the valley sides, whether comprising clifflines, large talus slopes or colluvium.

Predictions of valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington 2004) which assumes a stress related mechanism for valley related movements (Kay, Barbato, Mills 2007). A detailed description of valley related movements and the method used to predict such movements, are provided in Section 1.7 of the online document "General Discussion of Mine Subsidence Ground Movements" mentioned previously.

The predicted values of upsidence and closure were plotted against observed values of upsidence and closure from several collieries and the results are presented in Fig. 3.4 and Fig. 3.5. The results show that the observed upsidence and closure movements are almost always less than predicted values of upsidence and closure.

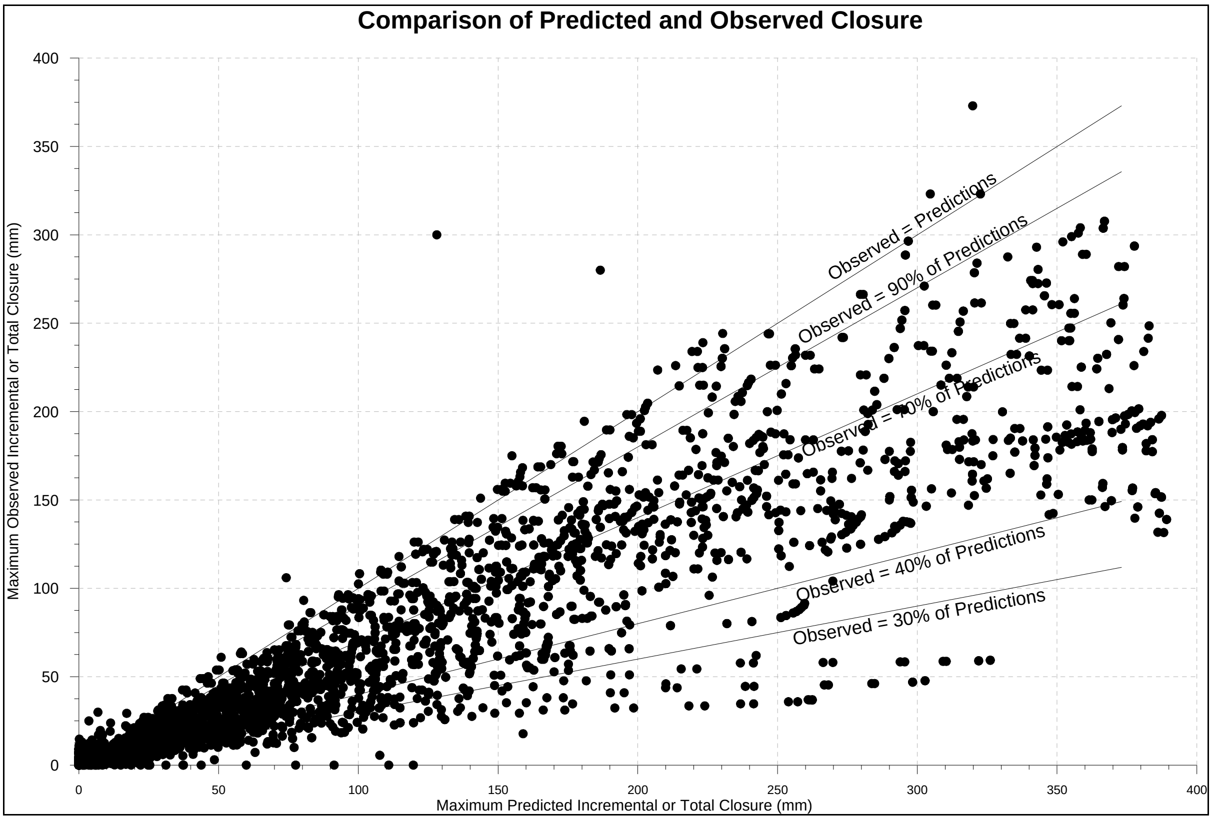

Fig. 3.4 Plot of Predicted versus Observed Closure

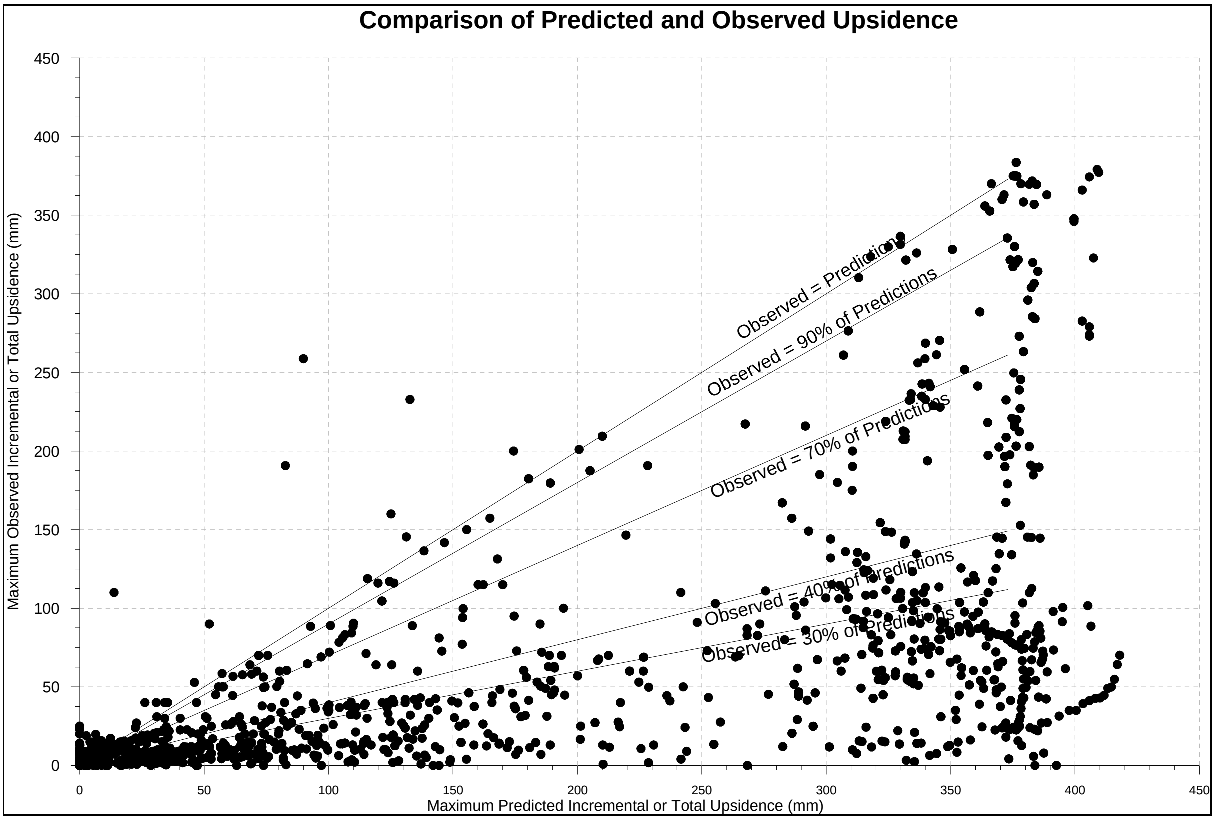

Fig. 3.5 Plot of Predicted versus Observed Upsidence

The few cases where the observed upsidence or closure has exceeded the predicted values were reviewed and in all cases the local geology in the bed of the river comprised thinly bedded or cross bedded or high jointed strata, which often comprised shale or claystone, whilst far less upsidence and closure has been observed, compared to predicted, in those valleys where the local geology in the bed of the river comprised thick alluvial beds or thick massive sandstone units. Ongoing studies are continuing research into understanding the strata mechanisms causing upsidence and closure and into improving the current prediction methods.

3.6. Far-field Movements

In addition to the systematic horizontal movements which occur above and adjacent to extracted longwalls, far-field horizontal movements have been observed at considerable distances from extracted longwalls. Such movements are predictable and have been measured whenever significant excavations occur at the surface or underground in strata with significant in-situ horizontal stresses.

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 impact, except where they occur at large structures which are very sensitive to differential horizontal movements.

Detailed descriptions of far-field horizontal movements, and the method used to predict such movements, are provided in provided in Section 5.20 of this report and Section 1.7 of the online document “General Discussion of Mine Subsidence Ground Movements” mentioned previously.

3.7. Testing of the Incremental Profile Method

3.7.1. Testing of the Incremental Profile Method against Longwalls 12 to 19 at Ulan Mine

The predicted subsidence movements were compared to the observed subsidence movements along the monitoring line D at Ulan Mine.

The Standard Incremental Profile Method for the Southern, Hunter, Newcastle and Western Coalfields results in a maximum incremental subsidence of 65% of the extracted seam thickness. The model for Moolarben and Ulan Coal Mine was adjusted to predict a maximum incremental subsidence factor of 60% of the extracted seam thickness due to known presence of strong sandstone and conglomerate strata layers above the seam and the lower subsidence values that are observed in the Hunter, Newcastle and Western coalfields where these strong strata layers are present. It should be noted that the maximum total subsidence over a series of longwall panels can be higher than 65% of the extracted seam thickness when the maximum incremental subsidence for each panel is limited to 60% of the extracted seam thickness.

A plot showing observed and predicted subsidence parameters for monitoring line D over Ulan Mine Longwalls 12 to 19 are presented in Fig. 3.6.

The observed subsidence results represent 30% to 40% of the 3.2 metre seam thickness extracted. This observed subsidence is considerably lower than the predicted subsidence profiles that were based on a constant maximum subsidence factor of 60% of the seam thickness, a constant panel void width of 265 metres, a constant extracted seam thickness of 3.2 metres and average depths of cover per longwall ranging from 140 metres to 260 metres.

The maximum subsidence per longwall along this monitoring line was observed to vary between 970 mm to 1300 mm and similar variations are often seen when reviewing the observed subsidence along longitudinal lines over the length of a panel; especially where the depths of cover are relatively shallow.

The Longwalls 1 to 13 at Stage 2 of the Moolarben Coal Project are proposed to be wider (305 metres) than those at Ulan Longwalls 11 to 19 and depth of covers over the proposed Moolarben longwalls are shallower. Hence, the panel width to depth ratios for the proposed Longwalls at Moolarben vary from approximately 2 to greater than 3, which is higher than the width to depth ratios for these longwalls at Ulan Mine of approximately 1 to 1.7.

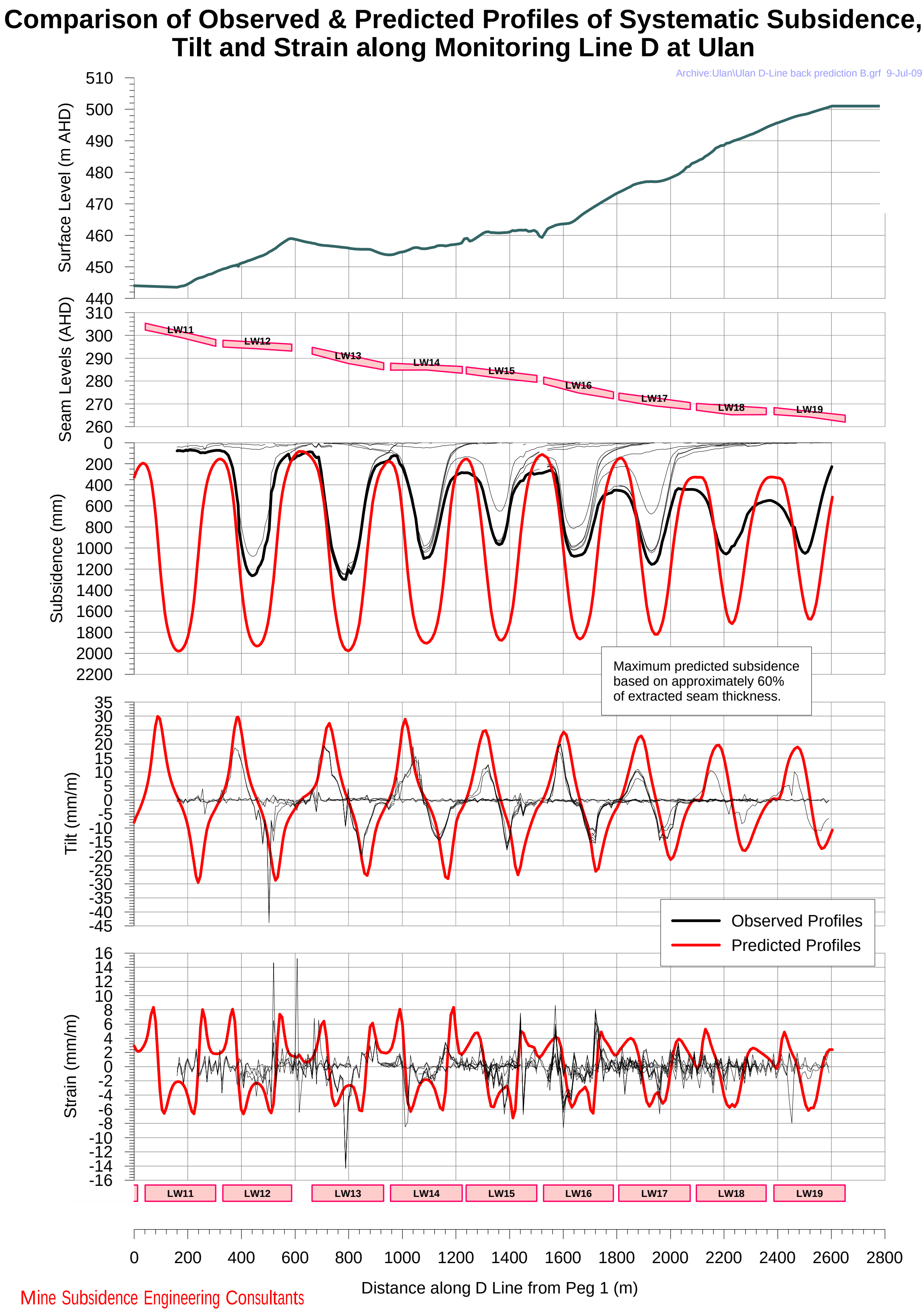

Fig. 3.6 Ulan Mine Longwalls 11 to 19 Monitoring Results along Monitoring Line D in the Ulan Seam

3.7.2. Testing of the Incremental Profile Method against Longwall 1 at the Beltana Mine

The predicted subsidence profiles, obtained using the Incremental Profile Method, have been compared against the measured subsidence survey results after the extraction of Longwall 1 within the Whybrow Seam in Beltana Central Mining Area, where the geology and depths of cover are similar to those at Stage 2 of the Moolarben Coal Project.

A graph comparing the predicted and measured subsidence profiles along the monitoring line at the Longwall 2 Ridge Cross Line is shown in Fig. 3.7. It can be seen that the predicted subsidence, tilts and strains were comparable to the observed subsidence, tilts and strains, however, there was a slight lateral shift between the predicted and observed results. This lateral shift is typically accounted for in the impact assessments by predicting the maximum subsidence parameters within a 20 metre radius of an isolated natural feature as described in Section 5.1.

Graphs comparing the predicted and measured subsidence profiles along the monitoring lines at the Optical Fibre Cross Line, West Charlton Road Cross Line and East Fence Cross Line are shown in Fig. 3.8, Fig. 3.9 and Fig. 3.10, respectively. It can be seen that the predicted subsidence, tilts and strains closely match the observed profiles, and generally provide slightly conservative results. The slight lateral shift between the predicted and observed results has been accounted for in the impact assessments as described above.

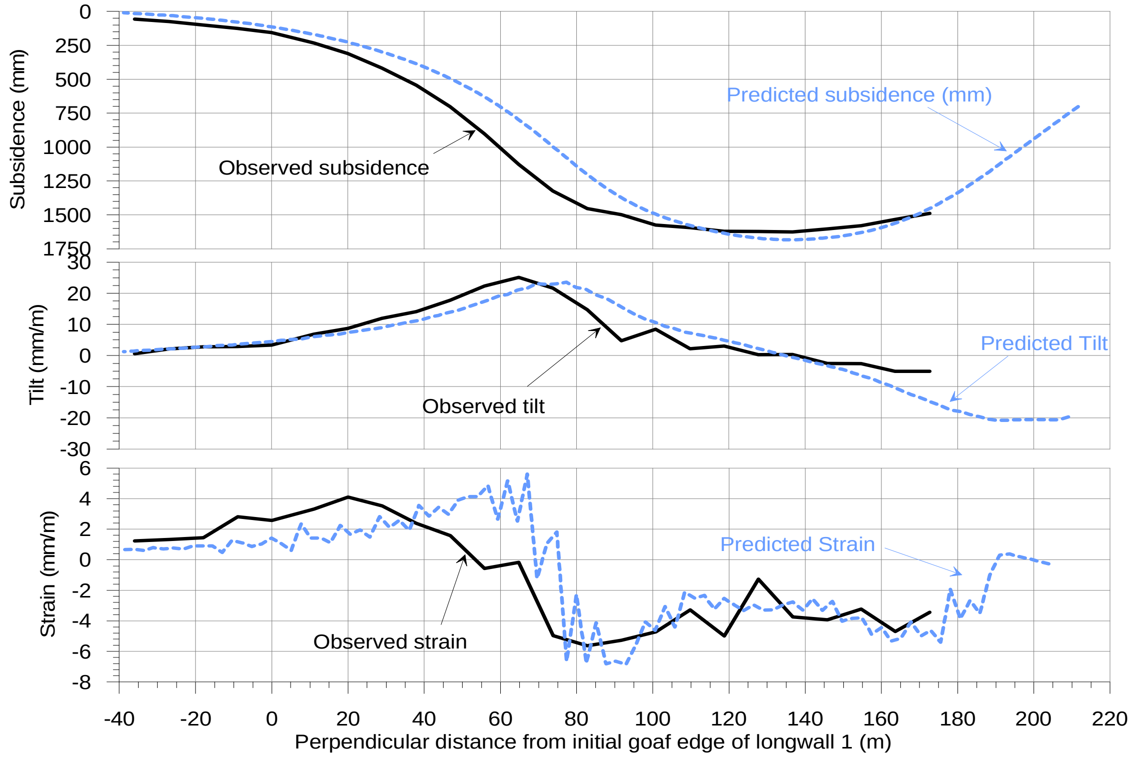

Fig. 3.7 Beltana Mine Monitoring Results after extraction of Longwall 1 in Whybrow Seam – Ridge Cross Line

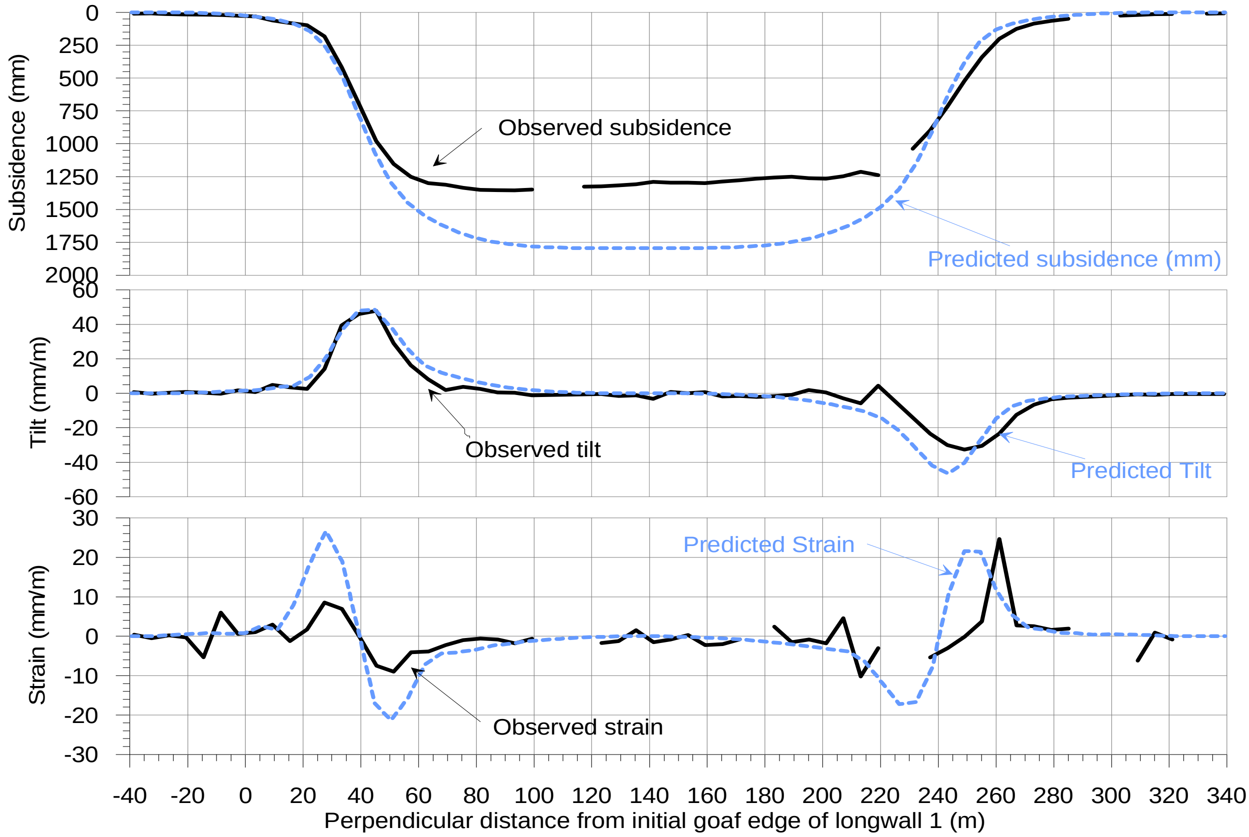

Fig. 3.8 Beltana Mine Monitoring Results after extraction of Longwall 1 in Whybrow Seam – Optical Fibre Cross Line

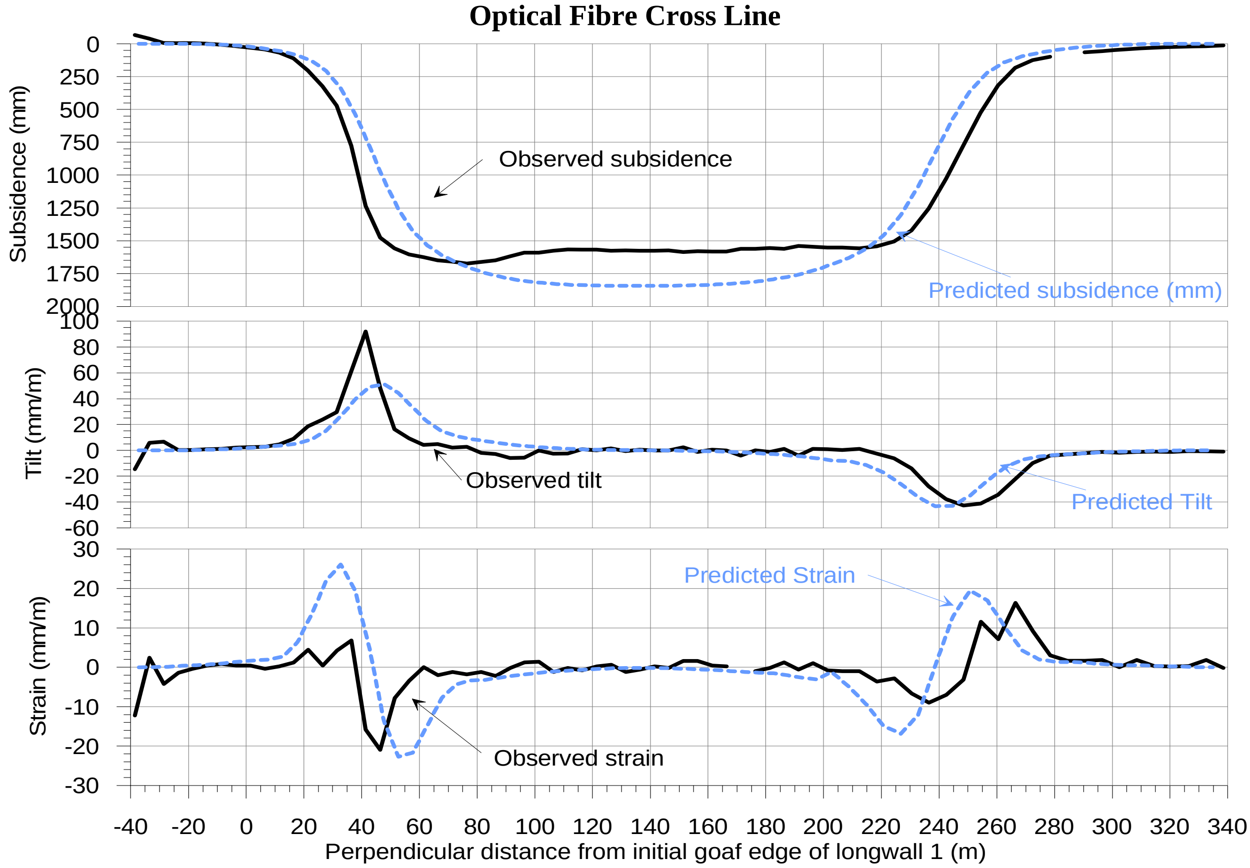

Fig. 3.9 Beltana Mine Monitoring Results after extraction of Longwall 1 in Whybrow Seam – West Charlton Road Cross Line

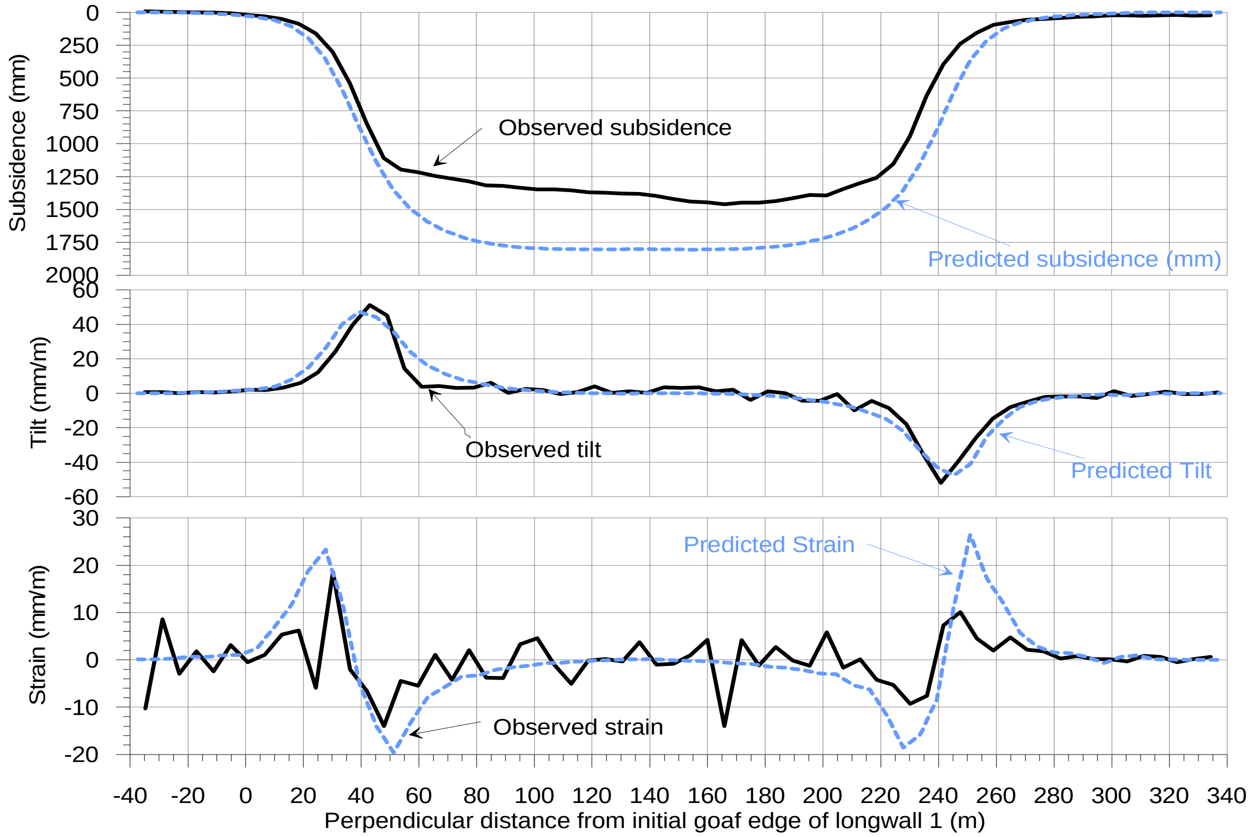

Fig. 3.10 Beltana Mine Monitoring Results after extraction of Longwall 1 in Whybrow Seam – East Fence Cross Line

CHAPTER 4. MAXIMUM PREDICTED SYSTEMATIC SUBSIDENCE PARAMETERS FOR THE PROPOSED LONGWALLS

4.1. Introduction

The following sections in this Chapter provide the maximum predicted systematic subsidence parameters resulting from the proposed extraction of Longwalls 1 to 13 at the Moolarben Coal Project, using the calibrated Incremental Profile Method, which was described in Chapter 3. The predicted subsidence parameters and the impact assessments for each of the natural features and items of surface infrastructure that have been identified within the Study Area, as detailed in Chapter 2, are provided in Chapter 5.

4.2. Maximum Predicted Systematic Subsidence Parameters for the Proposed Longwalls

The maximum predicted subsidence parameters, which are detailed in this Chapter and the site specific predicted subsidence parameters in Chapter 5, are referred to as systematic ground movements and do not include the valley related upsidence and closure movements, or the effects of faults and other geological structures, or other non-systematic ground movements, which are discussed in Section 3.6. Such effects have been addressed separately in Chapter 5.

Typical examples of the predicted shapes of the systematic subsidence profiles have been prepared along prediction lines called Prediction Line 1, Prediction Line 2, Prediction Line 3 and Prediction Line 4, the locations of which are shown in Drawing No. MSEC353-16, which can be found in Appendix E. The predicted incremental and total systematic subsidence, tilt and strain profiles along these prediction lines are shown in Fig. C.01, Fig. C.02, Fig. C.03, and Fig. C.04 which can be found in Appendix C.

A summary of the maximum predicted incremental systematic subsidence parameters, i.e. subsidence, tilt and tensile and compressive strain ground movements, within the Study Area, due to the extraction of each of the proposed longwalls, is provided in Table 4.1.

Table 4.1 Maximum Predicted Incremental Systematic Subsidence Parameters due to the Extraction of Longwalls 1 to 13

Longwall	Maximum Predicted Incremental Subsidence (mm)	Maximum Predicted Incremental Tilt (mm/m)	Maximum Predicted Incremental Tensile Strain (mm/m)	Maximum Predicted Incremental Compressive Strain (mm/m)
Due to LW1	1840	50	30	25
Due to LW2	1860	45	25	20
Due to LW3	1890	45	25	18
Due to LW4	1860	55	40	30
Due to LW5	1810	70	>50	40
Due to LW6	1760	70	>50	40
Due to LW7	1780	65	>50	40
Due to LW8	1780	55	35	30
Due to LW9	1800	95	>50	>50
Due to LW10	1580	70	>50	>50
Due to LW11	1620	50	35	25
Due to LW12	1700	70	>50	45
Due to LW13	1700	70	>50	45

The greatest maximum incremental subsidence of 1890 mm has been predicted for Longwall 3, and the smallest maximum incremental subsidence of 1580 mm has been predicted for Longwall 10. The maximum predicted incremental subsidence of 1890 mm for Longwall 3 represents approximately 59% of the proposed extracted seam thickness at this location (3.2 metres). At this location, the depth of cover to the seam was 143 metres, the panel width to depth ratio is 305/143 = 2.13 and the pillar width to depth ratio is 30/143 = 0.21.

A summary of the maximum predicted total systematic subsidence parameters within the Study Area, after the extraction of the proposed Longwall 13, is provided in Table 4.2. The predicted total systematic subsidence contours, after the extraction Longwall 13, are shown in Drawing No. MSEC353-17 in Appendix E.

Table 4.2 Maximum Predicted Total Systematic Subsidence Parameters within the Study Area after the Extraction of Longwall 13

Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
After LW1	1840	50	30	25
After LW2	1925	50	30	25
After LW3	1940	50	30	25
After LW4	1980	60	40	30
After LW5	1980	70	>50	40
After LW6	1980	70	>50	40
After LW7	1980	70	>50	40
After LW8	1980	70	>50	40
After LW9	1980	95	>50	>50
After LW10	1980	95	>50	>50
After LW11	1980	95	>50	>50
After LW12	1980	95	>50	>50
After LW13	1980	95	>50	>50

The maximum predicted total systematic subsidence due to Longwalls 1 to 13 and within the Study Area is 1980 mm which occurs above the middle of Longwall 3 after the extraction of Longwall 4. At this location the depth of cover was 143 metres and the proposed extracted seam thickness is 3.2 metres. This predicted total subsidence of 1980 mm represents 62% of the extracted seam thickness at this location.

The maximum predicted total systematic tilt due to Longwalls 1 to 13 and within the Study Area of 95 mm/m (i.e. 9.5 %), or a change in grade of 1 in 10, occurs near the maingate of Longwall 9 after the extraction of Longwall 9. The maximum predicted total systematic tensile and compressive strains resulting from the extraction of the proposed longwalls, are both greater than 50 mm/m and the associated minimum radii of curvatures are both less than 0.3 kilometres. The maximum predicted total systematic tensile and compressive strain both occur near the maingate of Longwall 9, after the extraction of Longwall 9.

As discussed above, these predictions of systematic subsidence parameters do not include the valley related upsidence and closure movements, or the effects of faults and other geological structures. Such effects have been addressed separately in Chapter 5.

4.3. Estimation of the Reliability of the Subsidence Predictions

The Incremental Profile Method should provide realistic, if not conservative predictions of subsidence, tilt, curvature, and strain over the proposed longwalls within the Moolarben Coal Project (Stage 2). 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.

Empirical methods of subsidence prediction are generally accepted as providing predictions of maximum subsidence to an accuracy of ±10 % to ±15 %. It was indicated by Dr Lax Holla, in his paper entitled, “Reliability of Subsidence Prediction Methods for use in Mining Decisions in New South Wales” (1991), that the accuracy of predictions of maximum subsidence, made using the Department’s Empirical Method, generally ranged from +8 % to -11 %. Only four of the 14 examples referred to in the paper had a maximum predicted subsidence less than the maximum observed subsidence, based on the information from seven different collieries in the Southern and Newcastle Coalfields. When the predictive graphs used in the Incremental Profile Method have been calibrated to local data, even greater accuracies have been found to be possible in predicting the maximum values of the subsidence parameters.

As shown in the above comparison for observed and predicted subsidence over Longwalls 11 to 19 at the neighbouring Ulan Mine, the predicted subsidence is significantly higher than the observed subsidence and this difference is expected for the Longwalls 1 to 13 at Stage 2 of the Moolarben Coal Project.

The prediction of subsidence parameters at a specific point is more difficult. Based upon a large number of comparative analyses, however, it has been concluded that the vertical subsidence predictions for single seam extractions, obtained using the Incremental Profile Method, should generally be conservative where the geology is consistent and the model has been calibrated to local data. Where subsidence is predicted at points beyond the goaf edge, which are likely to experience very low values of subsidence, the predictions should generally be accurate to within 50 mm of subsidence.

The systematic tilts can be predicted to a similar level of accuracy as subsidence as detailed above. It has been found, however, that variations between predicted and observed tilts 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 tilts being greater than those predicted in some locations, with the observed tilts being less than those predicted in other locations.

It is highlighted, however, that measured strains have been found to 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. This variation is seen as a reflection, not only in the variations of the local surface geology, that pre-existing natural joints influence actual ground movements, and the difficulties in measuring small changes in distances accurately, but it also reflects the fact that strains result from both mining induced curvatures and differential horizontal movements.

Accordingly the confidence levels that we assign to subsidence and tilt predictions cannot be assigned to strain predictions.

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, this shearing can occur at relatively low values of stress. These variations in longwall in local geology can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zone, existing joints can be opened up 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 systematic 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 joints open up or cracks develop in the tensile phase and fail to close in the compressive phase, as they sometimes do if they are subsequently filled, the ground can appear to be in tension when 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 systematic 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 the existing natural joints, which have been found to be at an average spacing of 7 to 15 metres.

- Current systematic horizontal prediction methods are principally based on factors being applied to the predicted curvature ground movements and do not account for the release of insitu horizontal stress, the far field movement mechanism or valley related movements.
- It is also recognised that the ground movements above a longwall 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.

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 strains at every point, which would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts. However, because of the variability in observed strain values, the prediction of strain at a point obtained using the Incremental Profile Method should be considered within an appropriate confidence interval.

The comparison between predicted and observed subsidence movements will be undertaken during the extraction of the proposed longwalls. The subsidence predictions made using the Incremental Profile Method can be refined based on the monitoring data obtained during mining. Further refinement can also be made to the predictions where local monitoring data close to the Study Area becomes available.

Predictions of strain at isolated features have been provided in this report for comparison purposes, such that the potential for impacts can be compared from place to place. As described above, it is possible that the actual strain at each feature could be greater or less than that predicted, or could be tensile where compression was predicted, or vice versa. It is expected, however, that the observed strains at the features will generally be within the range of the maximums predicted within the Study Area, which were provided in Section 4.2.

4.4. Comparison of Predicted Subsidence Parameters Obtained using the Holla Series and Department's Handbook Methods

The maximum predicted systematic subsidence parameters over Prediction Line 1 that, as shown in Drawing MSEC353-16, crosses over the proposed Stage 2 Moolarben Coal Project Longwalls 1 to 5, obtained using the Incremental Profile Method, were compared with the maximum predicted subsidence parameters obtained using the Holla Series Method (Holla, 1988) and the Department's Handbook Method for the Western Coalfields (Holla, 1991).

The Holla Series and the Department's Handbook Methods only allow the prediction of the maximum values of subsidence, tilt, curvature and strain, and do not precisely indicate where these maxima will occur. The comparisons were limited to, therefore, the maximum predicted values of each parameter over the proposed longwalls.

The overall void widths of Longwalls 1 to 5 are 305 metres and the solid chain pillar widths between each of the proposed longwalls are 30 metres. Along Prediction Line 1, the depth of cover varies between 90 and 150 metres, with an average depth of cover of 120 metres. The average seam thickness along Prediction Line 1 is 3.0 metres.

The maximum predicted systematic subsidence obtained using the Holla Series Method is determined from Figure 4 of a published paper which has been reproduced in Fig. 4.1. This figure provides the maximum predicted subsidence, as a ratio of the extracted seam thickness, for varying panel width-to-depth ratios and varying pillar width-to-depth ratios, based on critical extraction conditions.

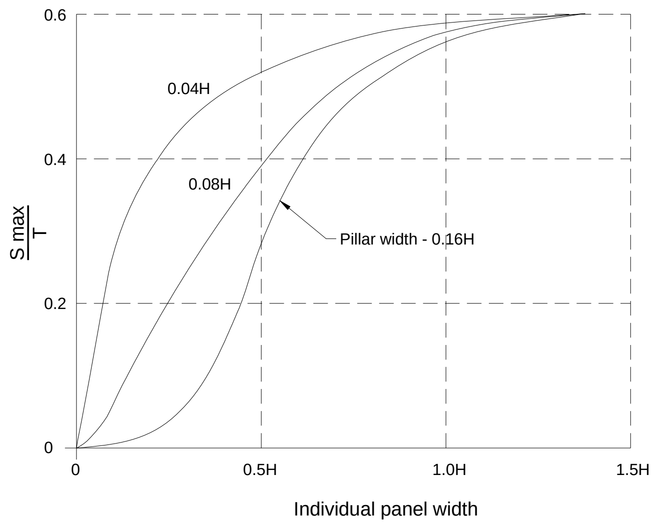

Fig. 4.1 Graph for the Prediction of Maximum Subsidence Over a Series of Panels for Critical Extraction Conditions (after Holla 1988)

This figure was developed from longwall data with a range of width-to-depth ratios between 0.23 and 0.4, which does not include supercritical longwalls such as for the proposed longwalls. From the figure, a prediction of 60% of the extracted seam thickness can be used for the proposed Stage 2 Moolarben Coal Project Longwalls 1 to 5 for comparative purposes.

Using the Department's Handbook Method for the Western Coalfields and based on an individual panel width-to-depth ratio of 2.5 (i.e. 305 metres / 120 metres) the maximum predicted subsidence, obtained using Figure 7 of the Handbook, is 65% of the extracted seam thickness.

The maximum predicted systematic tilts and strains can be obtained using the Department's Handbook Method and are determined by multiplying various factors by the maximum predicted subsidence in millimetres and dividing the result by the depth of cover in metres.

The maximum predicted values of systematic subsidence, tilt and strain along Prediction Line 1 obtained using the Incremental Profile Method are compared to those obtained using the Holla Series and Department's Handbook Methods in Table 4.3.

Table 4.3 Comparison of Maximum Predicted Parameters Obtained using Alternative Methods

Predicted Parameter	Incremental Profile Method	Holla Series and the Departments Handbook Methods
Vertical Subsidence (mm)	1956	1950
Tilt (mm/m)	35	80
Tensile Strain (mm/m)	16	24
Compressive Strain (mm/m)	11	40

It can be seen from Table 4.3, that the maximum predicted systematic subsidence and tensile strain obtained using the Incremental Profile Method are similar to, but slightly greater than those obtained using the Holla Series and Department's Handbook Methods.

It can also be seen from this table, that the maximum predicted systematic tilt and compressive strain obtained using the Incremental Profile Method are similar to, but slightly less than those obtained using the Holla Series and Department's Handbook Methods.

CHAPTER 5. PREDICTED SUBSIDENCE PARAMETERS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES AND ITEMS OF SURFACE INFRASTRUCTURE WITHIN THE STUDY AREA

5.1. Introduction

This Chapter provides site specific predicted subsidence parameters and impact assessments for each of the natural features and items of surface infrastructure that are located within the Study Area, due to the proposed extraction of Longwalls 1 to 13. In particular, the following sections of this Chapter address:-

- Drainage Lines (Section 5.2);
- Cliffs and Rock Ledges (Section 5.3);
- Steep Slopes (Section 5.4);
- Threatened Species (Section 5.5);
- Vegetation Communities (Section 5.6);
- Railway (Section 5.7);
- Roads (Section 5.8);
- Powerlines (Section 5.9);
- Optical Fibre Cables (Section 5.10);
- Copper Telecommunications Cables (Section 5.11);
- Fences, Farm Dams (Sections 5.12 to 5.13);
- Out of pit emplacement (Section 5.14);
- The Highwall of the Open Cut Mine (Section 5.15);
- Archaeological Sites (Section 5.16);
- Heritage Items (Section 5.17);
- Survey Control Marks (Section 5.18); and

The predicted subsidence parameters for each of the natural features and items of surface infrastructure were determined using the calibrated Incremental Profile Method, which is described in Chapter 3. The Incremental Profile Method is generally conservative, i.e. it provides predicted subsidence values that are generally higher than those actually measured after mining. Similarly the predictions of valley upsidence and closure movements using the ACARP method for predicting upsidence and closure are also generally higher than those actually measured after mining.

Accordingly the observed parameters at a specific site are more likely to be less than predicted, particularly when comparing the maximum predicted values with the maximum observed values. But, when comparing site specific predictions, the actual subsidence parameters often vary from those predicted, depending on many factors including differences in local geology, and the exact position of each feature or item within the subsidence trough. Therefore to provide additional conservatism for these site specific predictions the predicted values of subsidence, tilt, curvature and strain have been determined at the specific location and within a distance of 20 metres from the perimeter of each specific location. The maximum of these predicted values for each natural feature or item of surface infrastructure has been reported. This methodology may therefore increase the site specific predictions, especially where the predicted values are small.

As described in Section 4.3, the prediction of strain at a point is more difficult than the prediction of subsidence and tilt at a point. This variation is seen as a reflection, not only in the variations in the local surface geology, that pre-existing natural joints influence actual ground movements, and the difficulties in measuring small changes in distances accurately, but it also reflects the fact that strains result from both mining induced curvatures and differential horizontal movements. It is possible, therefore, that the actual strain measured at each isolated feature could be greater or less than that predicted, or the measured strain could be tensile where compression was predicted, or vice versa.

Because of the variability in the observed strain values, the prediction of strain at a point obtained using the Incremental Profile Method should be considered within appropriate confidence intervals. Therefore the predictions of strain at isolated features have been provided in this report for comparison purposes, such that the potentials for impact can be compared from place to place. It is expected, however, that the actual strains at the isolated features will generally be within a range of the maximums predicted within the Study Area.

5.2. Drainage Lines

A number of small drainage lines have been identified above the longwalls and within the Study Area, as shown in Drawing No. MSEC353-06. Some of these drainage lines flow to the west and north towards Moolarben Creek and then flow into the Goulburn River near Ulan. The other drainage lines flow to the east towards the Murragamba Creek, Wilpinjong Creek, Wollar Creek and then to the Goulburn River. After the Open Cuts have been formed most of these drainage lines will flow into the Open Cut Pit. Some of the drainage lines are also located under the proposed northern out of pit emplacement and will therefore be filled in before the longwalls are proposed to be extracted. The predictions and impact assessments for a selected number of drainage lines within the Study Area are provided in the following sections.

5.2.1. Predictions for the Drainage Lines

The drainage lines are located across the Study Area and are likely, therefore, to be subjected to the full range of predicted systematic subsidence and valley related movements. The predicted movements have been determined along seven drainage lines, which have been called DL1 to DL7 inclusive, and these drainage lines are shown in Drawing No. MSEC353-06.

The predicted profiles of systematic subsidence, tilt and strain along the alignments of Drainage Lines 1 to 7 resulting from the extraction of the proposed longwalls, are shown in Figs. C.05 to C.11, respectively, in Appendix C. A summary of the maximum predicted total systematic subsidence parameters along these drainage lines, after the extraction of each proposed longwall, is provided in Table 5.1.

Table 5.1 Maximum Predicted Systematic Subsidence Parameters along the Alignments of the Drainage Lines Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Drainage Line 1	1390	45	35	30
Drainage Line 2	1490	60	>50	40
Drainage Line 3	1390	35	15	20
Drainage Line 4	1840	60	>50	30
Drainage Line 5	1890	70	>50	40
Drainage Line 6	1830	70	>50	40
Drainage Line 7	1850	70	>50	40

The drainage lines will also be subjected to travelling tilts and strains where the extraction faces of the proposed longwalls pass beneath them. It is expected that the drainage lines could be subjected to travelling tilts up to 60 mm/m (i.e. 6 %), or changes in grade up to 1 in 17, and could be subjected to travelling strains up to 40 mm/m.

It is also possible that the drainage lines could experience some valley related movements resulting from the extraction of the proposed longwalls. The magnitudes of these upsidence and closure movements are expected to be much lower than the systematic movements and hence may not be significant. It is possible, however that the closure strains resulting from valley related closure movements may extend beyond the limit of systematic subsidence related movements. It is also noted, however, that the valley shapes of the drainage lines become much flatter beyond the Study Area and the resulting magnitudes of valley related closure strains would be significantly lower.

5.2.2. Impact Assessments for the Drainage Lines

The drainage lines within the Study Area are ephemeral and so water only typically flows during and for short periods after each rain event. Ponding naturally develops along some sections of the drainage lines, for short periods of time, after major rain events.

The maximum predicted systematic subsidence along drainage lines resulting from the extraction of the proposed longwalls ranges from 1390 mm at Drainage Line 3 to 1890 mm at Drainage Line 5. The maximum predicted systematic tilts along the alignments of the drainage lines vary between 35 mm/m (i.e. 4 %) and 70 mm/m (i.e. > 7 %), or changes in grade between 1 in 30 and greater than 1 in 14.

The predicted changes in grade along the drainage lines are generally less than most of the natural grades, which vary from approximately 20 mm/m to 500 mm/m, with the shallower grades being located along Drainage Lines 5, 6 and 7. It is expected, therefore, that some ponding may occur along the drainage lines resulting from the extraction of the proposed longwalls. The predicted final surface levels along the drainage lines following the completion of mining are illustrated in Figs. C.05 to C.11.

The drainage lines within the Study Area contain predominantly alluvial and colluvial deposits and it is expected, therefore, that sections of beds downstream of the additional ponding areas, may erode during subsequent rain events, especially during times of high flow. It is expected over time, that the gradients along the drainage lines would approach grades similar to those which existed before mining. The extent of additional ponding along the drainage lines would, therefore, be expected to decrease with time.

The maximum predicted systematic tensile and compressive strains at the drainage lines, at any time during or after the extraction of the proposed longwalls, are >50 mm/m and 40 mm/m respectively. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are both less than 0.3 kilometres and 0.4 kilometres.

It is expected, at strains of these magnitudes, that fracturing and dilation of the bedrock would occur as a result of the extraction of the proposed longwalls. The drainage lines may have relatively thin alluvial and colluvial deposits above the bedrock but it is still expected that fracturing in the bedrock would be observed at the surface, especially around the locations of natural jointing in the bedrock and where the depths soil above the bedrock are the shallowest.

In times of heavy rainfall, the majority of the surface water runoff would be expected to flow over the surface cracking in the beds and only a small proportion of the flow would be diverted into the fractured and dilated strata below. In times of low flow, however, a larger proportion of the surface water flow could be diverted into the strata below the beds and this could affect the quality and quantity of this water flowing through the cracked strata beds. Nevertheless, during high flow or low flow times this small quantity is expected to have little impact on the overall quality of water flowing out of the drainage lines.

It is also expected that with time the fracturing in the bedrock would be filled with alluvial and colluvial materials during subsequent flow events, reducing the diversion of surface water flows into subsurface flows. It may be necessary, however, that some remediation of the beds of the drainage line would be required, such as the infilling of surface cracks with materials comprising a high clay content, or by locally regrading and re-compacting the surface.

It is expected that the height of the fractured zone above the proposed longwalls will extend up from the Ulan Seam to the surface. Further discussion on the height of the fracture zone is provided in Section 5.21. This would result in increased connectivity between surface water, ground water resources and the mine workings particularly where depths of cover are shallowest. Further discussion on the effects of fracturing on groundwater flows are provided in the report by Aquaterra (2011).

The drainage lines located within the footprint of the northern out of pit emplacement will be stripped and filled in as part of the emplacement operations. Further discussion on the northern out of pit emplacement is provided in Section 5.14. The drainage line profiles DL4 and DL5, which are presented in Fig. C.08 and C.09 respectively, will be located below the northern out of pit emplacement. The approximate surface and subsided surface profiles above the drainage lines has been shown in these figures.

On the uphill sides of the northern out of pit emplacement, drainage lines will flow towards the northern out of pit emplacement. Measures should be incorporated to provide for the adequate management of the flows in these drainage lines around or over the northern out of pit emplacement, including preventing the erosion of the out of pit emplacement and preventing ponding on the surface of the northern out of pit emplacement following extraction of the longwalls.

5.2.3. Impact Assessments for the Drainage Lines Based on Increased Predictions

If the predicted systematic subsidence and tilts along the drainage lines were increased by a factor of 1.25 to 2 times, the extents of additional ponding and scouring would increase accordingly. It would still be expected, however, that the methods of remediation, if required, would not significantly change.

If the predicted systematic strains at the drainage lines were increased by a factor 1.25 to 2 times, the extent of fracturing and dilation in the bedrock and, hence, the extent of potential cracking in the alluvial deposits would increase accordingly. It would still be expected, however, that the methods of remediation, if required, would not significantly change.

5.2.4. Recommendations for the Drainage Lines

It is recommended that the drainage lines are visually monitored as the proposed longwalls mine beneath them. It is also recommended that management strategies are developed for the drainage lines, such that the impacts can be identified and remediated, as and if they are required.

5.3. Cliffs, Overhangs and Rock Ledges

A total of 10 cliffs were identified within the Study Area as described in Section 2.3.8. The locations of the cliffs within the Study Area are shown in Drawing No. MSEC353-07. The predictions and impact assessments for the cliffs are provided below. Three of the cliffs (C2, C3 and C4) are located in the footprint of the northern out of pit emplacement and will therefore be filled in before the longwalls are proposed to be extracted.

5.3.1. Predictions for the Cliffs

A summary of the maximum predicted values of total systematic subsidence, tilt and strain at the cliffs and overhangs within the Study Area, at any time during or after the extraction of the proposed longwalls, is provided in Table 5.2. The predicted values are the maximum values within a distance of 20 metres from the identified extents of the cliffs that occur during or on completion of the extraction of the proposed Longwalls 1 to 13.

Table 5.2 Maximum Predicted Total Systematic Subsidence, Tilt and Strain at the Cliffs within the Study Area Resulting from the Extraction of Longwalls 1 to 13

Cliff	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total or Travelling Tilt (mm/m)	Maximum Predicted Total or Travelling Tensile Strain (mm/m)	Maximum Predicted Total or Travelling Compressive Strain (mm/m)
C1	1240	55	35	30
C2	460	25	15	1.4
C3	1790	50	19	19
C4	0	0.0	0.0	0.0
C5	1790	35	20	16
C6	1770	30	19	20
C7	80	2.0	1.5	0.9
C8	1760	40	40	20
C9	1360	45	25	18
C10	0	0.0	0.0	0.0

The Cliff C7 comprises two main sections of a cliff line, each of which is approximately 50 metres in length. The outline that is shown in Drawing No. MSEC353-07 delineates the extremities of the rock outcrop that contains the Cliff C7 and the rock art shelter as described in Section 2.8. The location of the cliff is on the north eastern side of the outline.

The maximum predicted subsidence parameters that are presented above in Table 5.2 are the maximum subsidence parameters predicted anywhere over the rock outcrops and within a distance of 20 metres from the extents of the outcrops. The actual parameters that are presented for Cliff C7 were determined to occur only at locations that are 20 metres beyond the north west and south eastern ends of this outcrop. The predicted maximum total subsidence after all the proposed longwalls are extracted at the two 50 metre lengths of cliff line at C7 is <5 mm. The maximum predicted tilt, tensile strain and compressive strain at the two 50 metre lengths of cliff line at C7 are 0.5 mm/m, 0.7 mm/m, and 0.1 mm/m respectively.

5.3.2. Impact Assessments for the Cliffs and Overhangs

Rock falls occur naturally at locations where there is no mining and this is a reminder that cliffs and rock overhangs are landforms that are part of a naturally occurring erosion/weathering cycle and hence they can be marginally stable. This highlights that caution is required when inspecting surface areas near these natural features and when proposing any surface management plans near or around cliffs and overhangs before, during and immediately after mining.

Extensive databases of mining induced rock falls have been established that include details on the various mining and geographical parameters that are thought to effect the likelihood of rock falls, including data on the topography, the geometries of the mine and the cliff faces and the magnitudes of the observed and predicted subsidence induced ground subsidence, tilt, curvature and strain movements at cliff sites at the time of known rock falls and these provide a guide as to the likelihood or frequency of rock falls and rock instabilities.

The maximum predicted total subsidence at a cliff face is 1790 mm. The maximum predicted total systematic tilt at the identified cliffs, resulting from the extraction of the proposed longwalls, is 55 mm/m (i.e. 5.5 %), or a change in grade of 1 in 18. The maximum predicted systematic total tensile strain resulting from the extraction of Longwalls 1 to 13 of 40 mm/m is predicted to occur at Cliff C8, and the associated minimum radius of curvature is 0.4 kilometres. The maximum predicted systematic total compressive strain, resulting from the extraction of Longwalls 1 to 13 of 30 mm/m is predicted to occur at Cliff C1 and the associated minimum radius of curvature is 0.5 kilometres. These predicted levels of ground movements are higher than the magnitudes of the observed and predicted subsidence induced ground subsidence, tilt, curvature and strain movements at cliff sites at the time of known rock falls and hence rock falls can be expected at these cliff lines.

Tilt does not directly induce differential movements along cliffs, which is thought to be the main cause of cliff instabilities, however, tilt can increase the overturning moments in steep or overhanging cliffs which, if they are of sufficient magnitude, could result in toppling type failures. A review of the occurrence and location of observed cliff falls with respect to panel edges and increasing or decreasing the steepness of the slopes of the cliff faces at known cliff falls indicates that this mechanism does not result in many of the observed cliff falls in NSW.

Where the mining induced ground strains are of sufficient magnitude, sections of rock faces could fracture along existing bedding planes or existing joints and become unstable, resulting in sliding or toppling type failures along the cliffs and overhangs. Fracturing of sandstone has generally been observed where the systematic tensile and compressive strains have exceeded 0.5 mm/m and 2 mm/m, respectively. Most of the predicted systematic tensile and compressive strains at the cliffs are much greater than 0.5 mm/m and 2 mm/m and are therefore, expected to be of sufficient magnitude to result in the fracturing of sandstone. However, it should be recognise that it is extremely difficult to assess the likelihood of mining induced cliff instabilities based upon the predicted ground movements.

The likelihood of a particular cliff becoming unstable naturally, i.e. without the effects of mining induced ground movements, is dependent on many factors, including the existing vertical and horizontal jointing, inclusions or weaknesses within the rock mass, the height, extent of undercutting, the length and orientation of the particular cliff with respect to the valley and the water pressure and seepage flow behind the rock face. Even if these factors could be determined, it is even more difficult to assess an individual cliff's stability after being exposed to mine subsidence movements which are influenced by the magnitude of the mining-induced subsidence parameters, the location of the cliff with respect to the longwall panels, the orientation of the cliff with respect to the panels and the river valley.

Therefore, rather than trying to quantify the likelihood of falls at a particular cliff, it has been found to be more meaningful to quantify the likely proportion of a cliff line that will be affected by mining. This proportion is increased with increasing mining induced movements, higher and larger cliffs, and shallower depths of cover. For example, when assessing the effect of mining at shallow depths of cover under high and large cliff lines it was found to be difficult to predict which particular cliff would experience a fall, however, the proportion of that cliff line that was damaged was more easily assessed. Statistics have been gathered on the effects of the various factors that influence the proportion or extent of the cliff falls per length of cliff line.

The number and the size of instabilities along cliffs as the result of mining have been recorded at a number of collieries in the NSW Coalfields. A database of observed rock falls was compiled to determine the proportion of instabilities that occurred due to mining, being the total length of instabilities divided by the total length of undermined cliffline. Data was only included from collieries where the details of all instabilities due to mining were identified and recorded. The total length of undermined cliffline, over and near the goaf edges, was also determined for each colliery.

A summary of the observed instabilities and the total length of undermined cliffs at Angus Place, Baal Bone, Invincible, Lithgow Valley and Nattai North Collieries, is provided in Table 5.3

Table 5.3 Lengths of Observed Instabilities and Undermined Cliffs at Other Collieries within the NSW Coalfields

Colliery	Coalfield	Longwalls	Number of Recorded Instabilities due to Mining	Total Length of Recorded Instabilities due to Mining (m)	Total Length of Undermined Cliff within 0.7 times Depth of Cover from the Goaf (m)	Observed Proportion of Rockfalls due to Mining (%)
Angus Place	Western	LWs 1-11	58	862	6 820	12.6
Baal Bone	Western	LWs 1-9	127	1 350	14 640	9.2
Invincible	Western	LW 2	1	30	150	20.0
Lithgow Valley	Western	N/A	5	150	4 400	3.4
Nattai North	Southern	N/A	22	1 365	4 600	29.7
		TOTAL	213	3 757	30 610	12.3

The proportion of instabilities due to mining at each colliery was determined by dividing the total length of observed instabilities due to mining by the total length of undermined cliff above or within 0.7 times the depth of cover from the extracted longwalls.

The proposed Study Area at Moolarben, has similar depths of cover to the some of the collieries identified above in Table 5.3, however, the depths of the valleys and heights of the cliffs that were undermined at the other collieries were much higher than the cliffs that are located over the proposed longwalls at Moolarben.

It is also important to note that during extensive field monitoring for a NERDDC funded research project that was titled “Effects of Subsidence on Steep Topography and Cliff Lines" (Kay, 1991), no rock falls were noticed to occur off narrow lengths of cliff lines or escarpments where the cliff line length was less than 30 metres, i.e. no falls were observed off narrow pagoda type rock features. Eighty per cent of the observed falls at Baal Bone Colliery occurred off rock formations that were relatively continuous and had cliff line lengths that were greater than 60 metres. That is, the rock falls at these other collieries occurred off long lengths of cliff lines or escarpments, whilst, the cliff lines at Moolarben are shorter and more discrete rock formations and this can result in a smaller proportion of rock falls.

It has been observed that cliff instabilities typically occur after the cliff has been directly mined beneath, and almost all of the rock falls occurred when the cliff was located above the goaf. Of the 10 cliffs that are identified within the Study Area, three of the cliffs, Cliffs C4, C7, and C10, are not located over the proposed longwalls. The edges of the nearest proposed longwall are approximately 95 metres from Cliffs C4 and C10. This represents approximately 0.9 times the depth of cover for Cliff C4 and 0.8 times the depth of cover for Cliff C10. Cliff C10 is the tallest cliffline and the only cliffline that is readily visible from a public road or public vantage point but, being well outside the proposed longwall footprint, this cliff will not be impacted by the proposed mining.

Cliff C7, which contains a significant rock art shelter, is to be protected by leaving a barrier of coal below the cliff. The barrier width has been designed based on distance of 0.5 times the depth of cover at the edge of the nearest panel to the delineated outcrop since cliff instabilities have not been observed for cliffs that are located outside approximately 0.5 times the depth of cover from the nearest longwall.

Of the remaining seven cliffs that are located over the proposed longwalls, five of the cliffs, Cliffs C1, C2, C3, C5 and C6, have lengths of approximately 20 metres and heights varying from approximately 10 metres to 15 metres. Cliffs C2, C3 and C4 will be covered by the northern out of pit emplacement before the extraction of the longwalls. Cliffs C8 and C9 are considerably larger. Cliff C8 has a length of approximately, 50 metres, height of approximately 20 metres and an overhang of approximately 5 metres. Cliff C9 has a length of approximately, 100 metres, height of approximately 20 metres and overhang of approximately 7 metres. It is noted that Clifflines C8 and C9 are not visible from public roads or public vantage points and are positioned behind environmental bund walls, open cut pits and out of pit emplacement spoil heaps.

Based on the above information, and in particular, the depth of cover and predicted subsidence for the cliffs, it is expected that cliff instabilities could occur on up to approximately 15% of the length of the exposed cliffs that are located over the proposed longwalls. It is possible that, given the increased length, height and overhang of Cliffs C8 and C9, that these cliffs would be most susceptible to cliff falls. A summary of assessed impacts to the cliffs identified in the Study Area is provided in Table 5.4.

Table 5.4 Summary of Assessed Cliff Impacts due to Extraction of Longwalls 1 to 13

Cliffline	Length (m)	Height (m)	Location	Predicted Impact
C1	20	10	Over LW5, 20m from tailgate	Minor impact expected
C2	20	15	Over LW4, 15m from maingate	Covered by out of pit emplacement
C3	20	12	Over LW4, 50m from finishing end	Covered by out of pit emplacement
C4	20	15	Over Solid coal, 30m from LW4 finishing end	None - Beyond edges of Panels
C5	20	15	Over LW8, 90m from maingate	Minor impact expected
C6	20	10	Over LW8, 80m from maingate	Minor impact expected
C7	2 @ 50	10	Over Solid coal, between LW12 and 13	None - Protected by sterilised coal
C8	50	20	Over LW12, 60m from tailgate	Rock falls likely
C9	100	20	Over LW11, commencing end	Rock falls likely
C10	200	40	Over Solid coal, 90m from LW10 commencing end	None - Beyond edges of Panels

5.3.3. Impact Assessments for the Cliffs Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 1.25 to 2 times, the likelihood and extent of cliff instabilities would not be expected to significantly increase, as the changes in grade would still be small when compared to the existing slopes of the cliff faces.

If the predicted systematic strains were increased by factors of up to 1.25 to 2 times, the potential for cliff instabilities would increase accordingly.

5.3.4. Recommendations for the Cliffs.

One of the most significant consequences associated with cliff instabilities is the potential to cause injury or death and it is paramount that access is denied whilst the longwalls pass under the cliffs even if the probability of rock falls is low. Owners of the land above the proposed longwalls include MCM, the nearby Ulan Coal Mines Pty Ltd, private owner Mr Swords and some land is Crown land. Whilst the area is generally not available for public access, it is possible that the area will be visited during the mining period. It is recommended, therefore, that persons who enter the area in the vicinity of the cliffs are made aware of the potential for rockfalls resulting from the extraction of the proposed longwalls by appropriate signs and temporary fencing.

The aesthetics of the landscape could be temporarily altered by isolated rock falls, which would typically occur off pre-existing natural joints, but, they could result in the exposure of a fresh face of rock and debris scattered around the base of the cliff. As with naturally occurring instabilities, the exposed fresh rockface weathers and erodes over time to a point where it blends in with the remainder of the cliff face and vegetation below the cliff regenerates.

As there is a small possibility of rock falls, it is recommended that appropriate management strategies are put in place to ensure the safety of people that may be within the vicinity of the cliffs during the mining period. With these measures in place, it is unlikely that there would be a significant impact associated with the cliffs resulting from the extraction of the proposed longwalls.

It is recommended that the cliffs should be visually monitored during the mining period from a remote and safe location until such time that the mine subsidence movements have ceased. Should any cliff face appear to become unstable, management strategies should be put in place to further restrict access or to possibly make the site area safe. It is also recommended that the existing condition of cliffs within the Study Area should be documented and photographed prior to mining.

5.3.5. Clifflines above and adjacent to Longwalls at the Ulan West Project

A review of the approved nearby underground coal project at Ulan was carried out at the request of regulators to assess the similarities and consistencies between the approach and protection provided to clifflines at the Ulan West Project and the proposed Moolarben Coal Project.

The Ulan Coal Mine, which is owned by Ulan Coal Mines Limited (UCML), consists of two approved underground mining operations (Ulan No.3, which is existing, and Ulan West which has recently been approved) and an Open Cut coal reserve. Ulan West is located approximately 7.5 kilometres to the north west of UG1 at MCC.

The submitted EA documentation for the adjacent Ulan Continued Operations Project provides details of the likely impacts from the proposed mining operations on clifflines located above the proposed longwalls and details of the conservation barriers or offsets that are being provided to protect various cliff lines and archaeological sites.

It can be noted that there are more sandstone cliff formations located within the Ulan project area than over the Moolarben Coal Project. Inspections and photographic records were made of 260 cliff formations and are presented in the Ulan EA documentation. One area of longwalls was excluded from the proposed Ulan longwall plan, primarily to reduce the impacts on some of the moderate to higher significance archaeological sites. A barrier of unmined coal has also been excluded under a cliffline at Moolarben to protect an archaeological site from mine subsidence impacts from the proposed Moolarben Longwalls 12 and 13.

The one archaeological cliff site that has been identified at MCC has been protected. Despite protecting one area of archaeological cliff sites above longwalls at Ulan, i.e. those within the Brokenback Conservation Area, the approved longwall layout at Ulan West includes the proposed extraction of longwalls beneath many other cliff formations that have archaeological sites. The Department of Planning approval conditions for the Ulan Continued Operations Project notes that, whilst some of the archaeological sites and cliff sites must be protected with nil environmental consequences, i.e. those within the Brokenback Conservation Area, the other cliff formations that were identified as being higher than

20 metres and not visible from public vantage points, can be mined with “minor environmental consequences”.

Hence, although there are more cliff formations within the Ulan Project than over the Moolarben Coal Project, in both of the proposed projects, no mining is planned beneath the major archaeological sites at cliff formations. In both proposed projects mining is proposed beneath some clifflines with cliff faces that are up to and, in some cases, slightly higher than 20 metres, but in both projects these cliff faces cannot be seen from public roads and public vantage points.

Despite these consistent similarities in the approach and levels of protection being proposed for the clifflines at these two projects, it is not possible for there to be absolute consistency in the environmental impacts of the two mines when at MCC there are approved open cut sites, out of pit emplacement areas and environmental bund walls immediately below many of the clifflines.

5.3.6. Rock Ledges and Overhangs

As discussed in Chapter 2, there are many smaller cliffs or rock ledges with small overhangs distributed over the Study Area which are likely to be subjected to the full range of predicted systematic subsidence movements as presented in Chapter 4.

The maximum predicted total systematic subsidence due to Longwalls 1 to 13 and within the Study Area is 1980 mm which occurs above the middle of Longwall 3 after the extraction of Longwall 4. The maximum predicted total systematic tilt due to Longwalls 1 to 13 and within the Study Area of 95 mm/m (i.e. 9.5 %), or a change in grade of 1 in 10, occurs near the maingate of Longwall 9 after the extraction of Longwall 9. The maximum predicted total systematic tensile and compressive strains resulting from the extraction of the proposed longwalls, are both greater than 50 mm/m and the associated minimum radii of curvatures are both less than 0.3 kilometres.

Based on the maximum predicted tilts and strains, it is likely that fracturing of sandstone will occur as a result of the extraction of the longwalls and, hence, result in small rockfalls, particularly where the rock ledges or overhangs are marginally stable. It is noted that many of the exposed rocks are isolated from the parent rock by weathered bedding planes and joints and in such cases there would be a lower risk of fracturing of the rock and subsequent rock falls.

As there is a possibility of rock falls from these rock ledges and overhangs, it is recommended that appropriate management strategies are put in place to ensure the safety of people that may be within the vicinity of these rock ledges and overhangs during the mining period.

It is recommended that visual inspections of the exposed rock ledges within the Study Area that are easily inspected should be undertaken during the mining period. Should any rock ledge appear to become unstable, management strategies should be put in place to prevent access, make the site safe and appropriate signs should be provided to warn of the possibility of rock falls.

5.4. Steep Slopes

The locations of the natural steep slopes within the Study Area are shown in Drawing No. MSEC353-07. The predictions and impact assessments for the natural steep slopes are provided in the following sections. Discussion on the steep slopes on the sides of the northern out of pit emplacement area is provided in Section 5.14.1.

5.4.1. Predictions for the Steep Slopes

The steep slopes are located across the Study Area and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements as presented in Chapter 4.

5.4.2. Impact Assessments for the Steep Slopes

The maximum predicted total systematic tilt due to Longwalls 1 to 13 and within the Study Area of 95 mm/m (i.e. 9.5 %), or a change in grade of 1 in 10. The steep slopes are more likely to be impacted by the systematic strains, rather than tilt, as the maximum predicted tilt is small when compared to the existing surface gradients of the steep slopes.

The maximum predicted total systematic tensile and compressive strains within the Study Area resulting from the extraction of the proposed Longwalls 1 to 13, are both greater than 50 mm/m and the associated minimum radii of curvatures are both less than 0.3 kilometres. The maximum predicted total systematic tensile strains at the steep slopes are likely to result in surface cracking.

It has been observed that down slope movements occur on slopes that are located over or near extracted longwalls. Sometimes these movements are observed to be directed down the hill slope rather than towards the extracted goaf area. Where such movements occur on steep slopes, there is a higher likelihood that surface tension cracking can occur near the tops of the slopes. It is unlikely that mine subsidence would result in any large-scale slope failure, since such failures have not been observed elsewhere as the result of longwall mining.

5.4.3. Impact Assessments for the Steep Slopes Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 1.25 to 2 times, the potential impacts on the steep slopes would not be expected to significantly increase.

If the predicted systematic strains were increased by factors of up to 1.25 to 2 times, the extent of potential surface cracking and soil slippage would increase accordingly at the steep slopes located directly above the proposed longwalls. It is expected, however, that the surface cracking could be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface. The relevant approvals for such works would be obtained prior to undertaking any remediation works. With these remediation measures in place, it is unlikely that there would be any significant impact on the environment.

5.4.4. Recommendations for the Steep Slopes

It is recommended that the steep slopes are monitored throughout the mining period. Any significant surface cracking should be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface. It is also recommended that management strategies be developed, to ensure that the steep slopes are maintained throughout the mining period.

5.5. Threatened, Protected Species

There are records of the following two threatened bat species occurring within the Study Area:

Large-eared Pied Bat (*Chalinolobus dwyeri*)

Greater Long-eared Bat (*Noctophilus timoriensis*)

The Large-eared Pied Bat resides predominantly in caves and rock overhangs. The Greater Long-eared Bat roosts in tree hollows in savannah type woodlands. The specific locations of the bat habitats in the area are not known.

The roosting locations of the Greater Long-eared bat (ie. tree hollows in savannah type woodlands) are not expected to be impacted by the proposed longwall extraction, unless such roosting locations were located near existing cliffs above the proposed longwalls and were impacted by rock falls, which is considered unlikely to occur.

The caves and rock overhangs occur across the Study Area and, as described in Section 5.5, could be impacted by the proposed longwall extraction.

Where rock falls occur, the rock falls are, in most cases likely to be preceded by opening up of existing joints and formation of new cracks in the bedrock as the longwall extraction passes below. Also, should a rock fall occur at an existing cave or overhang, it is unlikely that all of the cave or overhang would be destroyed. It is expected that if rock falls occur where bats inhabit a cave or overhang, some of the bats could be injured or killed by a rock fall, however, it is also possible that as the rock strata cracks most of the bats would be expected to escape and either reinhabit the same location or find an alternative habitat. Similarly, if the bats were located in caves or crevices, the caves or crevices located above the proposed longwalls would likely by impacted by the proposed longwall extraction but it is unlikely that the habitats would be completely destroyed. Habitats located within the footprint of the northern out of pit emplacement will be covered during the filling operations.

A discussion on the effects of subsidence and emplacement on flora and fauna within the Study Area is included in a report by Ecovision Consulting and Marine Pollution Research (2008).

5.6. Vegetation Communities

The Critically Endangered Ecological Communities (CEECs) known as *White Box Yellow Box Blakely's Redgum Woodland and Derived Native Grasslands*, which occur near the isolated tertiary basalt deposits above UG1 and UG2 are shown on Drawing No. MSEC353-06. One CEEC (CEEC03) is partially located within the northern out of pit emplacement footprint.

The predictions and impact assessments for the vegetation communities that are within the Study Area are provided in the following sections. The effects of subsidence and emplacement on flora and fauna within the Study Area are considered within the report by Ecovision Consulting and Marine Pollution Research (2008).

5.6.1. Predictions for the Vegetation Communities

The provided maximum predicted tilts and strains at the CEECs are the maximum values which occur at any time during, or after the extraction of each proposed longwall, whichever is the greater. The values are the maximum predicted systematic subsidence parameters within a 20 metre radius of the perimeter of each vegetation community and do not include valley related upsidence and closure movements.

The maximum predicted systematic subsidence at the vegetation communities, ranges from 1460 mm to 1970 mm. The maximum predicted systematic tilt at the vegetation communities, at any time during or after the extraction of the proposed longwalls, is 85 mm/m (i.e. 8.5 %), or a change in grade of 1 in 12. The approximate natural grade of the surface within the mapped areas of these communities varies between near level surfaces to approximately 500 mm/m (i.e. 50 %) with an estimated average of approximately 140 mm/m (i.e. 14%) or a change of grade of 1 in 7.

The maximum predicted systematic tensile and compressive strains at the CEECs are >50 mm/m and 30 mm/m, respectively, and the associated minimum radii of curvatures are <300 metres and 500 metres, respectively.

5.6.2. Impact Assessments for the Vegetation Communities

The predicted systematic tilts at the vegetation communities are likely to result in changes in surface gradients in the CEECs by factors of up to about 2. The changes in gradients will result in reduced grades and increased grades depending on the position of the CEECs in the subsidence bowl. These changes in grade may result in ponding of surface water runoff where existing natural grades are relatively shallow, such as over proposed Longwalls 3, 4, and 5. The portion of CEEC03 that is located in the northern out of pit emplacement footprint will be covered during the filling operations and before the proposed extraction of the longwalls.

It is expected, at strains of the magnitudes noted in Section 5.6.1, that fracturing and dilation of the bedrock would occur as a result of the extraction of the proposed longwalls. It is possible that below some of the CEECs, massive basalt layers could be present that could resist the deformation and cracking that occurs in the sandstone layers. Fracturing and dilation of the bedrock could result in surface cracking, similar to that described for the steep slopes in Section 5.4, however, the extent of the basalt materials, is unknown.

It is expected, however, that the surface cracking could be easily and quickly remediated, if it is required, by infilling with soil or other suitable materials, or by locally regrading and compacting the surface. A management plan can be developed in consultation with the relevant officers from the Department of Environment and Climate Change (DECC) to monitor and manage these areas. The relevant approvals for such works would be obtained prior to undertaking any remediation works. With these remediation measures in place, it is unlikely that there would be any significant impact on the vegetation communities.

5.6.3. Impact Assessments for Vegetation Communities Based on Increased Predictions

If the predicted systematic subsidence and tilts along the vegetation communities were increased by a factor of up to 1.25 to 2 times, the extents of additional ponding and scouring would increase accordingly. It would still be expected, however, that the methods of remediation, if required, would not significantly change.

If the predicted systematic strains at the vegetation communities were increased by a factor 1.25 to 2 times, the extent of fracturing and dilation in the bedrock and, hence, the extent of cracking in the surface soils would increase accordingly. It would still be expected, however, that the methods of remediation, if required, would not significantly change.

5.6.4. Recommendations for the Vegetation Communities

It is recommended that the CEECs are visually monitored as the proposed longwalls mine beneath them. It is also recommended that management strategies are developed for the CEECs, such that the impacts can be identified and remediated, as they are required. With these strategies in place, it is unlikely that there would be any significant impacts on the CEECs resulting from the extraction of the proposed longwalls.

A detailed assessment of the likely impacts has been made in the reports by Ecovision Consulting (2008) and reference should be made to any recommendations by these authors.

5.7. Gulgong to Sandy Hollow Railway

The nearest edge of the proposed Longwalls 1 to 13 to the Gulgong to Sandy Hollow Railway line is approximately 330 metres from the nearest edge of Longwall 5. At this location the rail track will not be subjected to measurable systematic mine subsidence ground movements; however, it may experience small far field horizontal movements and possibly negligible upsidence and closure movements.

5.7.1. Predictions for the Gulgong to Sandy Hollow Railway

Since the predicted subsidence is negligible we have not prepared specific profiles of total systematic subsidence, tilt and strain along the alignment of the railway and culverts.

The upper limit of observed absolute far field horizontal movements, for ground sites located 330 metres from longwalls, is approximately 115 mm, however the far field horizontal movement data is comprised largely of data from the Southern Coalfield with typically much larger depths of cover. Observed data from Newstan Colliery, which is located in the Newcastle Coalfield, indicates an upper limit of observed absolute far field horizontal movement, for a site located 330 metres from longwalls, of approximately 25 mm.

A discussion of far field horizontal movements is presented in Section 5.20 of this report. 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 impact, except where they occur at large structures which are very sensitive to differential horizontal movements. The differential ground horizontal movements at this distance from the longwalls are expected to be negligible and these differences would not be transferred into the rails.

Recent detailed monitoring of rail tracks whilst longwalls approached and passed underneath showed that the movements had negligible impacts until the longwall passed under the rail track.

The effects differential far field movements due to the proposed longwalls on the Gulgong to Sandy Hollow Railway are small and are unlikely to adversely impact on the railway line.

5.7.2. Recommendations for Gulgong to Sandy Hollow Railway

The railway should be inspected on a regular basis as the proposed Longwalls 1 to 5 are mined, to confirm that the observed ground movements are consistent with the predictions. In this way, the railway can be maintained in a safe and serviceable condition throughout the mining period. For the preparation of the more detailed subsidence management plan, a probabilistic analysis of predicted far-field horizontal movements should also be carried out for the Gulgong to Sandy Hollow Railway at the nearest point to the proposed longwalls.

A management plan should be established for the railway to cover the mining of Longwalls 1 to 5. It is recommended that the management plan be prepared in consultation with the Australian Rail Track Corporation.

5.8. Roads

The locations of the roads within the Study Area are shown in Drawing No. MSEC353-08. There are no sealed roads within the Study Area. Murragamba Road is the only public access road and is located over the north east part of the Proposed Longwalls 4 and 5. After the proposed Stage 2 Open Cut Pit 4 is formed then access along Murragamba Road will end over Longwall 5.

5.8.1. Predictions for the Roads

Many of the tracks and unnamed roads are located directly above the proposed longwalls and will therefore experience the full range of subsidence movements during the extraction of the proposed longwalls, which are provided in Chapter 4.

5.8.2. Impact Assessments for the Roads

It is possible that increased levels of ponding could occur along the roads located in terrain with shallow grades, such as along Murragamba Road. It is expected, however, that the impacts of increased levels of ponding along the roads could be easily remediated by regrading and relevelling the roads using standard road maintenance techniques. It may be necessary to introduce speed restrictions along Murragamba Road until the appropriate remediation measures have been implemented.

The maximum predicted systematic tensile and compressive strains within the Study Area, at any time during or after the extraction of the proposed longwalls, are both greater than 50 mm/m and the associated minimum radii of curvatures are less than 0.3 kilometres.

It is expected, at the magnitudes of the predicted ground strains within the Study Area, that considerable cracking and rippling of the road surfaces would occur as a result of the extraction of the proposed longwalls. Predicted crack widths are discussed further in Section 5.23.1.

The roads are unsealed and can be regraded, repaired and reconstructed using standard road maintenance techniques as mining proceeds. The repairs will be progressive and, therefore, can be staged to suit the mining of each longwall in sequence.

It is recommended that the roads are monitored as the extraction faces of the proposed longwalls are mined beneath them, such that any impacts can be identified and remediated accordingly. It may be necessary to slow traffic along the affected section of road, or in some cases, it may be necessary to locally divert traffic, until the required remediation works have been implemented. With the implementation of suitable management strategies, it is expected that the roads can be maintained in safe and serviceable conditions throughout the mining period.

5.8.3. Impact Assessments for the Roads Based on Increased Predictions

If the predicted systematic subsidence and tilts at the roads were increased by a factor of 1.25 to 2 times, the impacts of increased ponding would increase accordingly. It would still be expected, however, that any impacts could still be remediated using standard road maintenance techniques.

If the predicted systematic strains at the roads were increased by a factor 1.25 to 2 times, the likelihood and extent of cracking and rippling in the road surfaces would increase accordingly. It would still be expected, however, that these impacts could be managed by monitoring, traffic management and the implementation of remediation works using standard road maintenance techniques.

5.8.4. Recommendations for Roads

It is recommended that the roads are monitored as the extraction faces of the proposed longwalls are mined beneath them, such that any impacts can be identified and remediated accordingly. It may be necessary to slow traffic along the affected section of road, or in some cases, to locally divert traffic, until the required remediation works have been implemented.

It is recommended that management strategies be developed, in consultation with the Local Council where necessary, to maintain the roads in a safe and serviceable condition throughout the proposed mining period.

5.9. Powerlines

There is one low voltage powerline within the Study Area, passing over the commencing end of proposed Longwalls 6 and 7 and the commencing end of Longwall 5.

The location of the powerline is shown in Drawing No. MSEC353-09. The predictions and impact assessments for the powerline are provided in the following sections.

5.9.1. Predictions for the Powerline

The predicted profiles of systematic subsidence, tilt along and tilt across the alignment of the powerline, resulting from the extraction of the proposed longwalls, are shown in Fig. C.12 in Appendix C. A summary of the maximum predicted total systematic subsidence parameters at the powerline, after the extraction of Longwalls 6 and 7, is provided in Table 5.5.

Table 5.5 Maximum Predicted Total Systematic Subsidence, Tilt Along and Tilt Across Low Voltage Powerline Resulting from the Extraction of Longwalls 6 and 7

Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt Along Alignment (mm/m)	Maximum Predicted Total Tilt Across Alignment (mm/m)
After LW6	1650	30	55
After LW7	1720	30	55

The powerline will be subjected to travelling tilts where the extraction faces of the proposed Longwalls 6 and 7 pass beneath it. It is expected that this powerline could be subjected to travelling tilts up to 45 mm/m (i.e. 4.5 %), or changes in grade up to 1 in 20.

5.9.2. Impact Assessments for the Powerline

The cables along the powerline are not affected by ground strains, as they are supported by the poles above ground level. The cables can, however, be affected by the changes in bay lengths, i.e. the distances between the poles at the height of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the poles caused by tilting of the poles. The stability of the poles can also be affected by the tilting of the poles and the changes in the catenary profiles of the cables.

The maximum predicted systematic tilts along and across the alignment of the Powerline are 30 mm/m (i.e. 3 %) and 55 mm/m (i.e. > 5.5 %), respectively, or changes in gradient of 1 in 35 and 1 in 20, respectively.

High tilts at the locations of the power poles can adversely impact on the cable catenaries or could result in stability problems in tension poles that are supported by guy ropes. Overhead powerlines can typically tolerate tilts up to 20 mm/m at the poles, without any significant impacts on the cables or poles.

It is likely, therefore, that the maximum predicted systematic tilts at the powerlines would be of sufficient magnitude to result in impacts on the powerlines. It is recommended that these powerlines are inspected by a suitably qualified person, prior to the proposed longwalls mining beneath them, to assess the existing conditions of the powerlines and to determine whether any preventive measures are required, such as the installation of cable sheaves and guy ropes.

It is also recommended that the powerlines are monitored as the extraction faces of the proposed longwalls are mined beneath them, such that any impacts can be identified and remediated accordingly. With the implementation of suitable management strategies, it is expected that the powerlines can be maintained in a safe and serviceable condition throughout the mining period.

5.9.3. Impact Assessments for the Electrical Services Based on Increased Predictions

If the predicted systematic tilts at the powerline were increased by a factor of 1.25 to 2 times, the likelihood of impacts would increase accordingly. It would still be expected, however, that these impacts could be managed by monitoring and the implementation of suitable management strategies.

5.9.4. Recommendations for the Powerline

It is recommended that the powerline is inspected by a suitably qualified person prior to mining, to determine the existing conditions and whether any preventive measures are required. It is also recommended that the powerline is monitored as the extraction faces of the proposed longwalls are mined beneath it, such that any impacts can be identified and remediated accordingly.

It is recommended that management strategies are prepared, in consultation with Country Energy, as required, to incorporate the assessed impacts to the powerline resulting from the extraction of the proposed longwalls.

5.10. Optical Fibre Cables

There is an optical fibre cable located along the northern side of Ulan-Wollar Road. The closest point of the cable to the proposed longwalls is approximately 240 metres from the north east end of Longwall 5. At this location the optical fibre cable will not be subjected to measurable systematic mine subsidence ground movements; however, it may experience small far field horizontal movements and possibly negligible upsidence and closure movements.

5.10.1. Predictions for the Optical Fibre Cable

Since the predicted subsidence is negligible we have not prepared specific profiles of total systematic subsidence, tilt and strain along the alignment of the optical fibre cable.

The upper limit of observed absolute far field horizontal movements, for ground sites located 240 metres from longwalls, is approximately 150 mm, however the far field horizontal movement data is comprised largely of data from the Southern Coalfield with typically much larger depths of cover. Observed data from Newstan Colliery, which is located in the Newcastle Coalfield, indicates an upper limit of observed absolute far field horizontal movement, for a site located 240 metres from longwalls, of approximately 35 mm.

A discussion of far field horizontal movements is presented in Section 5.20 of this report. 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 impact, except where they occur at large structures which are very sensitive to differential horizontal movements. The differential ground horizontal movements at this distance from the longwalls are expected to be negligible.

The effects of differential far field movements due to the proposed longwalls on the optical fibre cable are small and are unlikely to adversely impact on the optical fibre cable.

5.10.2. Recommendations for Optical Fibre Cable

It is recommended that the optical fibre cable are monitored during the extraction of the proposed Longwalls 1 to 5 using optical fibre sensing techniques, such as Optical Time Domain Reflector (OTDR) monitoring. Management measures can be undertaken, such as excavating and exposing the cable, if a strain concentration is detected during mining. With the required management measures in place, the optical fibre cable can be maintained in a serviceable condition throughout the mining period.

A monitoring, management and response plan should be established for the optical fibre cable prior to mining the proposed Longwalls 1 to 5, to the satisfaction of the owners of the optical fibre cable.

5.11. Copper Telecommunications Cables

The main copper telecommunications cables within the Study Area generally follow the alignment of Murragamba Road, which passes over the commencing ends of proposed Longwalls 4 and 5. The predictions and impact assessments for the copper telecommunications cables are provided in the following sections.

5.11.1. Predictions for the Copper Telecommunications Cables

The predicted profiles of systematic subsidence and strain along the alignments of the copper telecommunications cables along Murragamba Road are similar to those along the road, which are shown in Fig. C.13 in Appendix C.

The maximum predicted systematic tensile and compressive strains within the Study Area, at any time during or after the extraction of the proposed longwalls, are both greater 50 mm/m and the associated minimum radii of curvatures are less than 0.3 kilometres.

The copper telecommunications cable along Murragamba Road will also be subjected to travelling strains where the extraction faces of the proposed longwalls pass beneath it. It is expected that this cable could be subjected to travelling strains up to 30 mm/m.

The copper telecommunications cables cross some drainage lines and, therefore, could also be subjected to some valley related movements resulting from the extraction of the proposed longwalls. The equivalent valley heights of the drainage lines are small, typically less than 5 metres and, therefore, the upsidence and closure movements at the cables are expected to be an order of magnitude smaller than the predicted systematic movements and not significant.

5.11.2. Impact Assessments for the Copper Telecommunications Cables

The copper telecommunications cables within the Study Area are typically direct buried and, therefore, will not be impacted by the tilts resulting from the extraction of the proposed longwalls. The cables, however, are likely to experience the ground strains resulting from the extraction of the proposed longwalls.

The maximum predicted systematic tensile and compressive strains within the Study Area, at any time during or after the extraction of the proposed longwalls, are both greater than 50 mm/m and the associated minimum radii of curvatures are both less than 0.3 kilometres.

Based on previous experience of mining beneath copper telecommunications cables, it has been found that they can typically tolerate ground strains greater than 20 mm/m without significant impact. It is possible, therefore, that the predicted systematic strains at the copper telecommunications cable within the Study Area are of sufficient magnitudes to result in impact. The tensile strains along this cable could also be higher than predicted where the cable connects to the support structures, which may act as anchor points, preventing any differential movements that may have been allowed to occur between the cable and the ground.

The copper telecommunications cables within the Study Area are local cables and if any impacts occur, as a result of the extraction of the proposed longwalls, the cables can be easily repaired. With the implementation of suitable management strategies, it is expected that the cables can be maintained in a serviceable condition throughout the mining period.

5.11.3. Impact Assessments for the Copper Telecommunications Cables Based on Increased Predictions

If the predicted systematic strains at the copper telecommunications cables were increased by a factor 1.25 to 2 times, the likelihood of impact on the cables within the Study Area would increase accordingly.

5.11.4. Recommendations for the Copper Telecommunications Cables

It is recommended that management strategies are developed, in consultation with Telstra, for the implementation of suitable remediation measures should any impacts on the copper telecommunications cables occur as a result of the extraction of the proposed longwalls. With the implementation of these management strategies, it is expected that the copper telecommunications cables can be maintained in a serviceable condition throughout the mining period.

5.12. Fences

There are a number of fences within the Study Area which are constructed in a variety of ways, generally using either timber or metal materials. The fences are located across the Study Area and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements, which are summarised in Table 4.1 and Table 4.2.

Wire fences could be affected by tilting of the fence posts and changes of tension in the fence wires due to strain as mining occurs. Fence post tilts of less than 10 mm/m are barely noticeable and strains of less than 5 mm/m typically have little impact on wire tensions. However, this depends upon the existing tensions in the wires of the fences and their residual capacity to accept mining induced strains.

The maximum predicted systematic tilts and strains, resulting from the extraction of the proposed longwalls, are greater than those which can be typically tolerated by fences. It is likely, therefore, that some sections of the fences would be impacted by the predicted subsidence movements and would require repair or replacement.

Impacted fences are relatively easy to rectify by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

5.13. Farm Dams

Thirteen farms dams have been identified within the Study Area. The locations of the farm dams are shown in Drawings Nos. MSEC353-09 to MSEC353-14. The predictions and impact assessments for the farm dams are provided in the following sections. Six of the farm dams are located within or adjacent to the footprint of the northern out of pit emplacement and will be covered during the filling operations, prior to extraction of the longwalls.

5.13.1. Predictions for the Farm Dams

Predictions of systematic subsidence, tilt and strain have been made at the centroid and at points located around the perimeter of each farm dam within the Study Area, as well as at points located at a distance of 20 metres from the perimeter of each farm dam. The maximum predicted systematic subsidence parameters for each farm dam have then been taken as the maximum predicted values at these points.

The maximum predicted values of systematic subsidence, tilt and strain have been determined for the farm dams within the Study Area, after the extraction of each proposed longwall, and are provided in Table D.03 in Appendix D.

5.13.2. Impact Assessments for the Farm Dams

The maximum predicted systematic tilts at the farm dams, resulting from the extraction of the proposed longwalls, vary between a minimum of less than 1 mm/m (i.e. < 0.1 %) and a maximum of 35 mm/m (i.e. > 3.5 %), or changes in grade varying from less than 1 in 1000 to 1 in 29.

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. Large tilts can potentially reduce the storage capacity of farm dams, causing them to overflow, or affect the stability of the dam walls. The potential for overflowing dams is dependent on the freeboard at the dam wall at the time of mining and the direction of tilt relative to the dam.

The maximum predicted changes in freeboard for each farm dam has been determined by taking the maximum predicted subsidence anywhere around each dam from the minimum predicted subsidence anywhere around each dam. The maximum predicted changes in freeboard for the farm dams within the Study Area are summarised in Table D.03.

The maximum predicted change in freeboard at the farm dams, resulting from the extraction of the proposed longwalls, vary between a minimum of less than 50 mm and a maximum of greater than 100 mm. Farm dams A02d03 and A03d01 are predicted to experience changes in freeboard of 100 mm and all other farm dams within the Study Area are predicted to experience changes in freeboard of less than 50 mm.

The directions of the maximum predicted tilts at Dams Refs. A02d03 and A03d01 are such that the freeboards at the dam walls could slightly decrease (i.e. water levels slightly increase) by approximately 100 mm. This change in level is not expected to have any appreciable impact on the normal functioning of the dam.

The maximum predicted systematic strains, tensile or compressive, at the farm dams, resulting from the extraction of the proposed longwalls, vary between a minimum of less than 0.1 mm/m and a maximum of greater than 30 mm/m. The minimum radii of curvatures associated with the maximum predicted systematic strains vary from greater than 150 kilometres to less than 0.5 kilometres.

The farm dams within the Study Area are typically constructed of cohesive soils with reasonably high clay contents, and are likely to be capable of withstanding tensile ground strains up to 3 mm/m without impact. There are 6 farm dams which are predicted to experience systematic tensile strains of 3 mm/m or greater.

It is expected, therefore, that cracking and leakage of water could occur in the farm dams which are subjected to the greater strains, though, any cracking or leakages can be easily identified and repaired. Any loss of water from the farm dams would flow into the drainage line in which the dam was formed.

5.13.3. Impact Assessments for the Farm Dams Based on Increased Predictions

If the predicted systematic tilts and strains at the farm dams were increased by factors of 1.25 to 2 times, the likelihood of impact on the Dams would increase accordingly.

5.13.4. Recommendations for the Farm Dams

It is recommended that the farm dams are visually monitored as the proposed longwalls mine beneath them, such that any impacts can be identified and remediated accordingly. In this way all the farm dams within the Study Area can be maintained in a safe and serviceable condition throughout the mining period.

5.14. Mining Infrastructure

The open cut mine schedule includes a northern out of pit emplacement above several of the proposed UG1 longwalls, the location of which is shown in Drawing No. MSEC353-18. The predictions and impact assessments for the mine infrastructure are provided in the following sections.

5.14.1. Northern Out of pit emplacement

The proposed surface contours showing the location of the proposed northern out of pit emplacement area that is to be placed above Longwalls 3 to 8 in UG1 and the scheduled year of extraction of each of the UG1 longwalls are indicated on Drawing No. MSEC353-18.

Based on the provided surface contours, the northern out of pit emplacement area over UG1 will be formed by Year 7 and, based on the scheduled years of extraction for each longwall, the proposed Longwalls 3 to 8 will be extracted afterwards during Years 8 to 14. The proposed final surface contours above and immediately to the south east of the UG1 longwalls will be formed by Year 12, as re-presented in our Drawing No. MSEC353-18.

During the period of extraction of proposed Longwalls 3 to 8, some works associated with the Open Cut 4 will continue above and to the south east of UG1. These activities are understood to include operations associated with conveyors, which extend between Stage 2 ROM facilities and Stage 1 ROM coal facilities, and haul roads to and from Stage 2 ROM facilities. The locations of these proposed activities are shown in Drawing No. MSEC353-18. We understand that rehabilitation works for the northern out of pit emplacement area will also be undertaken above the UG1 area during the extraction of the UG1 longwalls.

The thickness of the northern out of pit emplacement area that will be placed over the UG1 longwalls will vary from zero metres around the periphery of the emplacement to a maximum thickness of approximately 65 metres over the north eastern corner of Longwall 6 (measured at MGA easting 762,200 m and northing 6,423,120 m) as shown on Drawing No. MSEC353-18. The thickness of the emplacement that will be placed above the extracted open cut pit and adjacent to Longwall 6 is approximately 120m (measured at MGA easting 762,040 m and northing 6,422,680 m).

The top of the northern out of pit emplacement area is proposed to be relatively flat with a surface level of RL 522m to 524m AHD.

The slopes of the batters formed at the sides of the emplacement area are proposed to vary from grades of approximately 1 in 4 to 1 in 6. The maximum batter height near or above UG1 is approximately 85 metres. Selected batter slopes and heights are shown in Drawing No. MSEC353-18.

The maximum predicted total subsidence due to the extraction of the proposed longwalls at the base of the northern out of pit emplacement will be approximately 1900mm in the south western end of Longwall 5. The maximum predicted total tilts are 70 mm/m and maximum predicted total compressive and tensile strains are 40mm/m and greater than 50mm/m respectively.

The predicted subsidence parameters provided in this report are the predicted movements at the natural surface, beneath the northern out of pit emplacement.

Additionally, it is expected that additional settlement would occur at the top of the northern out of pit emplacement, as the proposed longwalls mine beneath it, due to the consolidation and lateral shifting of the out of pit emplacement. Research reports on the response of UK out of pit emplacements to mine subsidence movements indicate that this extra settlement can initiate downhill slumping of out of pit emplacements.

A detailed discussion on the additional settlement of unconsolidated out of pit emplacements is provided in the background report entitled *General Discussion of Mine Subsidence Ground Movements (Revision A)* which can be obtained from *www.minesubsidence.com*. An empirical relationship for the additional settlement of unconsolidated out of pit emplacements which are directly mined beneath is provided in Fig. 5.1.

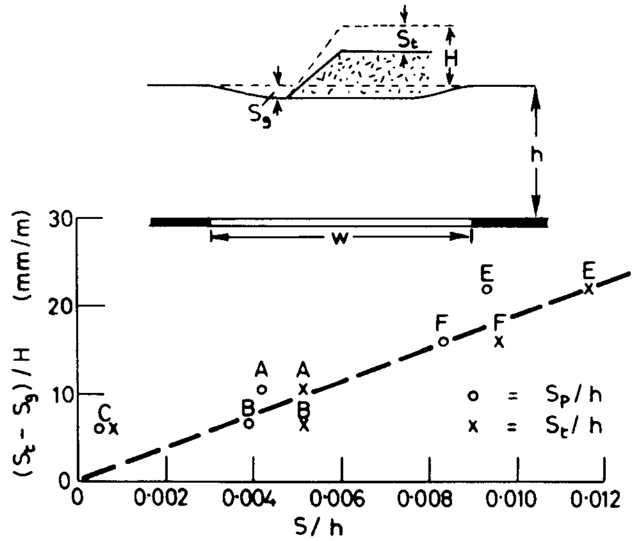

Fig. 5.1 Relationship between Excess Settlement of Mine Spoil Heap and the S/H Ratio. (From Whittaker and Reddish, 1989)

The maximum predicted subsidence (S) at the natural surface below the northern out of pit emplacement is approximately 1900 mm and the depth of cover (h) between the natural surface and the mined seam varies from approximately 70 metres to 130 metres. The ratio of subsidence (S) to depth of cover (h) at the northern out of pit emplacement varies from 0.014 to 0.026, which is beyond the maximum limit of the range of cases considered in Fig. 5.1.

Based on an extrapolation of the linear trend line, from Fig. 5.1 for S/h ratios of 0.014 and 0.026, the potential additional settlement at the surface of the northern out of pit emplacement above the extracted longwalls ranges from approximately 25 mm/m to 50 mm/m, or 2.5% to 5% of the height of the out of pit emplacement. This results in a potential additional settlement of the northern out of pit emplacement area above the UG1 longwalls of up to 3000 mm. The maximum predicted total subsidence plus potential excess settlement therefore is approximately 4900 mm.

As discussed above, the predicted subsidence at the natural ground surface and additional settlement of the emplacement area can initiate downhill slumping of the soils in the northern out of pit emplacement area. Other factors such as the presence of natural steep ground slopes, and surface water ingress may increase the risk of downhill slumping of the sides of the emplacement area. Longwall extraction will create depressions in the flat areas of the emplacement and surface cracks, which will increase the risk of water ingress into the emplacement soils during rain periods.

The areas of greatest concern are the possible failure of out of pit emplacement slopes above and close to the proposed work areas of the haul roads, the conveyors and the Stage 2 ROM facilities that are located in the south western corner of Longwall 5. Consideration could be given to restricting access to areas near slopes, particularly during the active subsidence period, until subsidence movements cease or the risk of slope failure is determined to be very low.

It is recommended, therefore, that management strategies are developed for the management of the surface and the slopes of the proposed northern out of pit emplacement area as the proposed UG1 longwalls are mined beneath the out of pit emplacement area.

Such management should include surface crack repair and remediation of the ground surface to ensure that adequate surface water drainage is maintained. It is also recommended that the settlement and movement of the northern out of pit emplacement be monitored as the proposed longwalls are mined beneath it. As noted previously, it may be necessary to monitor the northern out of pit emplacement area from a remote location using reflectors placed on the out of pit emplacement, or using aerial laser scan techniques.

5.14.2. Stage 2 ROM facilities and Conveyors

Stage 2 ROM facilities will be located above the south western end of Longwall 5 and conveyors between Stage 2 ROM facilities and Stage 1 ROM coal facilities will cross UG1 Longwall 1 to Longwall 5. Provision should be made for adjustments or repair of any mine infrastructure located above the proposed longwalls to accommodate the predicted subsidence parameters and to ensure that safety and serviceability is maintained.

5.15. The Highwall of the Open Cut Mine

The finishing ends of the longwalls, in the Ulan Seam, must be positioned by MCM to ensure that the longwalls do not affect the stability the highwalls of the open pit and to ensure that the mine accesses remain safe and serviceable throughout the mining period.

It is possible that some horizontal movement of the highwalls could occur, towards the open pit, due to relaxation of in situ stresses in the strata as they are undermined. It would, therefore, be prudent to establish survey lines along the top and bottom of the highwalls to monitor the movements as the longwalls are mined. Regular visual inspection of the faces of the highwalls and the tops of the highwalls, as mining occurs, would also be advantageous in order to ensure that any cracking in the strata is identified. In this way, preventive measures can be put in place, before the stability of the highwalls is compromised.

5.16. Archaeological Sites

There are 21 archaeological sites located within the Study Area, the locations of which are shown in Drawing No. MSEC353-15. One archaeological site is located within the northern out of pit emplacement footprint. The predictions and impact assessments for the archaeological sites are provided in the following sections.

5.16.1. Predictions for the Archaeological Sites

The maximum predicted total systematic subsidence parameters at the archaeological sites within the Study Area, resulting from the extraction of the proposed longwalls, are shown in Table D.01 in Appendix D.

A summary of the maximum predicted values of total systematic subsidence, tilt and strain at these 27 archaeological sites, after the extraction of the proposed longwalls, is provided in Table 5.6.

Table 5.6 Maximum Predicted Total Systematic Subsidence, Tilt and Strain at the Archaeological Sites within the Study Area after the Extraction of Longwalls 1 to 13

Type	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total or Travelling Tilt (mm/m)	Maximum Predicted Total or Travelling Tensile Strain (mm/m)	Maximum Predicted Total or Travelling Compressive Strain (mm/m)
Open Sites	1820	55	35	25
Overhang Sites	1790	85	>50	>50

The values provided in the above tables are the maximum predicted parameters within a 20 metre radius of each site. The predicted tilts and strains are the maximum values which occur during, or after the extraction of each proposed longwall, whichever is the greater.

5.16.2. Impact Assessments for the Archaeological Sites

Open sites containing artefact scatters and isolated finds can potentially be affected by cracking of the surface soils as a result of mine subsidence movements. It is unlikely that the scattered artefacts or isolated finds themselves would be impacted by surface cracking.

Whilst it is unlikely that the scattered artefacts or isolated finds themselves would be impacted by mine subsidence, it is possible that, if remediation works to the surface areas around the archaeological sites was required after mining, these works could potentially impact on the archaeological sites. Remediation works in areas adjacent to these sites will need to be supervised by a qualified archaeologist should any works be required. A discussion on surface cracking resulting from the extraction of the proposed longwalls is provided in Section 5.23.1.

Sites located within overhangs will be subject to similar impacts as described for the cliffs and overhangs in Section 5.3, and artefact scatters and isolated finds can potentially be affected by rock falls. Any artefacts that require protection from potential impacts would either need to be removed from the overhangs or would need to be protected by minimising the risk of rock falls at the relevant overhang.

One overhang site, Site ID S2MC236, will be protected by the leaving by a barrier or block of unmined coal below the site. This site is located at Cliff C7 and predictions and impact assessments for this cliff are detailed in Section 5.3.

One site, Site ID S2MC231 is located within the northern out of pit emplacement footprint and will be covered during the filling operations.

Further details and discussions on the potential impacts on the archaeological sites resulting from the extraction of the proposed longwalls and emplacement are provided in the report by Archaeological Risk Assessment Services (2008).

5.17. Heritage Site

There is one item of moderate local significance located near the finishing end of Longwall 6. The item is a dry stone wall that formed part of the Mudgee to Wollar road that ran via Moolarben. The item is known as Heritage Site No. 18 and is described in detail in a report by Archaeological Risk Assessment Services (2008). The location of the item is shown on Drawing No. MSEC353-15.

The maximum predicted subsidence at the heritage site, after the extraction of the proposed longwalls is 45 mm. The maximum predicted systematic tilt at the heritage site is 3.3 mm/m (i.e. 0.3 %), or a change in grade of 1in 300. The maximum predicted systematic tensile and compressive strains at the heritage site are 2.1 mm/m and <1 mm/m respectively.

At these low levels of tilt and strain, the dry stone wall is unlikely to be subjected to any significant impact resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors of 1.25 to 2 times. Potential impacts would most likely include loose stones that may become dislodged during mining.

It is recommended that a detailed photographic record of the pre mining condition of the dry stone wall be prepared so that if any stones become dislodged during mining, they can be identified and replaced in the correct positions following the completion of mining.

5.18. Survey Control Marks

There is one survey mark, known as Murragamba Trig Station, included in the Study Area. The location of the survey control mark is shown in Drawing No. MSEC353-15.

The trig station is located near the maingate and over proposed Longwall 6. The predicted maximum subsidence and tilt at this location are 1060 mm and 50 mm/m respectively.

At this location the predicted maximum horizontal movement resulting from the extraction of the proposed longwalls is approximately 500 mm. Further discussion on horizontal movements is provided in Section 5.19 of this report.

It will be necessary on the completion of the proposed longwalls, when the ground has stabilised, to re-establish this mark. Consultation between MCM and the Department of Lands will be required throughout the mining period to ensure that the survey mark is reinstated at an appropriate time, as required.

If the predicted horizontal movements were increased by factors up to 2 times, the predicted impacts to the survey mark would increase accordingly. It is anticipated that with appropriate remediation measures implemented, that there would be no significant impact on the survey mark as a result of the proposed mining.

5.18.1. Recommendations for the Survey Control Marks

It is recommended that management strategies are developed, in consultation with the Department of Lands, such that the survey control marks can be re-established, as required, at the appropriate time.

5.19. Predicted Horizontal Movements

Predicted horizontal movements over the proposed longwalls are calculated by applying a factor to the predicted tilt values. In the Newcastle, Hunter and Western coalfields, a uniform factor of 10 is typically adopted, being the same factor as that used to determine strains from curvatures and this has been found to give a reasonable correlation with measured data for single-seam conditions.

Based on available monitoring 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 uniform factor will generally lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the horizontal movements where the tilts are low, for single-seam conditions. However, it should be noted that the application of this factor of 10 does not allow for the possible additional non-systematic ground movements, such as far field movements, which is discussed below.

The maximum predicted systematic tilt in the Study Area, resulting from the extraction of the proposed longwalls, is 95 mm/m. Applying a factor of 10 to this magnitude of tilt would provide a very conservative prediction of the maximum horizontal movement.

It is expected, therefore, that the maximum horizontal movements resulting from the extraction of the proposed longwalls would be in the order to 950 mm.

Horizontal movements do not directly impact on natural features or items of infrastructure, rather impacts occur as the result of differential horizontal movements. Systematic strain is the rate of change of horizontal movement. The impacts of systematic strain on the natural features and items of infrastructure are addressed in the impact assessments for each feature in Sections 5.2 to 5.18.

5.20. Predicted Far-Field Horizontal Movements

In addition to the systematic movements that have been predicted above and adjacent to the proposed longwalls, and the predicted valley related movements along the creeks, it is also likely that some far-field horizontal movements will also be experienced during the extraction of the proposed longwalls.

Far-field horizontal movements result from the redistribution of horizontal in situ stress in the strata around the collapsed and fractured zones above longwall extractions. Such movements are, to some extent, predictable and occur whenever significant excavations occur at the surface or underground.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data primarily from the Southern Coalfield, from Collieries including Appin, Bellambi, Dendrobium, Douglas, Newstan, Tower and West Cliff. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwalls. 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 longwall, for all monitoring points within the database, is provided in Section 1.7 of the online document "General Discussion of Mine Subsidence Ground Movements" which can be downloaded from www.minesubsidence.com. The document also presents a plot of data points within the database only where there was solid coal between the longwalls and monitoring points.

The plots of data points indicate, that incremental far-field horizontal movements of up to 20 mm have been observed at distances of 2000 metres from extracted longwalls. It should be noted, however, that at the larger distances from the longwall extractions, the measured movements contain larger proportions of survey error, in addition to valley related closure movements, and movements along geological anomalies.

As successive longwalls within a series of longwalls 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 in the strata within the collapsed zones above the first few extracted longwalls has been redistributed, 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 longwalls.

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls are expected to be 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 less than 0.1 mm/m.

5.21. Likely Height of the Fractured Zone above the Proposed Longwalls

The background to sub-surface strata movements has been discussed in Section 1.7 of the online document "General Discussion of Mine Subsidence Ground Movements" which can be downloaded from www.minesubsidence.com. The following conclusions should be read in the context of the online document.

The terminology used by different authors to describe the strata displacement zones above extracted longwalls varies. Forster (1995) noted that most studies had recognised four separate zones, as shown in Fig. 5.2 with some variations in the definitions of each zone.

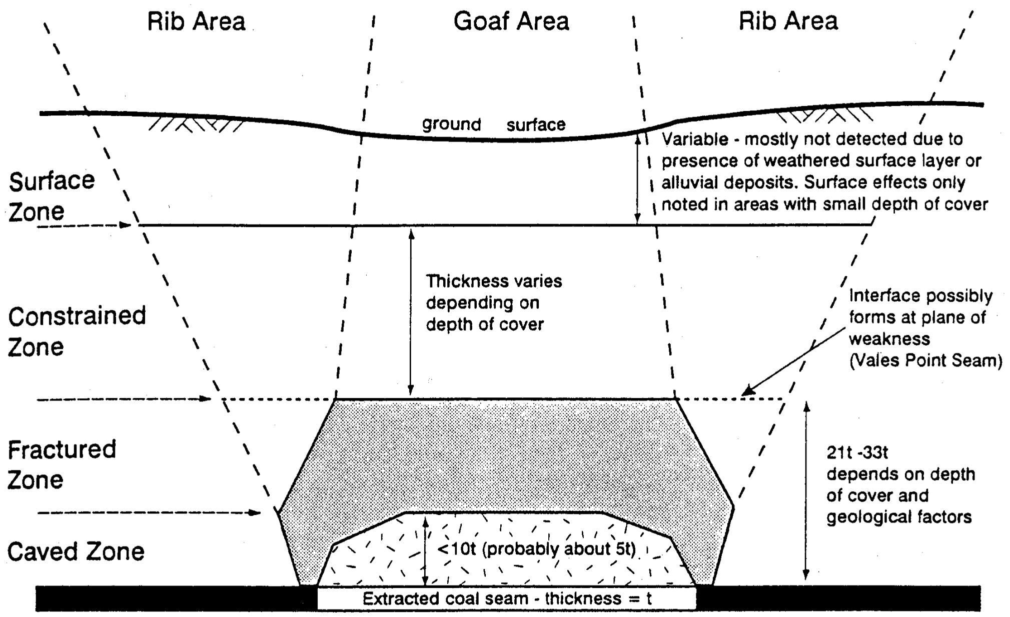

Fig. 5.2 Relationship between Vertical Dilation Heights and Seam Thickness (Forster 1995)

Peng and Chiang (1984) recognised only three zones as reproduced in Fig. 5.3.

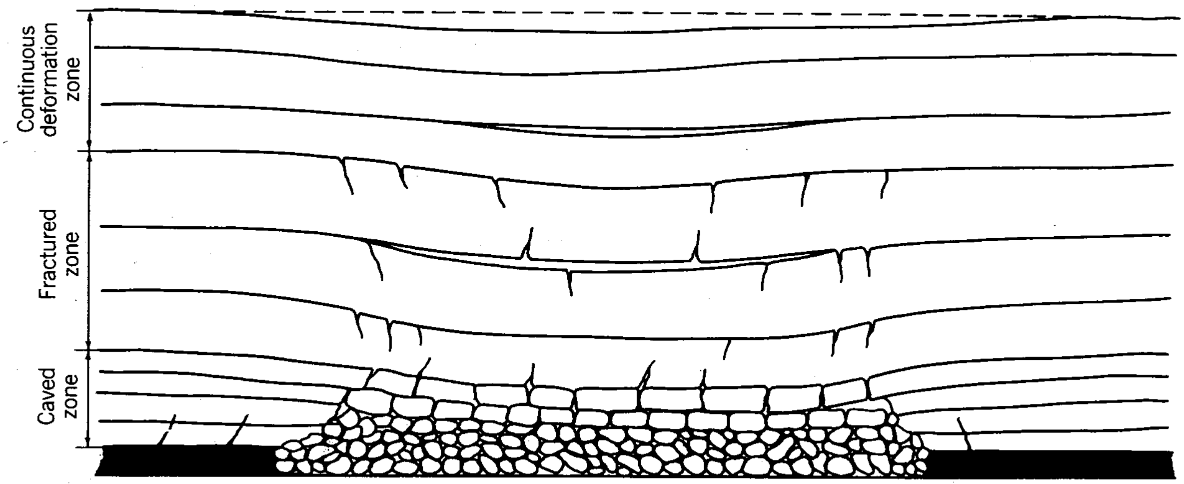

Fig. 5.3 Zones in the Overburden According to Peng and Chiang (1984)

McNally et al (1996) also recognised three zones, which they referred to as the caved zone, the fractured zone and the elastic zone. Kratzsch (1983) identified four zones, but he named them the immediate roof, the main roof, the intermediate zone and the surface zone.

For the purpose of this study, the following zones, as described by Singh and Kendorski (1981) and proposed by Forster (1995), as shown in Fig. Fig. 5.2 and described below, have been adopted:-

- *Caved or Collapsed Zone* comprises loose blocks of rock detached from the roof and occupying the cavity formed by mining. This zone can contain large voids. It should be noted, that some authors note primary and secondary caving zones.
- *Disturbed or Fractured Zone* comprises in-situ material lying immediately above the caved zone which have sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation. It should be noted, that some authors include the secondary caving zone.

- *Constrained or Aquiclude Zone* comprises confined rock strata above the disturbed zone which have sagged slightly but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present as well as discontinuous vertical cracks, usually on the underside of thick strong beds, but not of a degree or nature which would result in significant increases in vertical permeability. Some increases in horizontal permeability can be found. Weak or soft beds in this zone may suffer plastic deformation.
- *Surface Zone* comprises unconfined strata at the ground surface in which mining induced tensile and compressive strains may result in the formation of surface cracking or ground heaving.

As the terminology differs between authors, the means of determining the extents of each of these zones also varies. Some of the difficulties in establishing the heights of the various zones of disturbance above extracted longwalls stem from the imprecise definitions of the fractured and constrained zones, the differing zone names, the use of different groundwater testing methods, and differing interpretation of extensometer readings.

Some authors interpret the collapsed and fractured zones to be the zone from which groundwater or water in boreholes could be lost into the mine and, hence, look for the existence of aquiclude layers above this height to confirm whether surface water would or would not be lost.

The effects of mining geometry on the heights of the collapsed and fractured zones are not well documented and theory would suggest that the factors affecting the height of the collapsed zone are the:-

- Width of extraction;
- Height of extraction;
- Depth of cover;
- Type of previous workings, if any, above the current extraction;
- Interburden to previous workings;
- Presence of pre-existing natural joints within each strata layer;
- Thickness of each strata layer;
- Angle of break of each strata layer;
- Spanning capacity each strata layer, particularly those layers immediately above the collapsed and fractured zones;
- Bulking ratios of each of strata layer within the collapsed zone; and
- Presence of aquiclude zones.

Where the panel width-to-depth ratio is high and the depth of cover is shallow, it is clear that the fractured zone can extend from the seam to the surface. This is clearly indicated in the extensometer readings from boreholes above shallow areas of extraction, where the vertical strains close to the surface are as high as those close to seam level. Where the panel width-to-depth ratio is low, and where the depth of cover is high, it is clear that the height of the fractured zone would represent a small proportion of the depth of cover. Some authors have suggested simple equations to estimate the heights of the collapsed and fractured zones based solely on the extracted seam height, others have suggested equations based solely on the width of extraction, whilst others have suggested equations based on the width-to-depth ratio of the extraction, refer to Forster (1995), Gale (ACARP C13013, 2008) and Guo et al (ACARP C14033, 2007). As this is a complex issue, we understand that no simple equation can properly estimate the heights of the collapsed and fractured zones and a more thorough analysis is required.

A simplified analysis is presented to show the possible height of the fractured zone is dependent upon the angle of break (a), the width of the panel (W) and an assumed spanning capacity of a competent stratum at the top of the fractured zone, span (w). These are illustrated in Fig. 5.4. From the mining geometry it can be shown that the height of the fractured zone equals the panel width (W) minus the span (w) divided by twice the tangent of the angle of break.

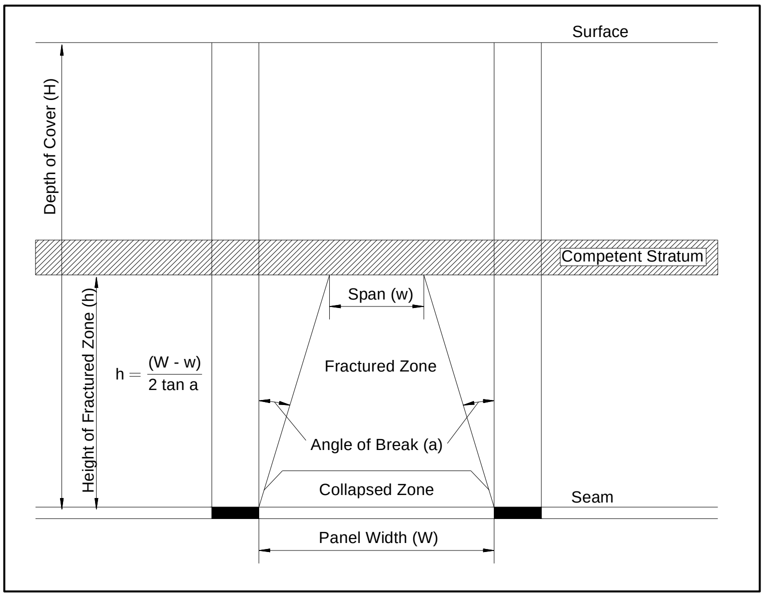

Fig. 5.4 Theoretical Model illustrating the Development and Limit of the Fractured Zone

MSEC has gathered observed data sourced from a number of literature studies. The data points collected to date are shown in Fig. 5.5 and these are compared with the results of the theoretical model developed by MSEC, using an angle of break of 20 degrees and a spanning width of 30 metres and also compared with lines representing factors of 1.0 times and 1.5 times the panel width, which were suggested by Gale (2008).

It can seen from Fig. 5.5, that the MSEC model and Gale's suggested factors of 1.0 and 1.5 provide reasonable estimates for the height of fracturing. The height of fracturing based on this approach may include part of the constrained zone, as defined by Forster (1995), which is shown in Fig. 5.4.

In some cases, it is likely that the upwards progression of the fractured zone was limited by stronger stratum or by the levels of vertical strain that could be developed, which is dependent upon the extracted seam thickness, the surface subsidence and the depth of cover.

It should also be noted that the height of fracturing, based on significant bed separation and vertical dilation, measured by extensometers, does not imply that vertical permeability has increased as it may be that only bed separation and horizontal permeability has increased.

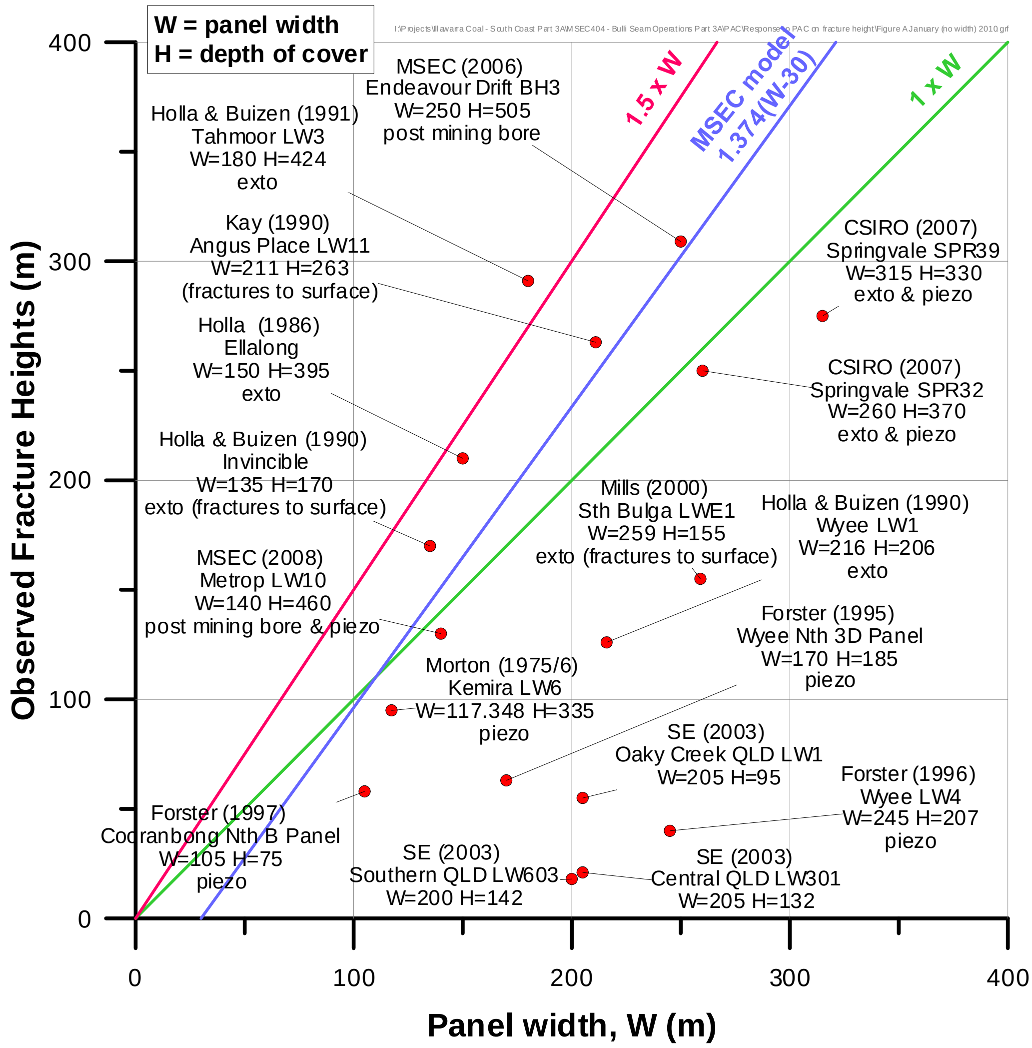

Fig. 5.5 Observed Fracture Heights versus Panel Width

5.21.1. Likely Height of the Fractured Zone above the Proposed Longwalls

The proposed Longwalls at Stage 2 of Moolarben Coal Project have width-to-depth ratios between 2 and 3. For panel width-to-depth ratios of greater than 2, without a clear aquiclude unit near the surface and with depths of cover shallower than 100 metres, it is expected that the height of the fracture zone will extend up to the ground surface. This is a conservative estimate as it assumes that there is no spanning of competent strata at the top of the fractured zone.

It is possible that some thick units of high strength basalt may exist at isolated locations over the proposed underground mining areas, such as near the identified CEECs shown in Drawing No. MSEC353-06. Geological borehole No. WMLB48 (adjacent to CEEC01) encountered approximately 20 metres thickness of low to medium strength basalt from 15 metres to 35 metres below ground surface level and borehole No. WMLB113 (CEEC03) encountered approximately 15 metres thickness of very high to extremely high strength basalt from 3 metres to 18 metres below ground surface level. These thick basalt layers, if they are of sufficiently high strength, and if they are spread over a significant area, could prevent the fractured zone from reaching the ground surface level.

Further discussion on the likely height of the fractured zone is provided in a report by Aquaterra (2011).

5.22. The Likelihood of Irregular Profiles

Wherever faults, dykes and abrupt changes in geology are present at the surface, it is possible that irregularities in the subsidence profiles could occur. Similarly, where surface rocks are thinly bedded, and where cross-bedded strata exist close to the surface, it is possible for surface buckling to occur, leading to irregular movements. By far the greatest number of irregularities in subsidence profiles, however, can be explained by the presence of surface incisions such as gorges, river valleys and creeks.

It is possible that anomalous movements could occur as a result of the extraction of the proposed longwalls. These have occurred in the past in the Southern Coalfield, as discussed in Section 1.7 of the online document "General Discussion of Mine Subsidence Ground Movements" mentioned previously. Given the relatively low density of surface features within the Study Area, the probability of an anomalous movement coinciding with a surface feature is assessed as low.

Irregularities also occur in very shallow mining situations, where the collapsed zone, above the extracted seam, extends all the way to the surface. This type of irregularity is generally only seen where the depth of cover is less than 100 metres.

Irregular profiles can also occur where longwall mining is carried out beneath previous workings such as bord and pillar extractions. In such situations, the stooks left in the upper seam can collapse, when mining occurs beneath them, leading to localised subsidence and irregular subsidence profiles. There are no earlier workings above the proposed longwalls, and this kind of irregularity will not occur in this case.

5.23. Other Potential Impacts

5.23.1. The Likelihood of Surface Cracking in Soils and Fracturing of 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 longwall perimeter. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeter. The cracks will generally be parallel to the longitudinal edges of the longwall and to the ends of the longwall.

At shallow depths of cover, it is also likely that smaller transient surface cracks will occur above and parallel to the moving extraction face, i.e. at right angles to the longitudinal edges of the longwall, 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 closes 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, therefore, surface cracking can potentially occur in any location above the extracted goaf areas of the proposed longwalls. The larger and more permanent cracks, however, are usually located in the final tensile zones around the perimeters of the longwalls.

The incidence of surface cracking is dependent on the location relative to the extracted longwall goaf edges, the depth of cover, the extracted seam thickness, and the thickness and inherent plasticity of the soils that overlie the bedrock. The surface soils above the proposed longwalls are generally weathered. 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.

The largest surface cracks within the Study Area are expected to occur as the result of soil slumping down the steep slopes, which is discussed in Section 5.4.

Where the surface is relatively flat, the relationship between surface crack width and depth of cover, based upon measured data in the NSW Coalfields and observations over mines in the United Kingdom, is discussed in Section 1.6 of the online document "General Discussion of Mine Subsidence Ground Movements". It can be seen that the crack width increases as the depth of cover reduces and that significant crack widths can develop at lower depths of cover.

The depths of cover over the underground mining areas vary from 35 metres to 165 metres. Based on the relationship between surface crack width and depth of cover, where the depths of cover above the proposed longwalls are less than 100 metres the predicted surface crack widths are, typically in the order of 150 to 200 mm wide, but could be as large as 500 mm wide where the depths of cover are the shallowest. The predicted surface crack widths are smaller where the depths of cover are greater, or where the surface cracks result from the travelling wave. Where the depths of cover above the proposed longwalls are 100 to 150 metres, the predicted surface crack widths are, typically in the order of 100 to 150 mm wide.

The surface cracks will tend to close and heal naturally, especially during rain events. If significant cracking is left untreated, however, it could form trip hazards for people and farm animals, or result in soil erosion on the steep slopes or in the drainage channels.

It is recommended that the natural surface is visually monitored during the extraction of the proposed longwalls, so that any significant cracking can be remediated, where required, by infilling, regrading, recompacting, and revegetating the surface. It is also recommended that test pits are dug in the locations of the largest surface cracks, to determine the profile of the cracks with depth, to aid in the remediation of these cracks.

5.23.2. The Likelihood of Gas Emissions at the Surface

It is known that the mining of coal causes fracturing of the strata above the coal seam and this may result in the liberation of methane and other gases. Methane, being a lighter gas, would tend to move upwards to fill the voids in the rock mass and diffuse towards the surface through any continuous cracks or fissures.

Emissions of strata gas have occurred in the past, generally within large river valleys, although some gas emissions have also been observed in smaller drainage lines and water bores. Analyses of gas compositions indicate that the coal seam is not the direct and major source of the gas and that the most likely source is the overlying sandstones.

Gas emissions from the beds of watercourses will not have time to dissolve in any surface water which is present. In addition to this, gas emissions as the result of mining comprises mainly of methane which is not significantly soluble in water. Any gas emissions are likely, therefore, to be released into the atmosphere and are unlikely to have any significant impact on water quality.

It is possible, if substantial gas emissions occurred at the surface, that localised vegetation die back could occur. Any impacts would be expected to be temporary and limited to small areas of vegetation local to the points of emission.

A literature and data review was conducted by MCM in October 2009, which included desorpable gas testing of three boreholes in the area during 2008. The review determined that low gas content levels were to be expected across all of Moolarben's tenements.

5.23.3. The Potential Impacts of Ground Vibration on Structures due to Mining

The settlement of the ground resulting from systematic subsidence is generally a gradual and progressive movement, the effect of which is not apparent to an observer at the surface. The major breakage and collapse of strata into the voids left by extraction of the seam occur in the layer immediately above the seam. Above that level, the breakage and collapse of the strata reduces to become a bending and sagging of the upper layers of rock with less sudden and much smaller movements occurring. In some instances, the movements can be concentrated at faults or other points of weakness in the strata with minor stepping at the surface.

Any major collapse below ground would result in some vibration in the layers of rock above it, which might be felt as a minor effect at the surface. This effect is generally only noticeable where the depth of cover is less than 100 metres, which occurs over some of the proposed longwalls.

It is possible, therefore, as the longwalls are mined and the strata subsides, for some vibrations to be felt at the surface, though these are more likely to occur directly above or close to the longwalls. The levels of vibration would, however, generally be very low and would not be of sufficient amplitude to result in any significant impact on the surface features or items of infrastructure. The impact due to vibration resulting from the extraction of the proposed longwalls is predicted to be insignificant.

5.23.4. The Potential for Noise at the Surface due to Mining

It would be very unusual for noise to be noticed at the surface due to longwall mining at depths greater than 100 metres. As systematic subsidence occurs and the near surface rocks are affected by tensile and compressive strains, the rocks open up at joints and planes of weakness, and displace due to rotation and shear.

Generally the movements are gradual and cannot be detected by an observer at the surface. These movements are also generally shielded by the more plastic surface soils which tend to distribute the strains more evenly and insulate against any sounds from below.

In some cases, the stresses in the rock can build up to the point that the rock suddenly shears to form a new fracture and if the rock is exposed or has only a thin covering of surface soil, the noise resulting from the fracturing can be heard at the surface. Normally the background level of noise in the countryside is high enough to ensure that the sound is not noticed, although in the stillness of night, it might occasionally be noticed when it occurs in close proximity. The Impact due to noise at the surface resulting from the extraction of the proposed longwalls is predicted to be insignificant compared to the surrounding open cut mining activities.

5.24. Proposed Underground Area No. 3

A possible future underground mining area known as UG3 is located at the eastern side of the lease area as shown on Drawing No. MSEC353-01. There is no current longwall layout planned for this area and further studies are to be carried out to assess the viability of longwall mining in this area. Depth of cover in the area of UG3 is expected to be similar to the depth of cover for UG1, ranging from approximately 80 metres to 130 metres. Surface features in the area are also expected to be similar to the UG1 area, including the nearby railway line, fences, tracks, natural features and flora and fauna.

No predictions were carried out for the UG3 area, however it is reasonable to expect that conditions and impacts will be similar to those predicted for UG1 in this report. A more detailed prediction model and assessment of possible impacts can be carried out once a longwall layout is prepared for the proposed area.

CHAPTER 6. MONITORING AND MITIGATION

A subsidence ground monitoring program of survey pegs at various items of surface infrastructure and along several gridlines over the proposed longwalls is proposed and a visual subsidence impact monitoring program is proposed.

Several subsidence mitigation measures have been recommended in the previous Chapters to minimise the impacts of subsidence at various items of infrastructure and natural features and these mitigation measures are summarised in Section 6.3.

6.1. Objectives of Ground Monitoring Program

The objectives of the proposed ground monitoring program are:-

- Provide general information on the magnitude of subsidence ground movements over the longwall panels and the extent of subsidence ground movements around the longwall panels,
- Compare actual ground movements with predicted ground movements,
- Monitor ground movements at or near surface infrastructure and sensitive natural features,
- Provide early detection of non-systematic movements within the subsidence zone, whilst allowing contingency for assessment and response in the event that predictions are exceeded.
- Satisfy the objectives of the Subsidence Management Plan,
- Satisfy the objectives of agreed management plans between MCM and infrastructure owners, and
- Meet the expectations of the community with regard to monitoring subsidence.

It should be noted that ground monitoring is only one portion of the overall subsidence management program. Other forms of monitoring include visual monitoring and specific monitoring related to items of infrastructure. Whilst traditional ground movement monitoring is important, these other forms of monitoring can be very effective in identifying potential subsidence impacts at early stages in their development.

6.2. Recommended Ground Movement Monitoring for the Proposed Longwalls

The monitoring of ground movements at various ground survey pegs is recommended, as subsidence occurs, so that the observed ground movements can be compared with those predicted and to allow regular reviews of the predictions and impact assessments in the light of measured data.

It is recommended that survey lines be established perpendicular to and across the proposed longwalls to monitor ground movements as the longwalls are extracted. Two survey lines should be established across the two groups of longwalls in UG1 (i.e. one across LW1 to LW5 and one across LW6 to LW9), and two survey lines should be established across the two groups of longwalls in UG2 (i.e. one across LW10 to LW12A and one across LW12B to LW13). The monitoring lines should be established prior to extraction of the longwalls and these monitoring lines should be monitored on the completion of each longwall and after a period of approximately 6 months after the completion of mining.

It is also recommended that visual monitoring, with photographic records, of the important natural features and items of surface infrastructure is undertaken during the mining period. A baseline inspection should be carried out to establish the condition of the natural features and items of surface infrastructure prior to extraction of the proposed longwalls. Inspections should then be carried out on a regular basis during the mining period and approximately 6 months after the completion of all mining or until results show that further subsidence has reduced to minimal levels.

A summary of the monitoring recommendations for the natural features and items of surface infrastructure are provided in Table 6.1. Reference should also be made to any monitoring recommendations given in the specialist reports.

A more detailed outline of proposed monitoring should be prepared for the Subsidence Management Plan when application is made to extract the proposed longwalls.

There is generally a higher risk of subsidence impacts occurring to natural features and items of infrastructure where the depth of cover is less than 100 m and this should be taken into account when preparing more detailed monitoring and mitigation programs.

Table 6.1 Summary of the Recommendations for the Natural Features and Items of Surface Infrastructure

Feature	Recommendations
Drainage Lines	Visual monitoring as the proposed longwalls mine beneath the drainage lines.
Cliffs, Overhangs and Rock Ledges	Visual monitoring during the mining period from a remote and safe location until such time as the mine subsidence movements have ceased. Visual monitoring should be complimented by surveyed movements for Cliffs C7 to C10.
Steep Slopes	Visual monitoring of steep slopes above the longwalls as they are mined.
Vegetation Communities	Visual monitoring of the vegetation communities as the proposed longwalls mine beneath them.
Gulgong to Sandy Hollow Railway	Surveyed ground monitoring of the railway line during extraction of Longwalls 1 to 5
Roads	Surveyed ground monitoring of the roads during extraction of Longwalls 1 to 5
Powerlines	Surveyed ground monitoring at the powerlines over the proposed longwalls during extraction of Longwalls 6 to 8
Optical Fibre Cables	Monitoring during the extraction of the Longwalls 1 to 5 using optical fibre sensing techniques, such as Optical Time Domain Reflector (OTDR) monitoring.
Copper Telecommunications Cables	Ensure telecommunications services are maintained until mining operations have ceased.
Mining Infrastructure	Monitor settlement of the northern out of pit emplacement as the proposed longwalls mine beneath it. It may be necessary to monitor the out of pit emplacement from a remote location using reflectors placed on the out of pit emplacement, or using aerial laser scan techniques. Establish survey lines along the top and bottom of the highwalls to monitor the movements as the longwalls are mined. Regular visual inspection of the faces of the highwalls and the tops of the highwalls, as mining occurs. Monitor mine infrastructure placed above the proposed longwalls and adjust or repair to maintain safety and serviceability during and following extraction of the longwalls.
Archaeological Sites	Monitor overhang sites as required in accordance with cliff line monitoring. Visual monitoring of open archaeological sites.
Heritage Sites – Dry Stone Wall	Photographic record of the pre mining condition and visual monitoring during extraction of Longwalls 6 and 7.
Survey Control marks	Murragamba Trig station should not be used during mining unless correction has been made for any movements of the trig station.

6.3. Mitigation

The detailed monitoring programs developed for the Subsidence Management Plans should include mitigation strategies, to ensure that safety and serviceability are maintained during the mining period and to ensure that that adequate remediation is carried out in a timely manner where impacts have occurred.

A summary of the recommendations for mitigation measures for the natural features and items of surface infrastructure that were discussed and recommended in the previous Chapters of this report to minimise the impacts of subsidence at various items of infrastructure and natural features are provided below in Table 6.2. Reference should also be made to the specialist reports for more information on potential impacts and mitigation measures.

Table 6.2 Summary of the Recommendations for Mitigation Measures for the Natural Features and Items of Surface Infrastructure

Feature	Recommendations for Mitigation Measures
Drainage Lines	Identified cracking in drainage lines should be remediated by infilling the surface cracks with materials comprising a high clay content, or by locally regrading and recompacting the surface.
Cliffs, Overhangs and Rock Ledges	The likelihood of cliff collapse or damage at some of the identified cliffs has been minimised by the design of the proposed longwall starting and finishing positions. Management strategies should include further restriction of access and possibly making site areas safe should any cliff face appear to become unstable. The existing condition of cliffs within the Study Area should be documented and photographed prior to mining.
Steep Slopes and Vegetation Communities	Any significant surface cracking should be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface.
Gulgong to Sandy Hollow Railway	A management plan should be established for the railway during the extraction of Longwalls 1 to 5. The management plan should be prepared in consultation with the Australian Rail Track Corporation.
Roads	Management strategies should be developed, in consultation with the Local Council where necessary, to maintain the roads in a safe and serviceable condition throughout the proposed mining period.
Powerlines	The powerline should be inspected by a suitably qualified person prior to mining, to determine the existing condition and whether any preventive measures are required. Management strategies should be prepared, in consultation with Country Energy, as required, to incorporate the assessed impacts to the powerline resulting from the extraction of the proposed longwalls.
Optical Fibre Cables	A monitoring, management and response plan should be established for the optical fibre cable prior to mining the proposed Longwalls 1 to 5, to the satisfaction of the owners of the optical fibre cable.
Copper Telecommunications Cables	Management strategies should be developed, in consultation with Telstra, for the implementation of suitable remediation measures should any impacts on the copper telecommunications cables occur.
Mining Infrastructure	Management strategies should be developed for the safe placement of spoil to maintain the stability of the slopes as the proposed longwalls are mined beneath and in the vicinity of the northern out of pit emplacement areas. Such management strategies should include surface crack repair and remediation of the ground surface to ensure that adequate surface water drainage is maintained. Management strategies should be developed to maintain stability of the highwalls during the underground mining period. Management strategies should be developed for the mine infrastructure located above the proposed longwalls to maintain safety and serviceability during extraction of the proposed longwalls
Archaeological Sites	Overhang site at Cliff C7, Site ID S2MC236, will be protected by the leaving by a barrier or block of unmined coal below the site. Any artefacts below overhangs that require protection from potential impacts would either need to be removed from the overhangs or would need to be protected by minimising the risk of rock falls at the relevant overhang. Care should be taken if any ground surface remediation is carried out to avoid disturbance of any of the archaeological sites. Approvals should be obtained from the appropriate authorities for remediation of the surface, if necessary, in the locations of the archaeological sites.
Heritage Sites – Dry Stone Wall	If any stones become dislodged during mining, they should be replaced in the correct positions following the completion of mining.
Survey Control marks	Survey control marks should be re-established, as required, following the completion of mining.

APPENDIX A - GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

Some of the more common mining terms used in the report are defined below:

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Critical area	The area of extraction at which the maximum possible subsidence of one point on the surface occurs.
Curvature	The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections.
Extracted seam thickness	The thickness of coal that is extracted. The extracted seam thickness is normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Flow diversion (mining-induced surface flow diversion)	The diversion of surface water through contiguous flow paths that mining-induced fractures in bedrock or rockbars.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Overlap adjustment factor	A factor that defines the ratio between the maximum incremental subsidence of a panel and the maximum incremental subsidence of that panel if it were the first panel in a series.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.

Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points.
Sub-critical area	An area of panel smaller than the critical area.
Subsidence	The vertical movement of a point on the surface of the ground as it settles above an extracted panel.
Super-critical area	An area of panel greater than the critical area.
Tilt	The difference in subsidence between two points divided by the horizontal distance between the points.
Uplift	An increase in the level of a point relative to its original position.
Upsidence	The difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

APPENDIX B - REFERENCES

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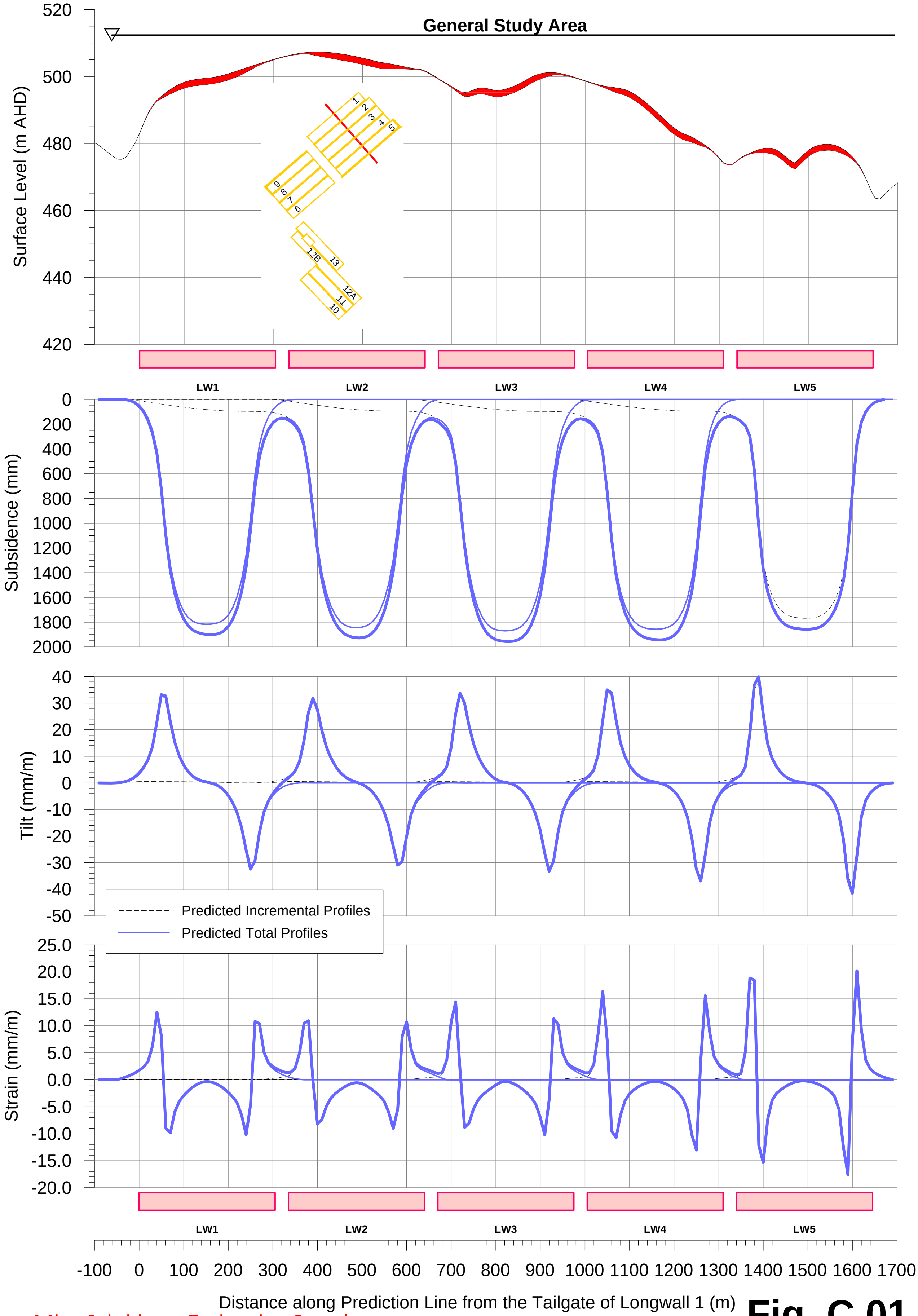
APPENDIX C. FIGURES

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Prediction Lines\Fig C.01 Prediction Line 1.grf.....09-Jul-08

Predicted Profiles of Systematic Subsidence, Tilt and Strain along Prediction Line 1 Resulting from the Extraction of Longwalls 1 to 13



Mine Subsidence Engineering Consultants

Fig. C.01

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Prediction Lines\Fig C.02 Prediction Line 2.grf.....09-Jul-08

Predicted Profiles of Systematic Subsidence, Tilt and Strain along Prediction Line 2 Resulting from the Extraction of Longwalls 1 to 13

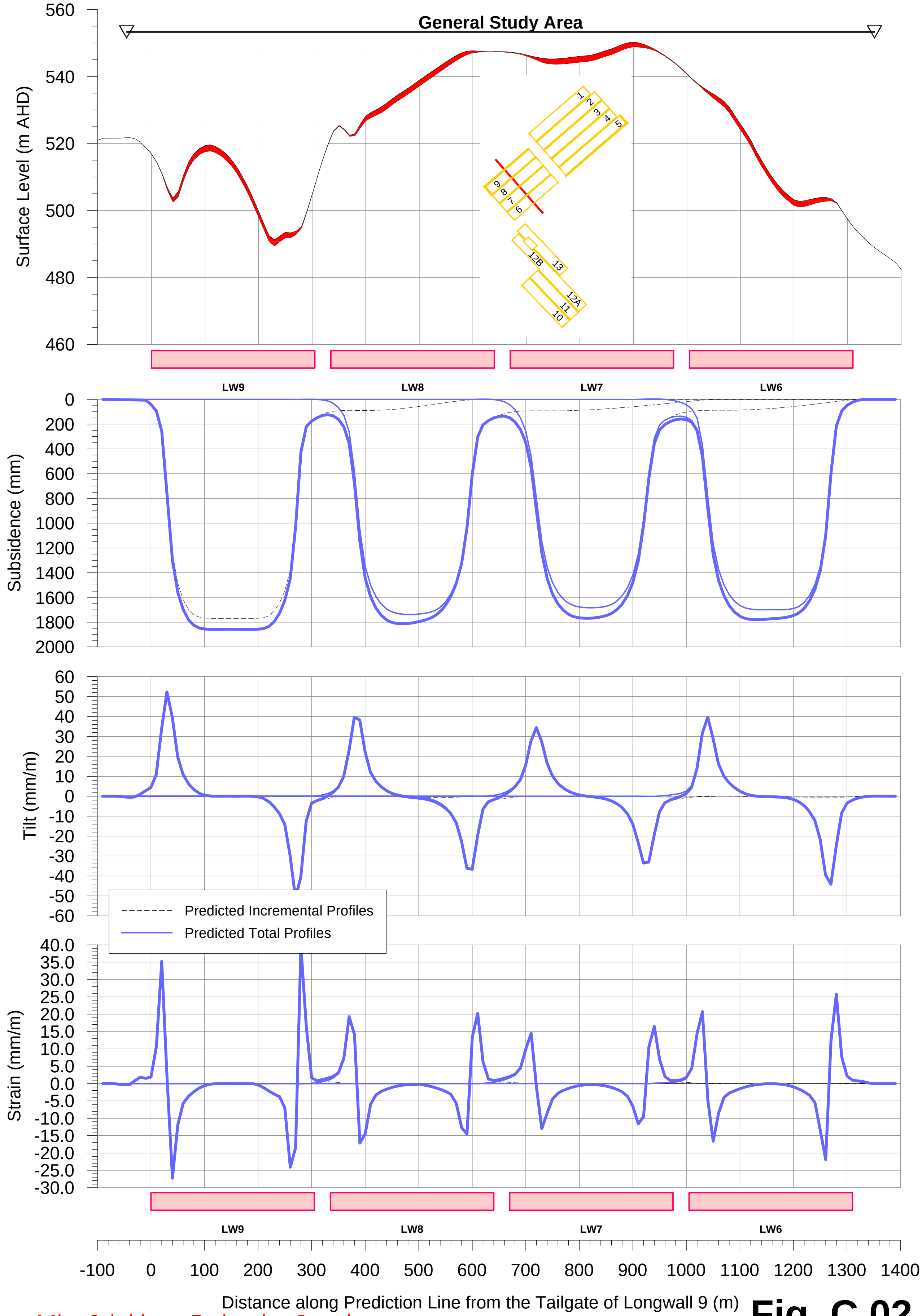


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Fig. C.02

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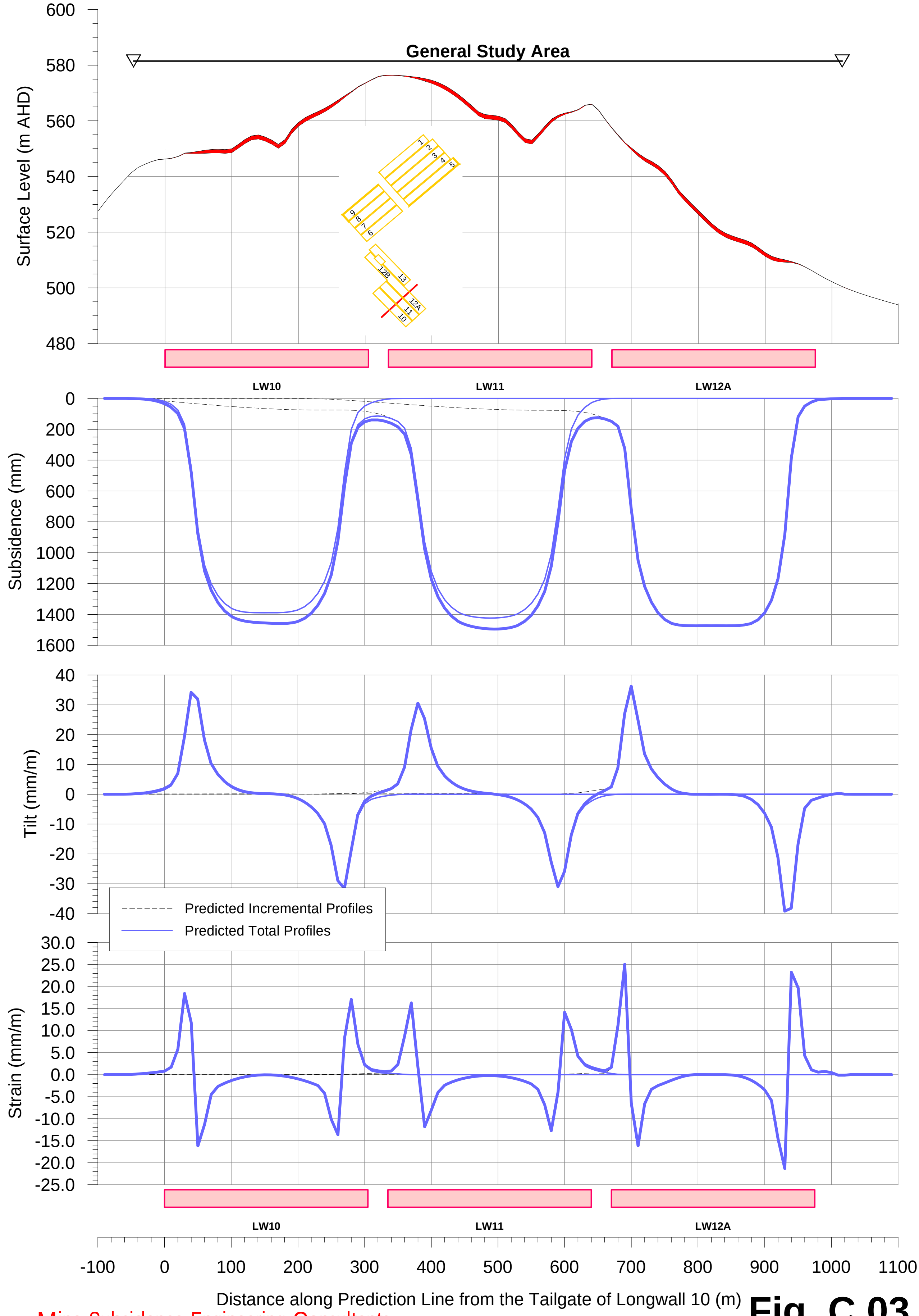
Predicted Profiles of Systematic Subsidence, Tilt and Strain along Prediction Line 3 Resulting from the Extraction of Longwalls 1 to 13

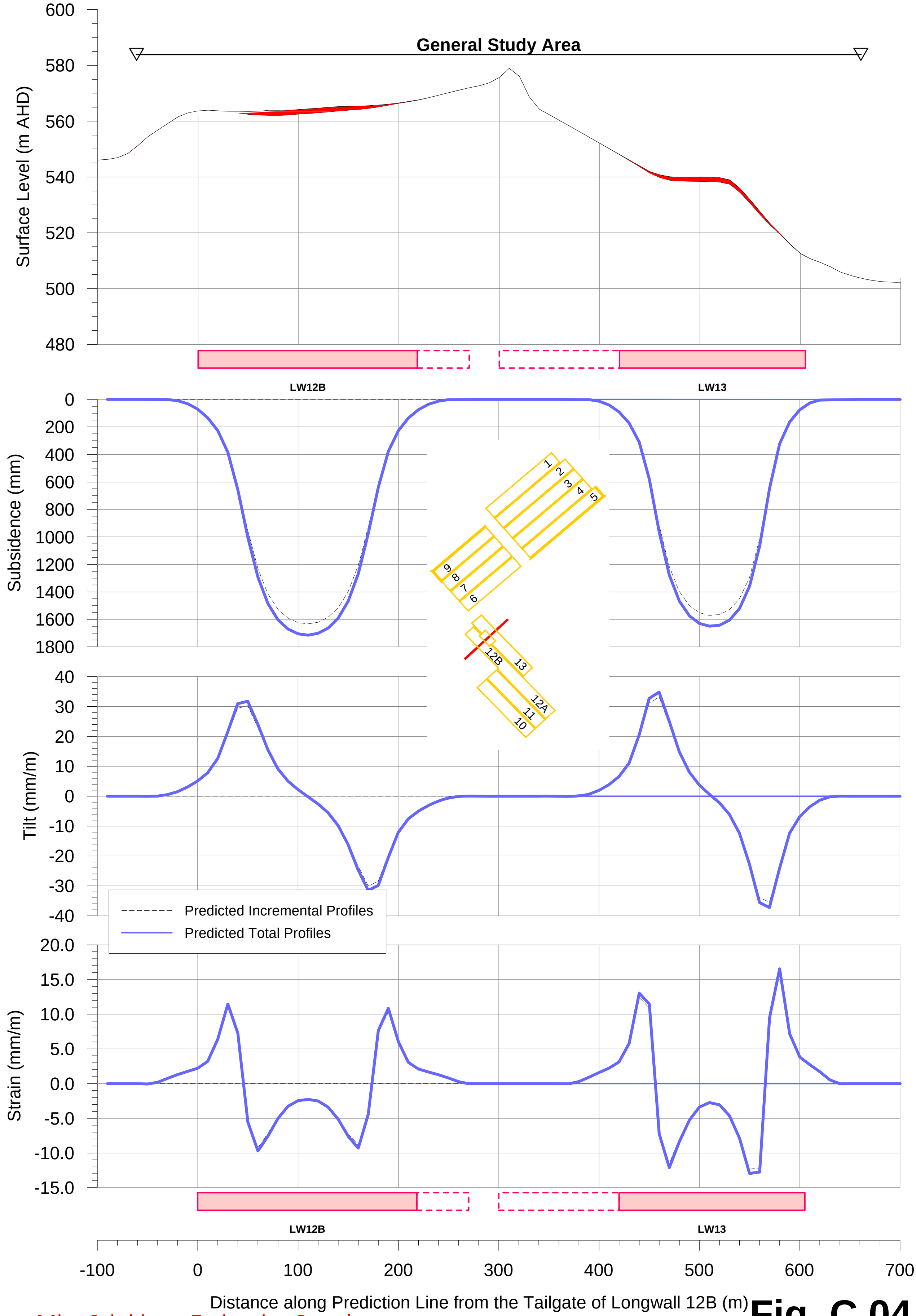


Mine Subsidence Engineering Consultants

Fig. C.03

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Prediction Lines\Fig C.04 Prediction Line 4.grf.....09-Jul-08

Predicted Profiles of Systematic Subsidence, Tilt and Strain along Prediction Line 4 Resulting from the Extraction of Longwalls 1 to 13

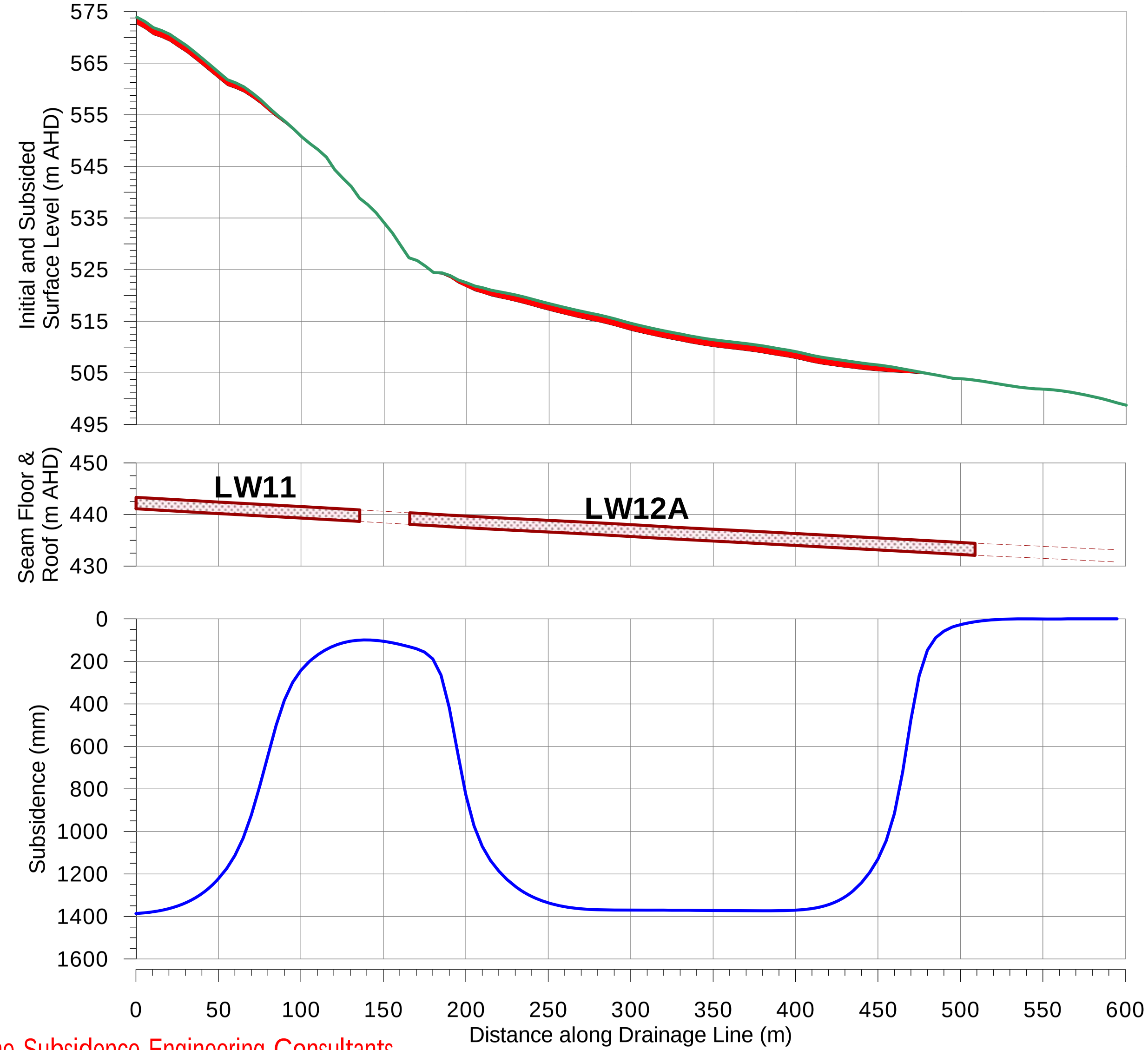


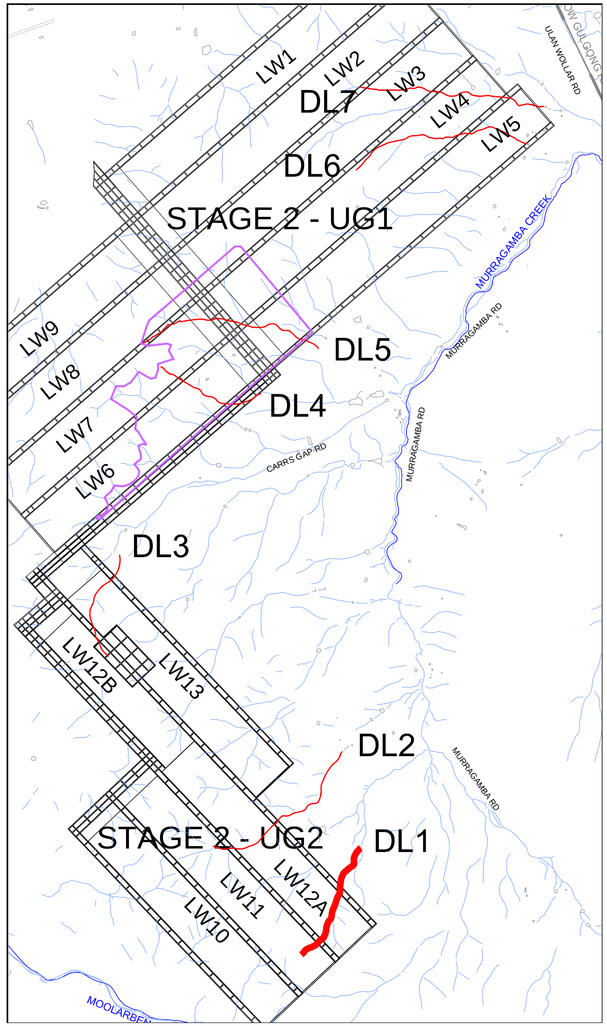
Mine Subsidence Engineering Consultants

Fig. C.04

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Drainage Lines\Fig C.05 Moolarben Drainage Lines - DL1 - Initial and Subsided surface levels Landscape.grf.....27-Jul-11

Moolarben Coal Project - Stage 2, Underground 1 and Underground 2 - Longwalls 1 to 13
Profiles of Initial and Subsided Surface Level, and Predicted Subsidence
Drainage Line DL1





Mine Subsidence Engineering Consultants

Fig. C.05

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Drainage Lines\Fig C.06 Moolarben Drainage Lines - DL2 - Initial and Subsided surface levels Landscape.grf.....27-Jul-11

Moolarben Coal Project - Stage 2, Underground 1 and Underground 2 - Longwalls 1 to 13
Profiles of Initial and Subsided Surface Level, and Predicted Subsidence
Drainage Line DL2

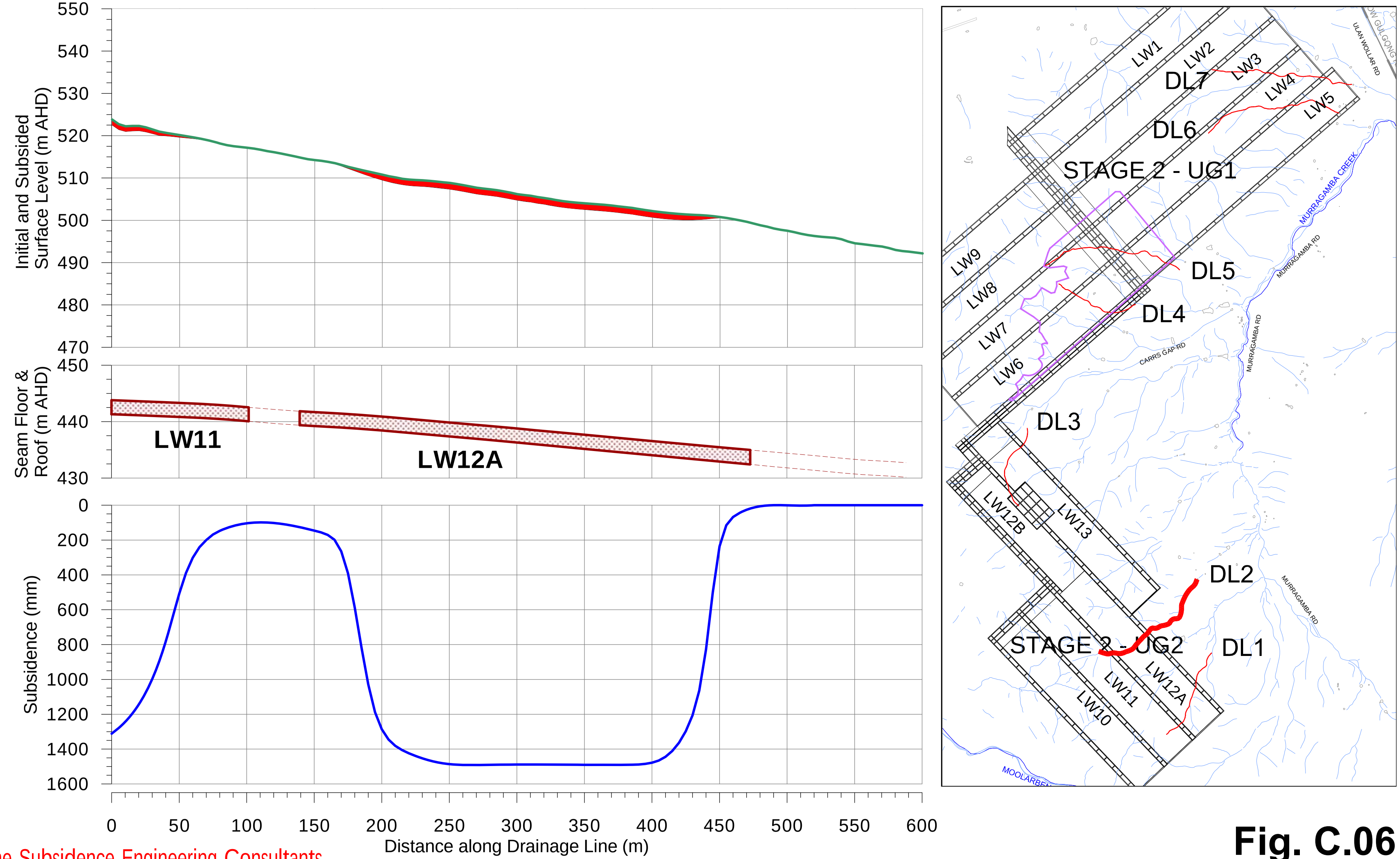


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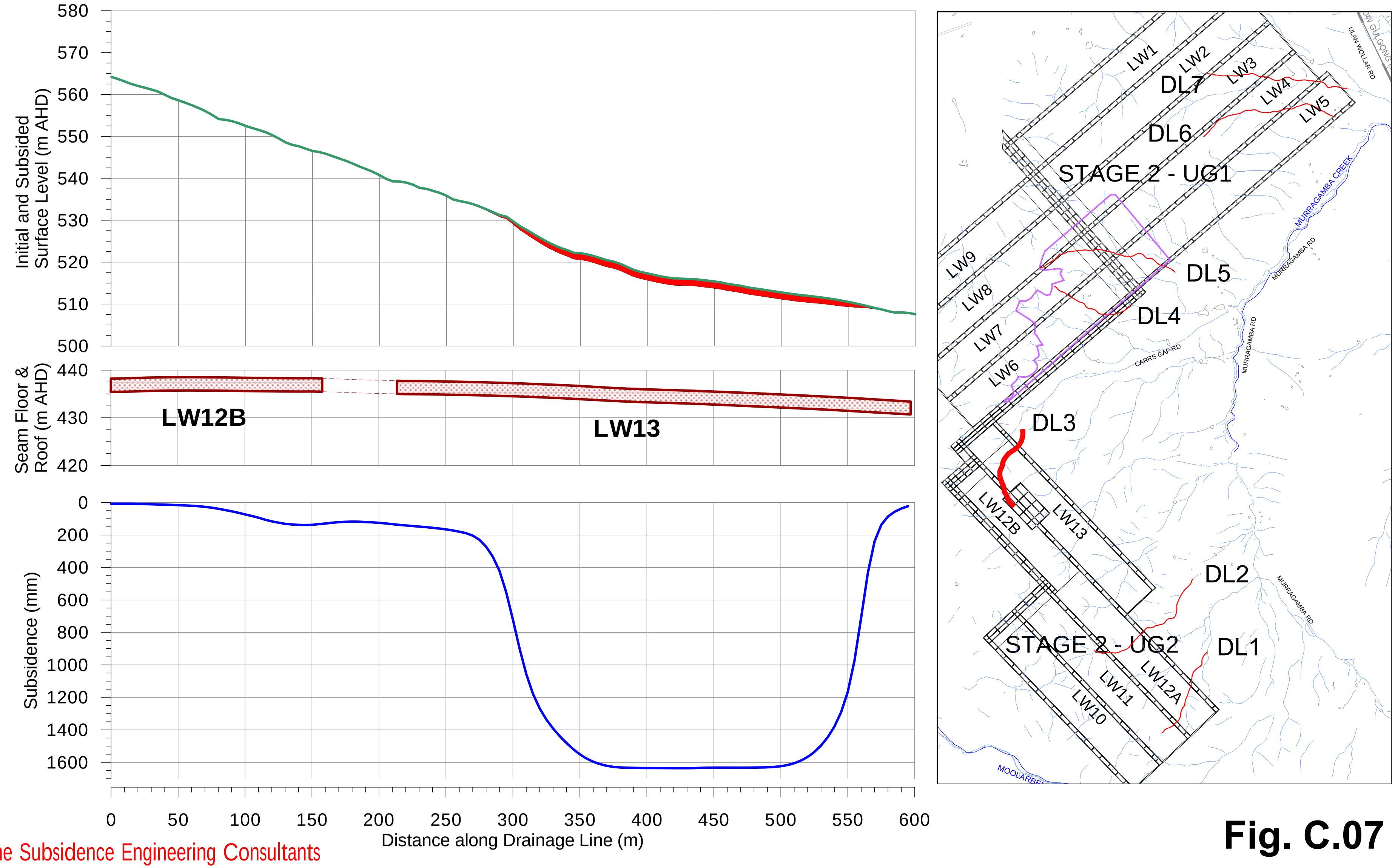
Fig. C.06

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Drainage Lines\Fig C.07 Moolarben Drainage Lines - DL3 - Initial and Subsided surface levels Landscape.grf.....27-Jul-11

Moolarben Coal Project - Stage 2, Underground 1 and Underground 2 - Longwalls 1 to 13
Profiles of Initial and Subsided Surface Level, and Predicted Subsidence
Drainage Line DL3

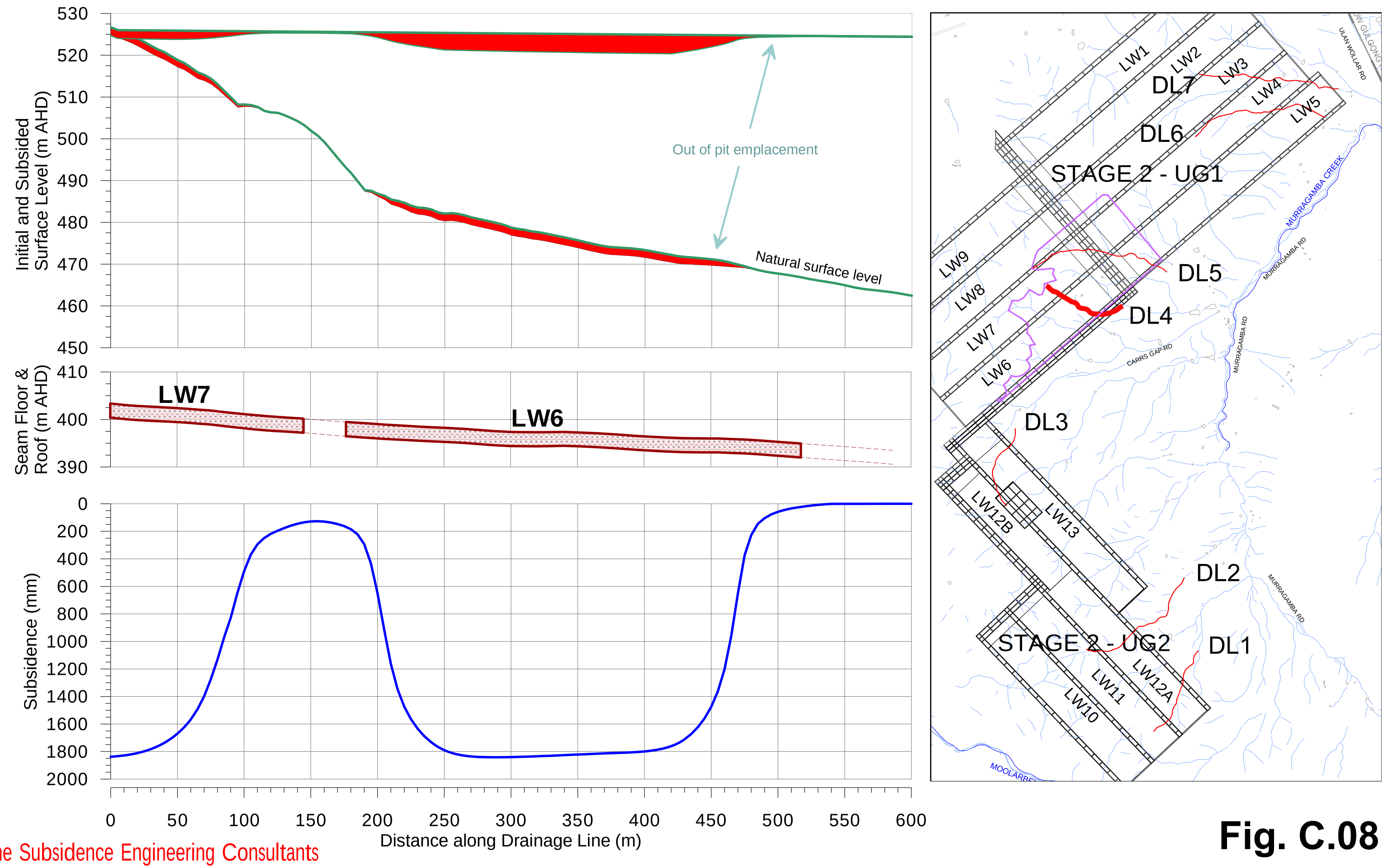


Mine Subsidence Engineering Consultants

Fig. C.07

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Drainage Lines\Fig C.08 Moolarben Drainage Lines - DL4 - Initial and Subsided surface levels Landscape.grf.....27-Jul-11

Moolarben Coal Project - Stage 2, Underground 1 and Underground 2 - Longwalls 1 to 13
Profiles of Initial and Subsided Surface Level, and Predicted Subsidence
Drainage Line DL4

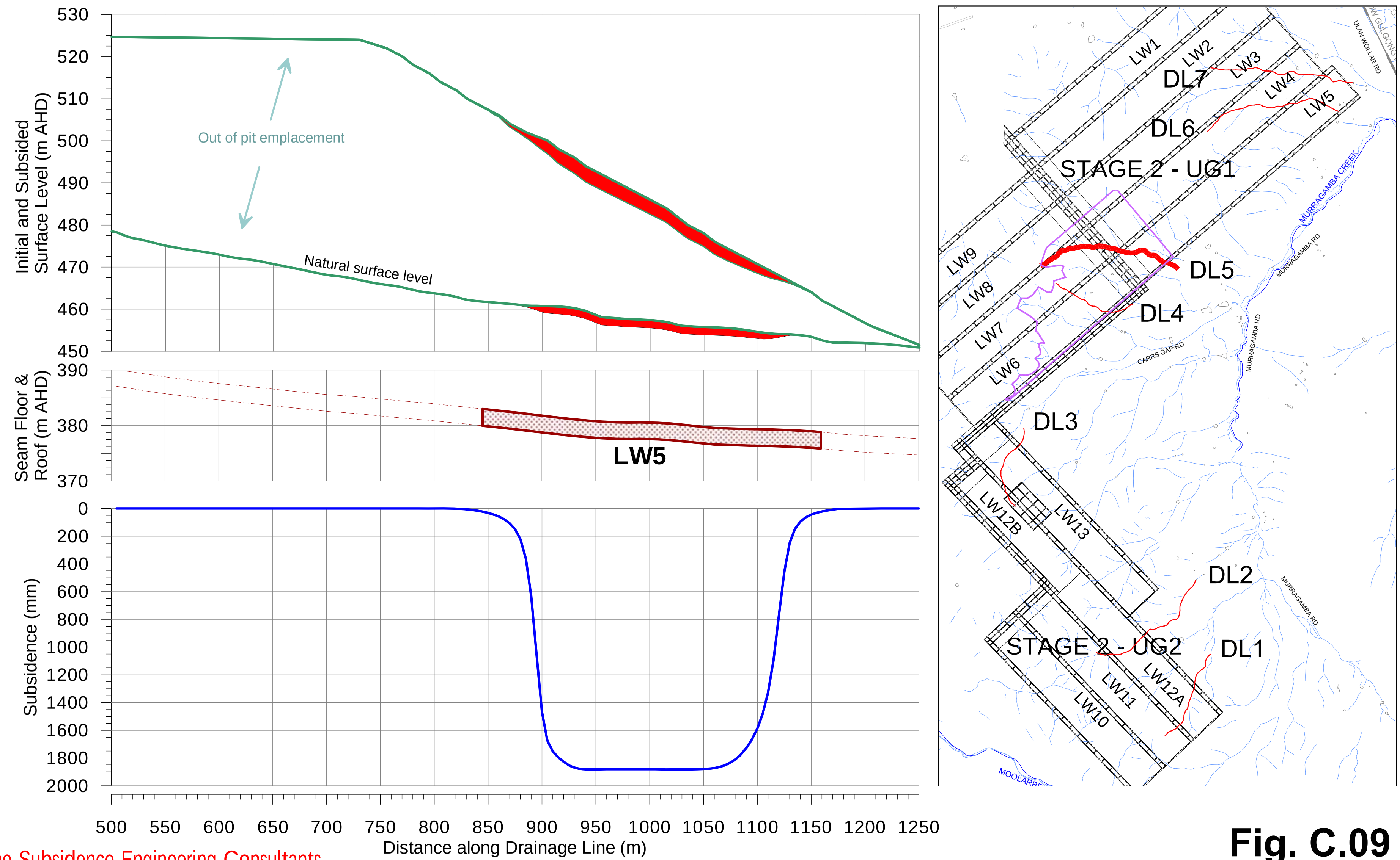


Mine Subsidence Engineering Consultants

Fig. C.08

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Drainage Lines\Fig C.09 Moolarben Drainage Lines - DL5 - Initial and Subsided surface levels Landscape.grf.....27-Jul-11

Moolarben Coal Project - Stage 2, Underground 1 and Underground 2 - Longwalls 1 to 13
Profiles of Initial and Subsided Surface Level, and Predicted Subsidence
Drainage Line DL5

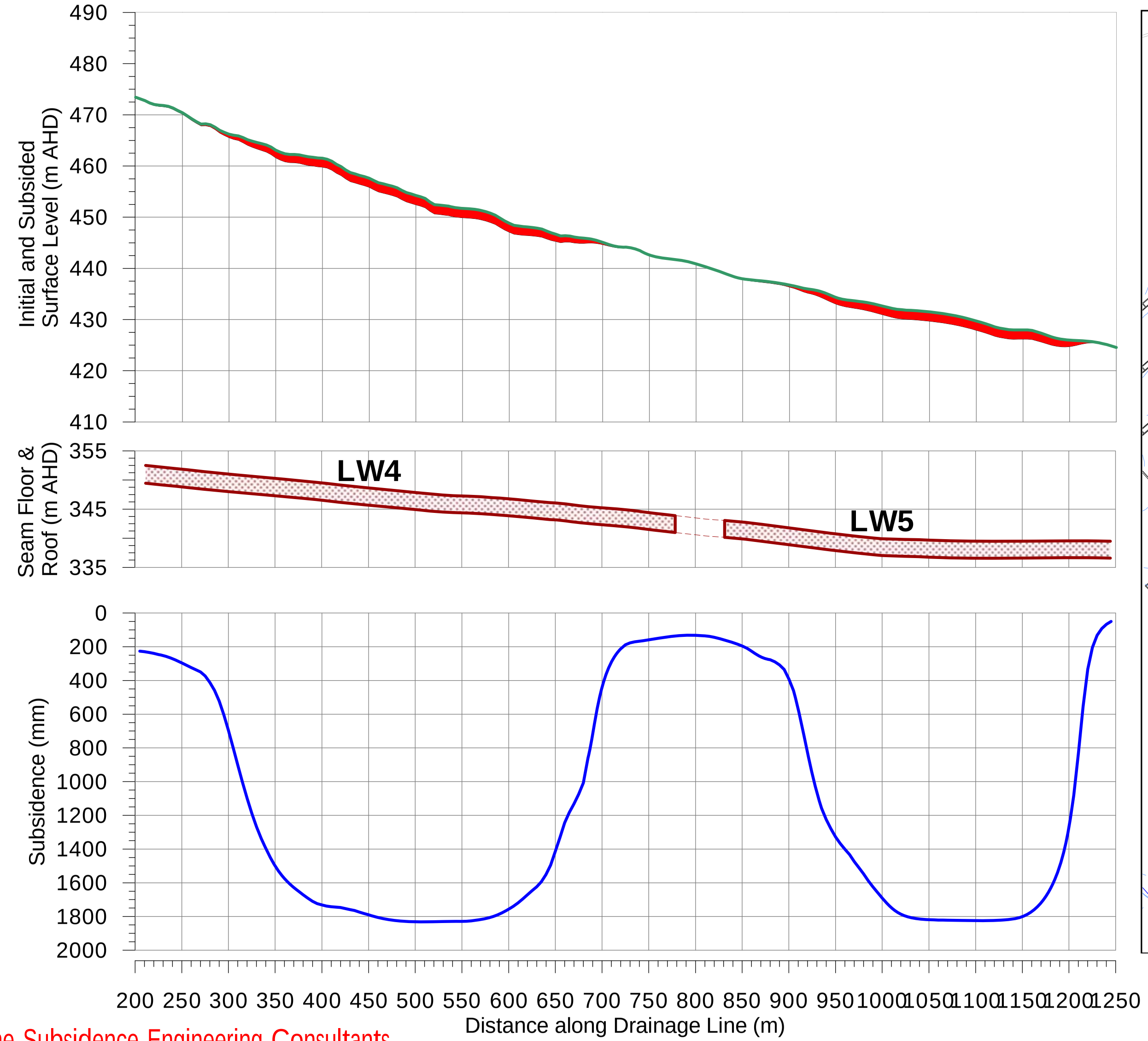


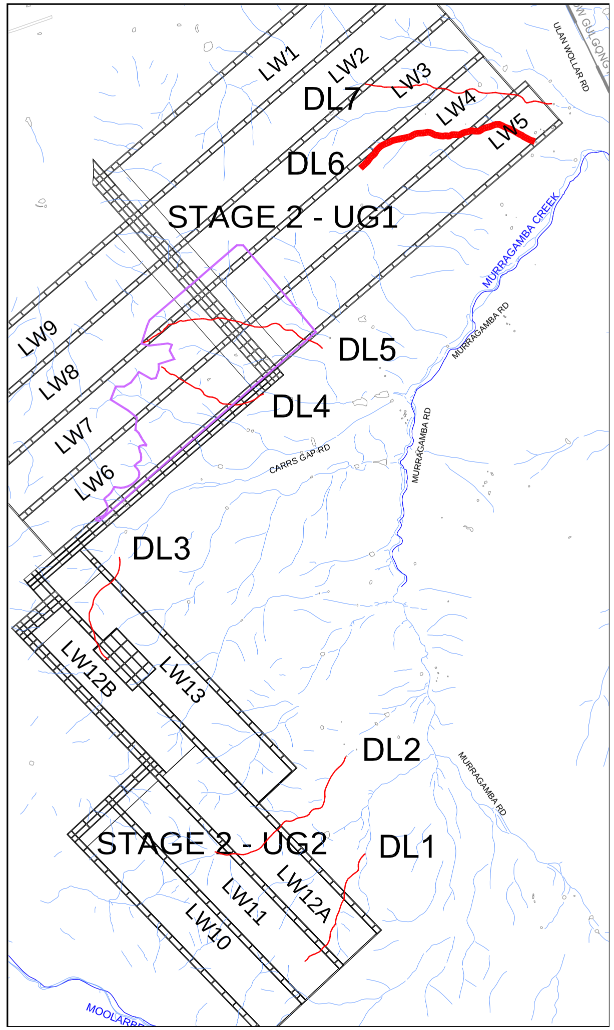
Mine Subsidence Engineering Consultants

Fig. C.09

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Drainage Lines\Fig C.10 Moolarben Drainage Lines - DL6 - Initial and Subsided surface levels Landscape.grf.....27-Jul-11

Moolarben Coal Project - Stage 2, Underground 1 and Underground 2 - Longwalls 1 to 13
Profiles of Initial and Subsided Surface Level, and Predicted Subsidence
Drainage Line DL6



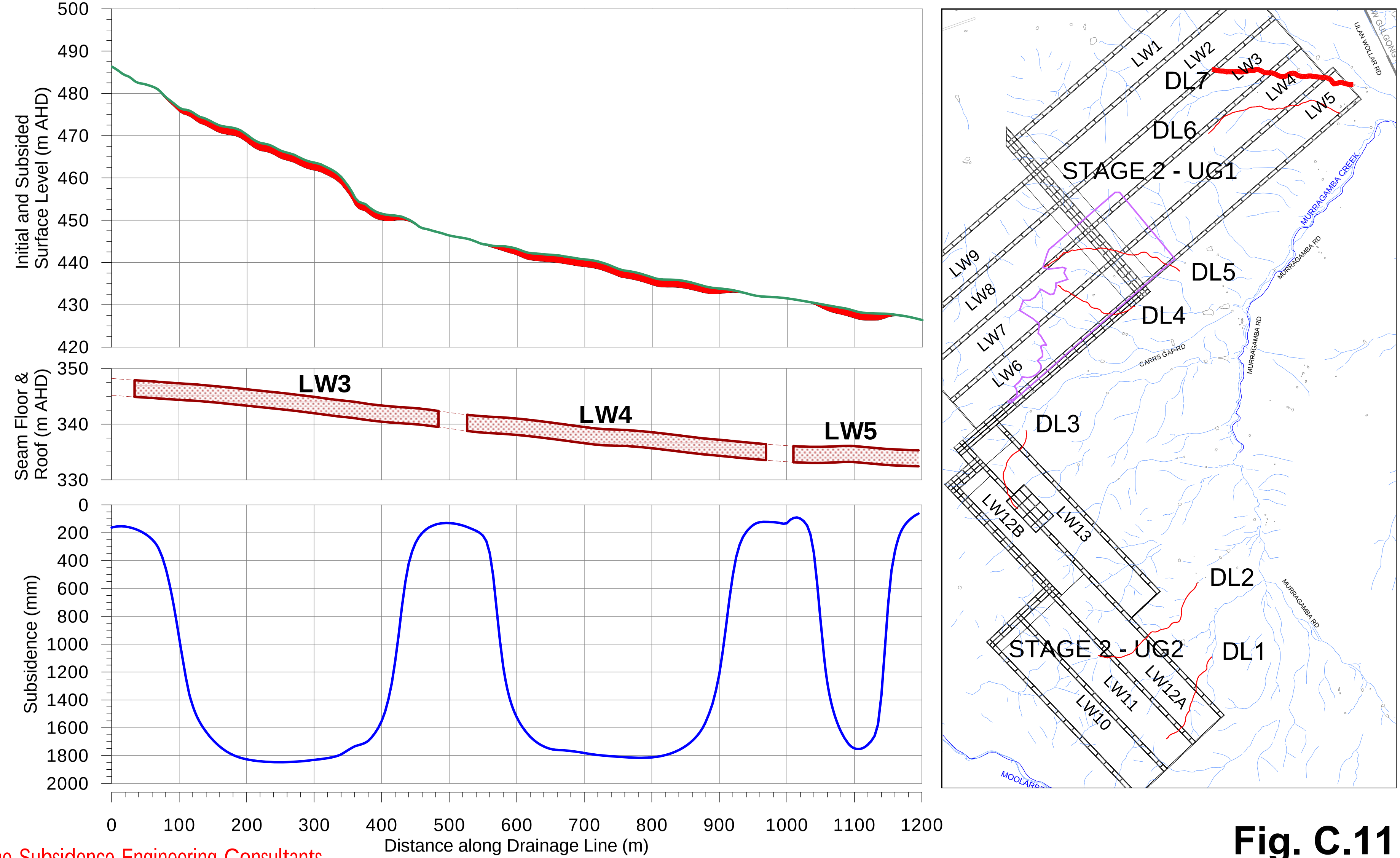


Mine Subsidence Engineering Consultants

Fig. C.10

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Drainage Lines\Fig C.11 Moolarben Drainage Lines - DL7 - Initial and Subsided surface levels Landscape.grf.....27-Jul-11

Moolarben Coal Project - Stage 2, Underground 1 and Underground 2 - Longwalls 1 to 13
Profiles of Initial and Subsided Surface Level, and Predicted Subsidence
Drainage Line DL7

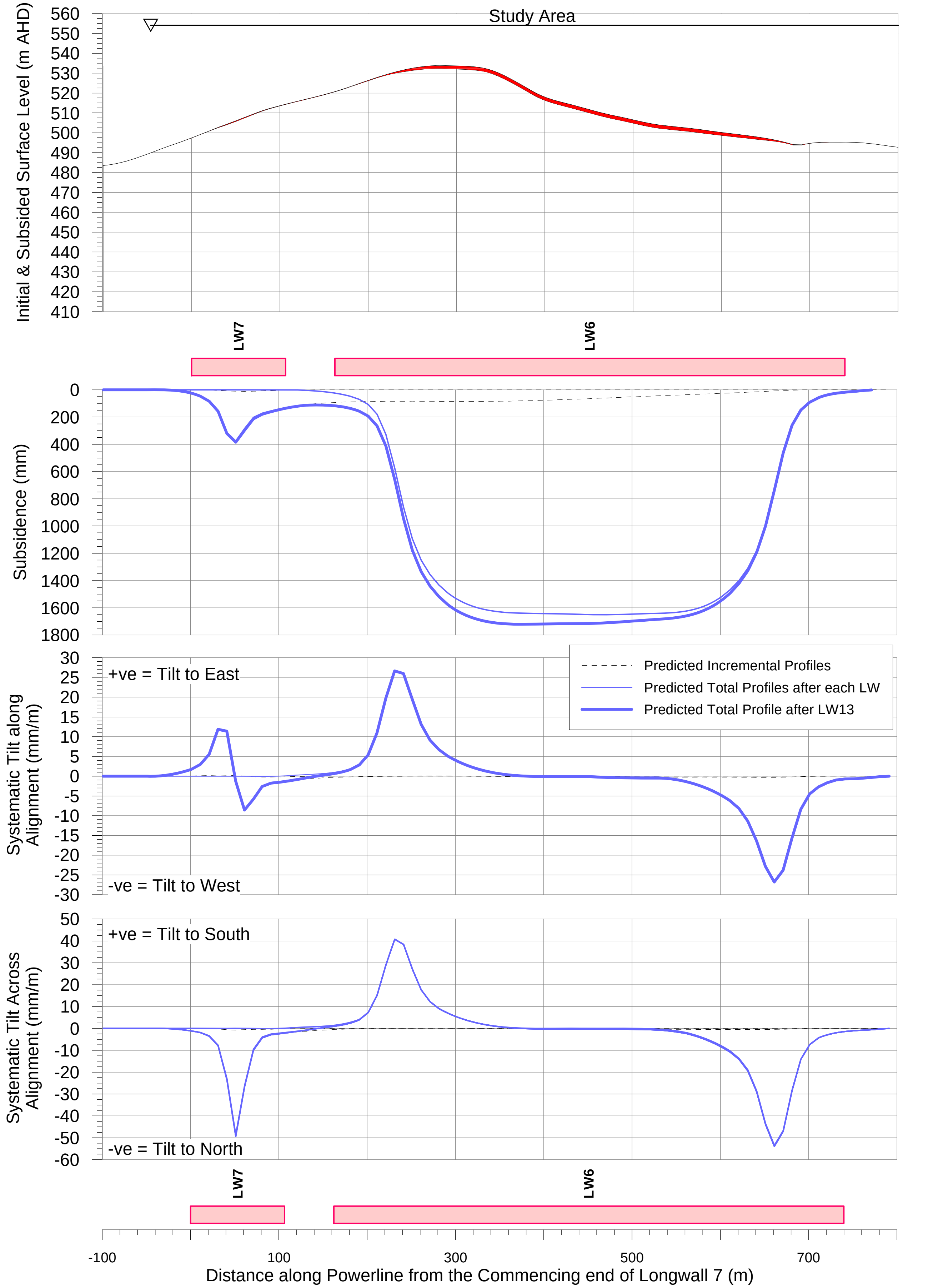


Mine Subsidence Engineering Consultants

Fig. C.11

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\powerline\Fig C.12 - powerline.grf.....09-Jul-08

Predicted Profiles of Systematic Subsidence, Tilt Along and Tilt Across the Alignment of the Powerline through UG1

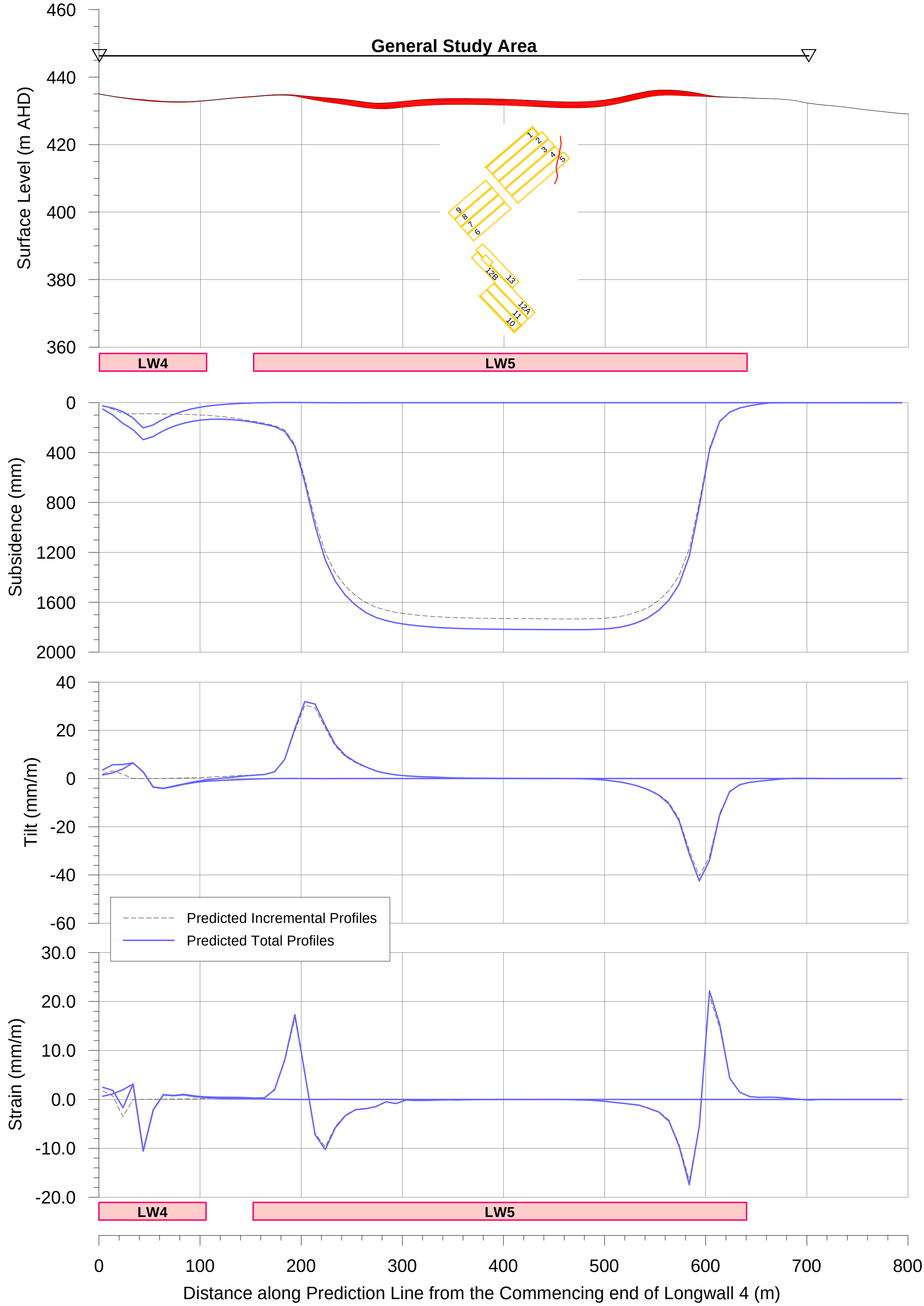


Mine Subsidence Engineering Consultants

Fig. C.12

I:\Projects\Moolarben\MSEC353 - Stage 2 MCP\Subsdata\Impacts\Roads\Fig C.13 Murragamba Road.grf.....09-Jul-08

Predicted Profiles of Systematic Subsidence, Tilt and Strain along Murragamba Road Resulting from the Extraction of Longwalls 1 to 13



Mine Subsidence Engineering Consultants

Fig. C.13

APPENDIX D. TABLES

Table D.01 - Moolarben Coal Project Stage 2 - Longwalls 1 to 13 Details and Predicted Systematic Subsidence Parameters for the Archaeological Sites

Label	Total Subs after LW1	Total Subs after LW2	Total Subs after LW3	Total Subs after LW4	Total Subs after LW5	Total Subs after LW6	Total Subs after LW7	Total Subs after LW8	Total Subs after LW9	Total Subs after LW10	Total Subs after LW11	Total Subs after LW12	Total Subs after LW13	Total Tilt after LW1	Total Tilt after LW2	Total Tilt after LW3	Total Tilt after LW4	Total Tilt after LW5
S1MC027	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
S1MC029	1449	1495	1495	1495	1495	1495	1495	1495	1495	1495	1495	1495	1495	34.0	34.5	34.5	34.5	34.5
S1MC074	0	0	0	0	0	0	0	0	0	1426	1494	1494	1494	0.0	0.0	0.0	0.0	0.0
S1MC075	0	0	0	0	0	0	0	0	0	1426	1492	1492	1492	0.0	0.0	0.0	0.0	0.0
S1MC076	0	0	0	0	0	0	0	0	0	1426	1492	1492	1492	0.0	0.0	0.0	0.0	0.0
S1MC077	0	0	0	0	0	0	0	0	0	828	861	861	861	0.0	0.0	0.0	0.0	0.0
S2MC005	0	0	0	1733	1816	1816	1816	1816	1816	1816	1816	1816	1816	0.0	0.0	0.0	3.1	2.9
S2MC006	0	0	0	1226	1320	1320	1320	1320	1320	1320	1320	1320	1320	0.0	0.0	0.0	45.3	45.3
S2MC007	0	0	0	1743	1817	1817	1817	1817	1817	1817	1817	1817	1817	0.0	0.0	0.0	0.6	1.1
S2MC008	0	844	939	939	939	939	939	939	939	939	939	939	939	0.0	34.5	34.5	34.5	34.5
S2MC009	0	161	261	261	261	261	261	261	261	261	261	261	261	0.0	7.6	7.2	7.2	7.2
S2MC010	0	40	195	219	219	219	219	219	219	219	219	219	219	0.0	3.0	4.0	4.5	4.5
S2MC011	0	3	436	472	472	472	472	472	472	472	472	472	472	0.0	0.7	24.3	24.8	24.8
S2MC012	0	139	240	241	241	241	241	241	241	241	241	241	241	0.0	6.8	6.4	6.3	6.3
S2MC229	0	0	0	0	851	851	851	851	851	851	851	851	851	0.0	0.0	0.0	0.0	47.6
S2MC230	0	0	0	0	1770	1770	1770	1770	1770	1770	1770	1770	1770	0.0	0.0	0.0	0.0	45.6
S2MC231	0	0	0	1697	1788	1788	1788	1788	1788	1788	1788	1788	1788	0.0	0.0	0.0	76.5	81.0
S2MC236	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
S2MC237	0	0	0	0	0	0	0	0	0	0	0	704	704	0.0	0.0	0.0	0.0	0.0
S2MC238	0	0	0	0	0	0	0	0	0	0	0	0	1568	0.0	0.0	0.0	0.0	0.0
S2MC239	0	0	0	0	0	0	0	0	0	0	0	0	1690	0.0	0.0	0.0	0.0	0.0

Table D.01 - Moolarben Coal Project Stage 2 - Longwalls 1 to 13 Details and Predicted Systematic Subsidence Parameters for the Archaeological Sites

Label	Total Tilt after LW6	Total Tilt after LW7	Total Tilt after LW8	Total Tilt after LW9	Total Tilt after LW10	Total Tilt after LW11	Total Tilt after LW12	Total Tilt after LW13	Maximum Predicted Tensile Strain during or after LW1	Maximum Predicted Tensile Strain during or after LW2	Maximum Predicted Tensile Strain during or after LW3	Maximum Predicted Tensile Strain during or after LW4	Maximum Predicted Tensile Strain during or after LW5	Maximum Predicted Tensile Strain during or after LW6
S1MC027	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S1MC029	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	15.4	15.4	15.4	15.4	15.4	15.4
S1MC074	0.0	0.0	0.0	0.0	38.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
S1MC075	0.0	0.0	0.0	0.0	38.5	0.8	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0
S1MC076	0.0	0.0	0.0	0.0	38.5	0.8	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0
S1MC077	0.0	0.0	0.0	0.0	44.7	45.1	45.1	45.1	0.0	0.0	0.0	0.0	0.0	0.0
S2MC005	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	0.0	0.0	0.0	21.1	1.4	0.0
S2MC006	45.3	45.3	45.3	45.3	45.3	45.3	45.3	45.3	0.0	0.0	0.0	31.0	31.1	31.1
S2MC007	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.0	0.0	0.0	21.2	1.1	0.0
S2MC008	34.5	34.5	34.5	34.5	34.5	34.5	34.5	34.5	0.0	11.0	11.1	11.1	11.1	11.1
S2MC009	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	0.0	2.6	2.8	2.8	2.8	2.8
S2MC010	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	0.0	1.5	2.5	2.5	2.5	2.5
S2MC011	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8	0.0	0.7	16.8	16.8	16.8	16.8
S2MC012	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	0.0	2.3	2.5	2.6	2.6	2.6
S2MC229	47.6	47.6	47.6	47.6	47.6	47.6	47.6	47.6	0.0	0.0	0.0	0.0	23.0	23.0
S2MC230	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	0.0	0.0	0.0	0.0	25.6	0.0
S2MC231	81.0	81.0	81.0	81.0	81.0	81.0	81.0	81.0	0.0	0.0	0.0	67.8	71.4	71.4
S2MC236	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC237	0.0	0.0	0.0	0.0	0.0	0.0	33.2	33.2	0.0	0.0	0.0	0.0	0.0	0.0
S2MC238	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.3	0.0	0.0	0.0	0.0	0.0	0.0
S2MC239	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.7	0.0	0.0	0.0	0.0	0.0	0.0

Table D.01 - Moolarben Coal Project Stage 2 - Longwalls 1 to 13 Details and Predicted Systematic Subsidence Parameters for the Archaeological Sites

Label	Maximum Predicted Tensile Strain during or after LW7	Maximum Predicted Tensile Strain during or after LW8	Maximum Predicted Tensile Strain during or after LW9	Maximum Predicted Tensile Strain during or after LW10	Maximum Predicted Tensile Strain during or after LW11	Maximum Predicted Tensile Strain during or after LW12	Maximum Predicted Tensile Strain during or after LW13	Maximum Predicted Comp. Strain during or after LW1	Maximum Predicted Comp. Strain during or after LW2	Maximum Predicted Comp. Strain during or after LW3	Maximum Predicted Comp. Strain during or after LW4
S1MC027	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S1MC029	15.4	15.4	15.4	15.4	15.4	15.4	15.4	-13.6	-13.6	-13.6	-13.6
S1MC074	0.0	0.0	0.0	29.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0
S1MC075	0.0	0.0	0.0	29.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0
S1MC076	0.0	0.0	0.0	29.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0
S1MC077	0.0	0.0	0.0	20.4	20.5	20.5	20.5	0.0	0.0	0.0	0.0
S2MC005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-14.8
S2MC006	31.1	31.1	31.1	31.1	31.1	31.1	31.1	0.0	0.0	0.0	-25.0
S2MC007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-15.0
S2MC008	11.1	11.1	11.1	11.1	11.1	11.1	11.1	0.0	-1.3	-0.6	0.0
S2MC009	2.8	2.8	2.8	2.8	2.8	2.8	2.8	0.0	-0.2	-0.7	0.0
S2MC010	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0.0	0.0	-0.9	-0.1
S2MC011	16.8	16.8	16.8	16.8	16.8	16.8	16.8	0.0	-0.1	-1.3	-0.2
S2MC012	2.6	2.6	2.6	2.6	2.6	2.6	2.6	0.0	-0.2	-0.7	-0.1
S2MC229	23.0	23.0	23.0	23.0	23.0	23.0	23.0	0.0	0.0	0.0	0.0
S2MC230	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC231	71.4	71.4	71.4	71.4	71.4	71.4	71.4	0.0	0.0	0.0	-55.3
S2MC236	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC237	0.0	0.0	0.0	0.0	0.0	14.3	6.1	0.0	0.0	0.0	0.0
S2MC238	0.0	0.0	0.0	0.0	0.0	0.0	35.1	0.0	0.0	0.0	0.0
S2MC239	0.0	0.0	0.0	0.0	0.0	0.0	27.5	0.0	0.0	0.0	0.0

Table D.01 - Moolarben Coal Project Stage 2 - Longwalls 1 to 13 Details and Predicted Systematic Subsidence Parameters for the Archaeological Sites

Label	Maximum Predicted Comp. Strain during or after LW5	Maximum Predicted Comp. Strain during or after LW6	Maximum Predicted Comp. Strain during or after LW7	Maximum Predicted Comp. Strain during or after LW8	Maximum Predicted Comp. Strain during or after LW9	Maximum Predicted Comp. Strain during or after LW10	Maximum Predicted Comp. Strain during or after LW11	Maximum Predicted Comp. Strain during or after LW12	Maximum Predicted Comp. Strain during or after LW13
S1MC027	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S1MC029	-13.6	-13.6	-13.6	-13.6	-13.6	-13.6	-13.6	-13.6	-13.6
S1MC074	0.0	0.0	0.0	0.0	0.0	-29.1	-0.6	-0.3	-0.3
S1MC075	0.0	0.0	0.0	0.0	0.0	-29.1	-0.6	-0.5	-0.5
S1MC076	0.0	0.0	0.0	0.0	0.0	-29.1	-0.6	-0.5	-0.5
S1MC077	0.0	0.0	0.0	0.0	0.0	-19.4	-19.4	-19.4	-19.4
S2MC005	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8
S2MC006	-25.0	-25.0	-25.0	-25.0	-25.0	-25.0	-25.0	-25.0	-25.0
S2MC007	-0.9	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
S2MC008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC229	-2.8	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
S2MC230	-24.3	-24.3	-24.3	-24.3	-24.3	-24.3	-24.3	-24.3	-24.3
S2MC231	-58.1	-58.1	-58.1	-58.1	-58.1	-58.1	-58.1	-58.1	-58.1
S2MC236	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S2MC237	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-11.0	0.0
S2MC238	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-23.5
S2MC239	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-23.3

Table D.02 - Moolarben Coal Project Stage 2 - Longwalls 1 to 13
Predicted Systematic Subsidence Parameters for the Farm Dams

Code	Total Subs after LW1	Total Subs after LW2	Total Subs after LW3	Total Subs after LW4	Total Subs after LW5	Total Subs after LW6	Total Subs after LW7	Total Subs after LW8	Total Subs after LW9	Total Subs after LW10	Total Subs after LW11	Total Subs after LW12	Total Subs after LW13
A01d02	0	0	0	0	6	6	6	6	6	6	6	6	6
A01d04	0	0	0	0	80	80	80	80	80	80	80	80	80
A01d05	0	0	0	0	0	0	0	0	0	0	0	0	0
A02d01	0	0	0	6	13	13	13	13	13	13	13	13	13
A02d02	0	0	0	1733	1811	1811	1811	1811	1811	1811	1811	1811	1811
A02d03	0	293	388	388	388	388	388	388	388	388	388	388	388
A03d01	0	0	0	1820	1914	1914	1914	1914	1914	1914	1914	1914	1914
A04d01	0	0	0	0	0	0	0	0	0	0	0	0	0
A04d02	0	0	0	0	0	0	0	0	0	0	0	0	0
A04d03	0	0	0	0	0	0	0	0	0	0	0	0	0
A04d04	0	0	0	0	0	1768	1856	1856	1856	1856	1856	1856	1856
A04d05	0	0	0	0	0	0	0	0	0	0	0	0	0
A05d01	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D.02 - Moolarben Coal Project Stage 2 - Longwalls 1 to 13
Predicted Systematic Subsidence Parameters for the Farm Dams

Code	Total Tilt after LW1	Total Tilt after LW2	Total Tilt after LW3	Total Tilt after LW4	Total Tilt after LW5	Total Tilt after LW6	Total Tilt after LW7	Total Tilt after LW8	Total Tilt after LW9	Total Tilt after LW10	Total Tilt after LW11	Total Tilt after LW12	Total Tilt after LW13
A01d02	0.0	0.0	0.0	0.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
A01d04	0.0	0.0	0.0	0.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
A01d05	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
A02d01	0.0	0.0	0.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
A02d02	0.0	0.0	0.0	3.5	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
A02d03	0.0	12.8	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
A03d01	0.0	0.0	0.0	36.2	36.2	36.2	36.2	36.2	36.2	36.2	36.2	36.2	36.2
A04d01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d04	0.0	0.0	0.0	0.0	0.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
A04d05	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
A05d01	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Table D.02 - Moolarben Coal Project Stage 2 - Longwalls 1 to 13
Predicted Systematic Subsidence Parameters for the Farm Dams

Code	Maximum Predicted Tensile Strain during or after LW1	Maximum Predicted Tensile Strain during or after LW2	Maximum Predicted Tensile Strain during or after LW3	Maximum Predicted Tensile Strain during or after LW4	Maximum Predicted Tensile Strain during or after LW5	Maximum Predicted Tensile Strain during or after LW6	Maximum Predicted Tensile Strain during or after LW7	Maximum Predicted Tensile Strain during or after LW8	Maximum Predicted Tensile Strain during or after LW9	Maximum Predicted Tensile Strain during or after LW10	Maximum Predicted Tensile Strain during or after LW11	Maximum Predicted Tensile Strain during or after LW12	Maximum Predicted Tensile Strain during or after LW13
A01d02	0.0	0.0	0.0	0.0	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
A01d04	0.0	0.0	0.0	0.0	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
A01d05	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
A02d01	0.0	0.0	0.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
A02d02	0.0	0.0	0.0	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1
A02d03	0.0	6.2	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
A03d01	0.0	0.0	0.0	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1
A04d01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d04	0.0	0.0	0.0	0.0	0.0	31.1	31.1	31.1	31.1	31.1	31.1	31.1	31.1
A04d05	0.0	0.0	0.0	0.0	0.0	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
A05d01	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table D.02 - Moolarben Coal Project Stage 2 - Longwalls 1 to 13
Predicted Systematic Subsidence Parameters for the Farm Dams

Code	Maximum Predicted Comp. Strain during or after LW1	Maximum Predicted Comp. Strain during or after LW2	Maximum Predicted Comp. Strain during or after LW3	Maximum Predicted Comp. Strain during or after LW4	Maximum Predicted Comp. Strain during or after LW5	Maximum Predicted Comp. Strain during or after LW6	Maximum Predicted Comp. Strain during or after LW7	Maximum Predicted Comp. Strain during or after LW8	Maximum Predicted Comp. Strain during or after LW9	Maximum Predicted Comp. Strain during or after LW10	Maximum Predicted Comp. Strain during or after LW11	Maximum Predicted Comp. Strain during or after LW12	Maximum Predicted Comp. Strain during or after LW13
A01d02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A01d04	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
A01d05	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
A02d01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A02d02	0.0	0.0	0.0	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9
A02d03	0.0	-0.5	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
A03d01	0.0	0.0	0.0	-14.8	-14.8	-14.8	-14.8	-14.8	-14.8	-14.8	-14.8	-14.8	-14.8
A04d01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A04d04	0.0	0.0	0.0	0.0	0.0	-25.7	-25.7	-25.7	-25.7	-25.7	-25.7	-25.7	-25.7
A04d05	0.0	0.0	0.0	0.0	0.0	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
A05d01	0.0	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3

APPENDIX E. DRAWINGS

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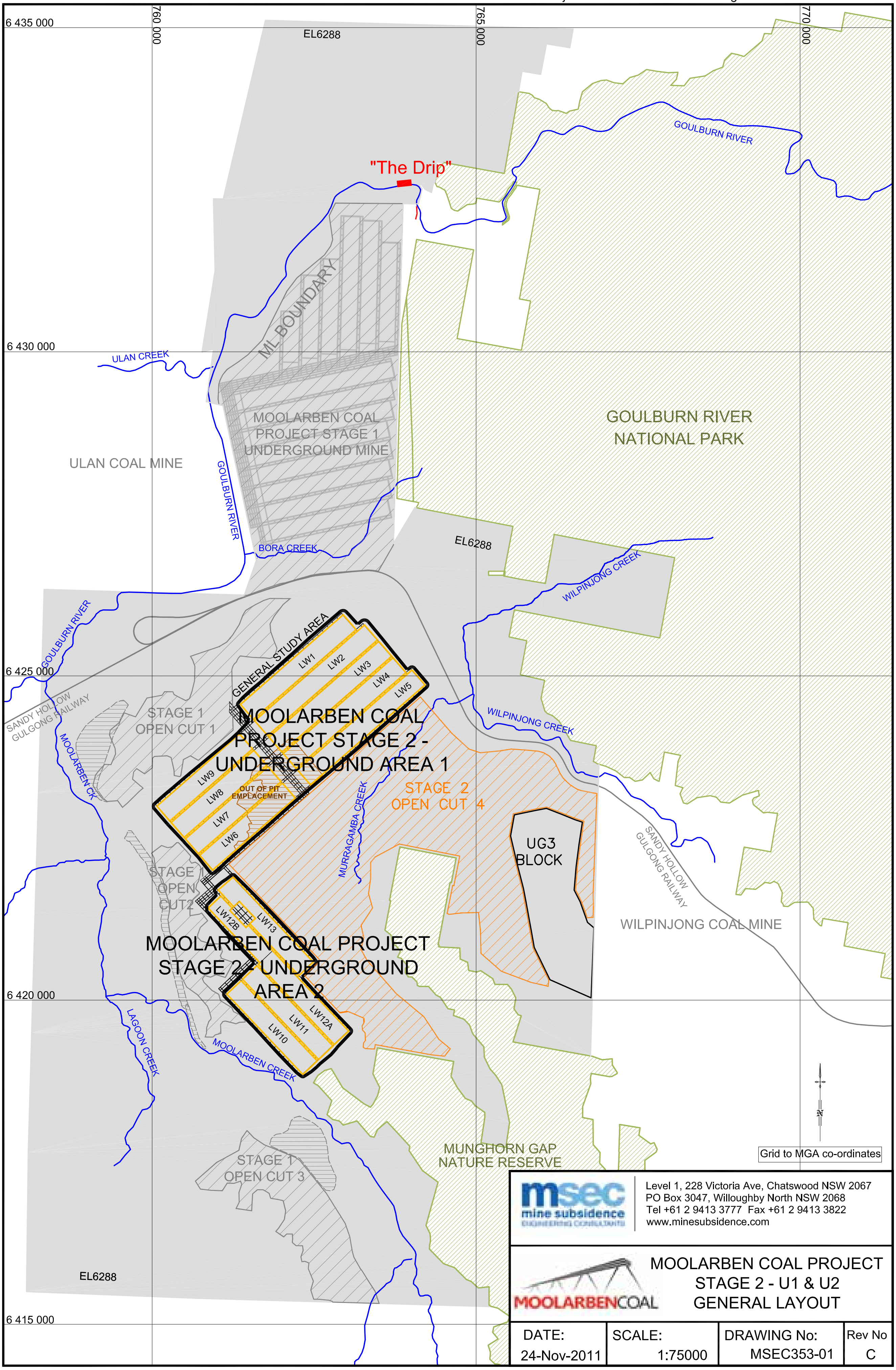

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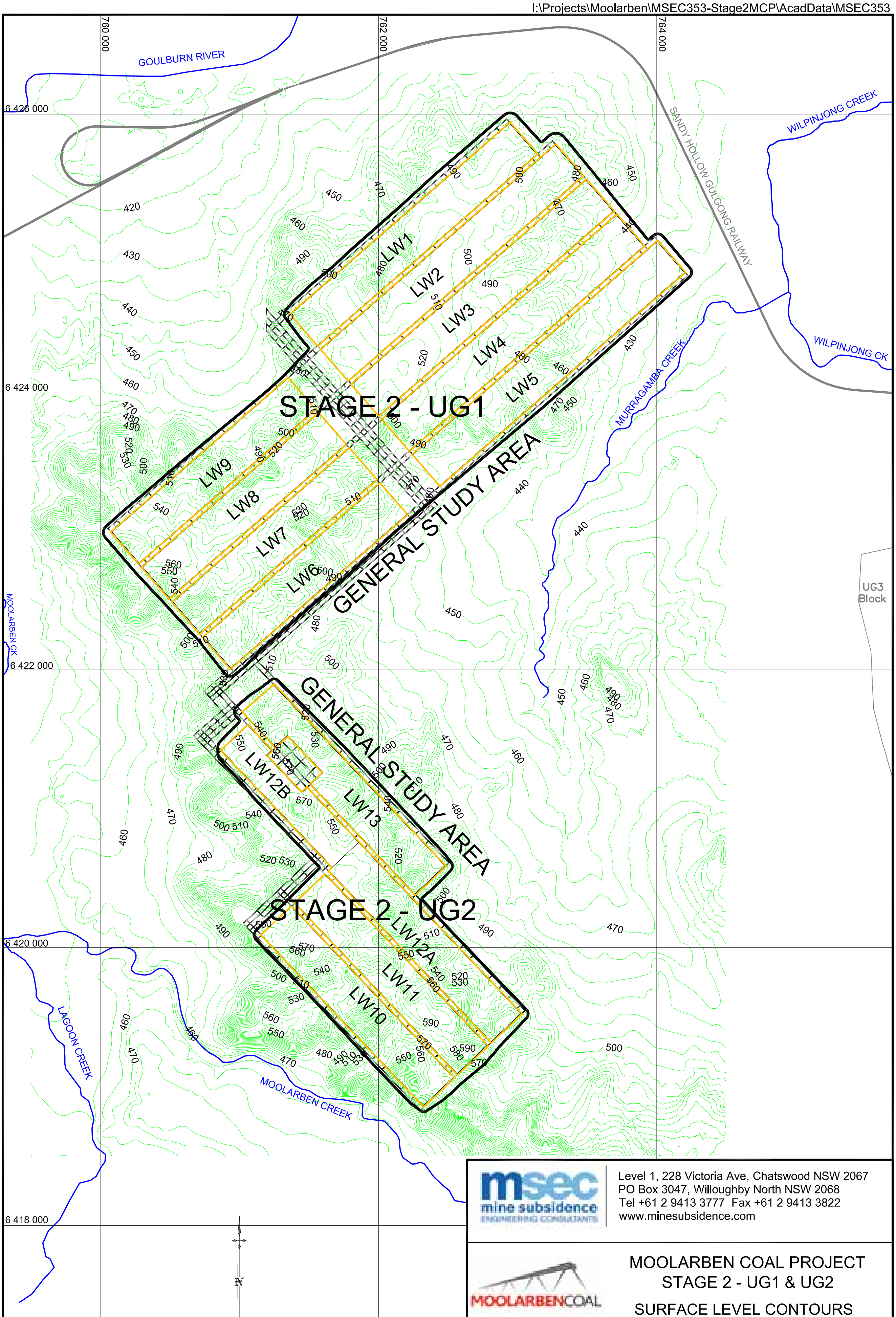

Grid to MGA co-ordinates

SURFACE LEVEL CONTOURS ARE IN m AHD

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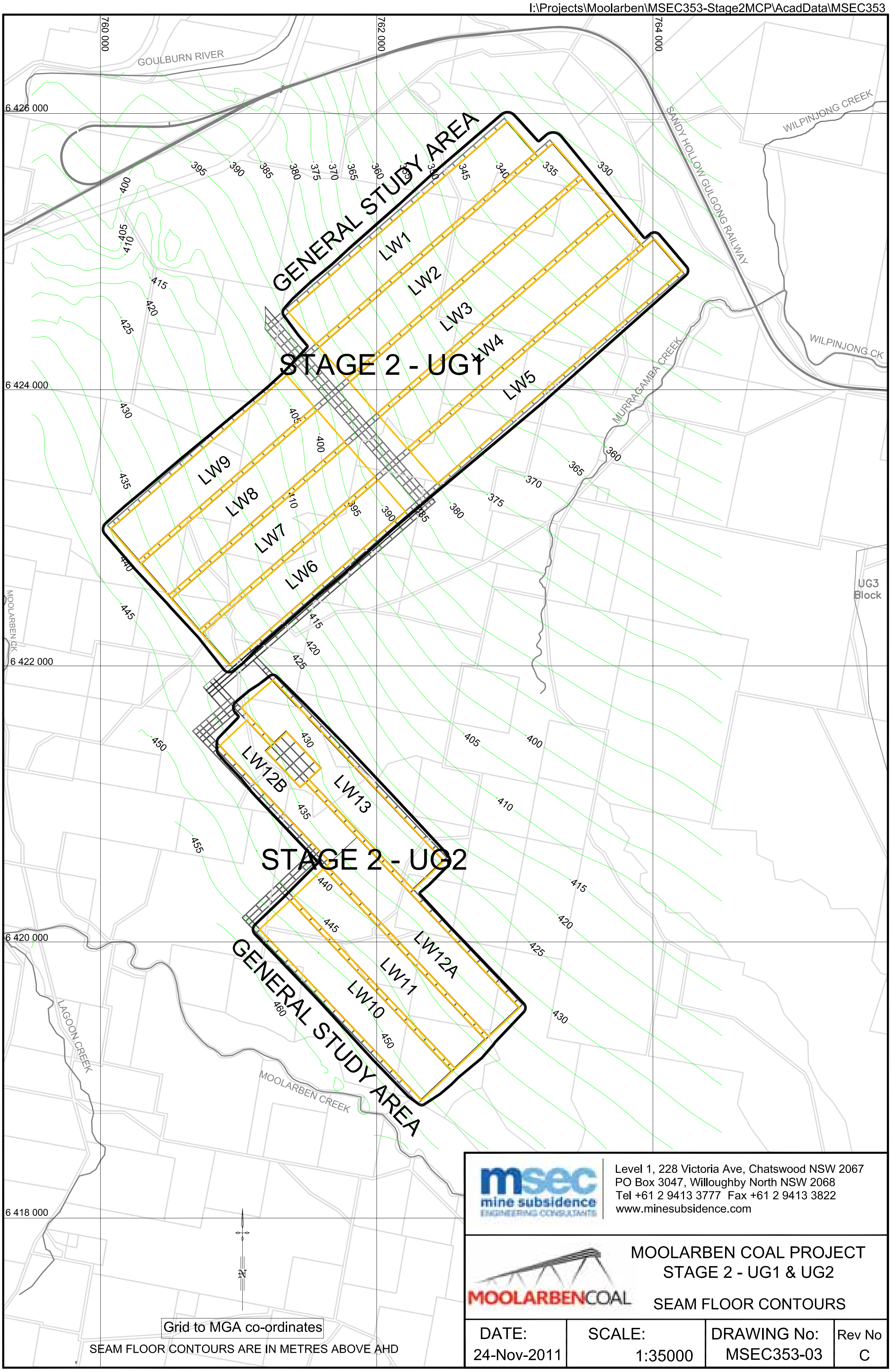
MOOLARBEN COAL PROJECT
STAGE 2 - UG1 & UG2
SURFACE LEVEL CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
24-Nov-2011	1:35000	MSEC353-02	C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GOULBURN RIVER
WILPINJONG CREEK
SANDY HOLLOW GULGONG RAILWAY
WILPINJONG CK
MURRAGAMBA CREEK
UG3 Block
MOOLARBEN CK
LAGOON CREEK
MOOLARBEN CREEK
GENERAL STUDY AREA
STAGE 2 - UG1
STAGE 2 - UG2
LW1
LW2
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12A
LW12B
LW13
Grid to MGA co-ordinates
SEAM FLOOR CONTOURS ARE IN METRES ABOVE AHD
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MOOLARBEN COAL PROJECT
STAGE 2 - UG1 & UG2
SEAM FLOOR CONTOURS
DATE: 24-Nov-2011
SCALE: 1:35000
DRAWING No: MSEC353-03
Rev No C

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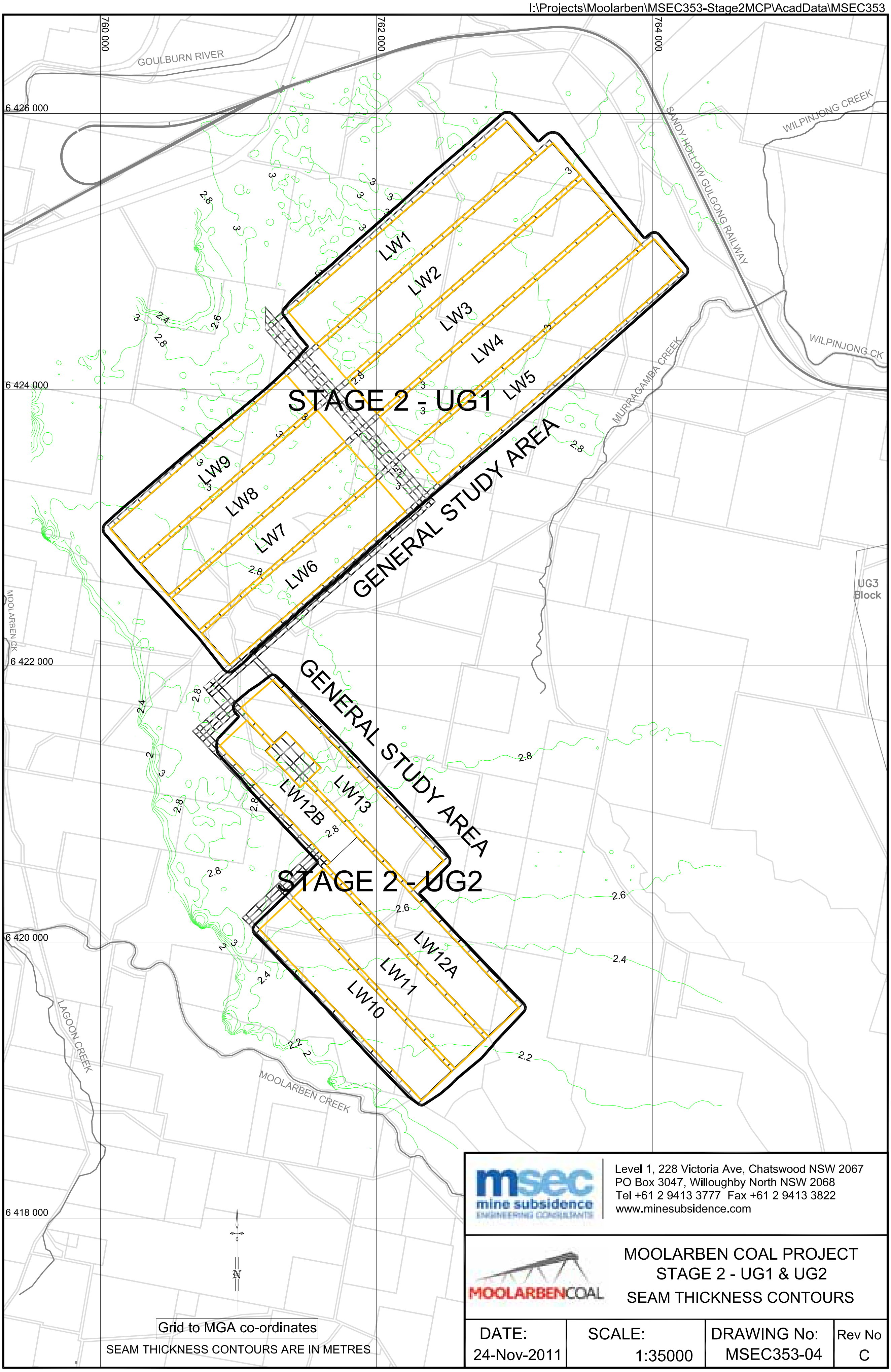

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MOOLARBEN COAL PROJECT
STAGE 2 - UG1 & UG2
SEAM THICKNESS CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
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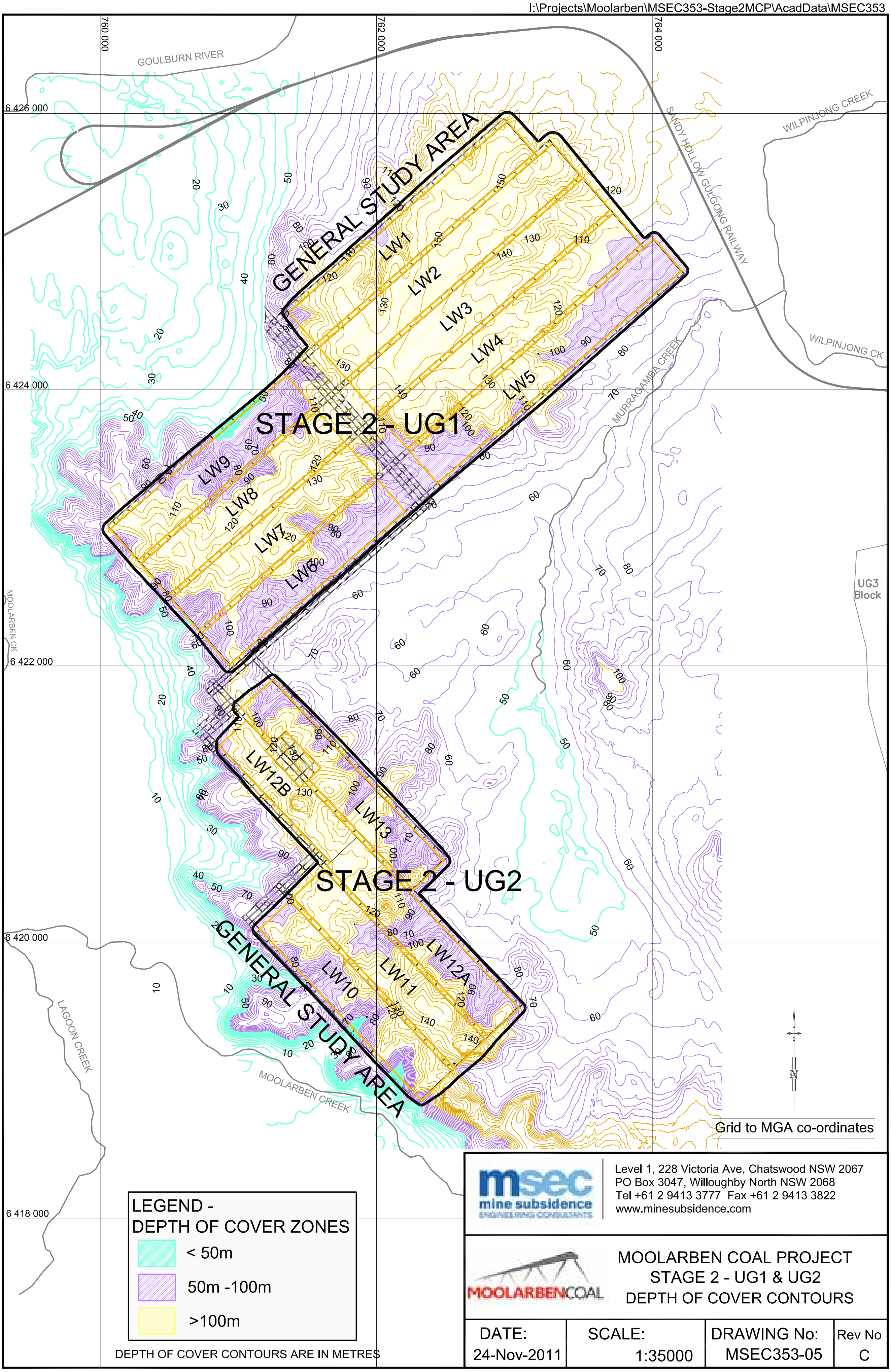

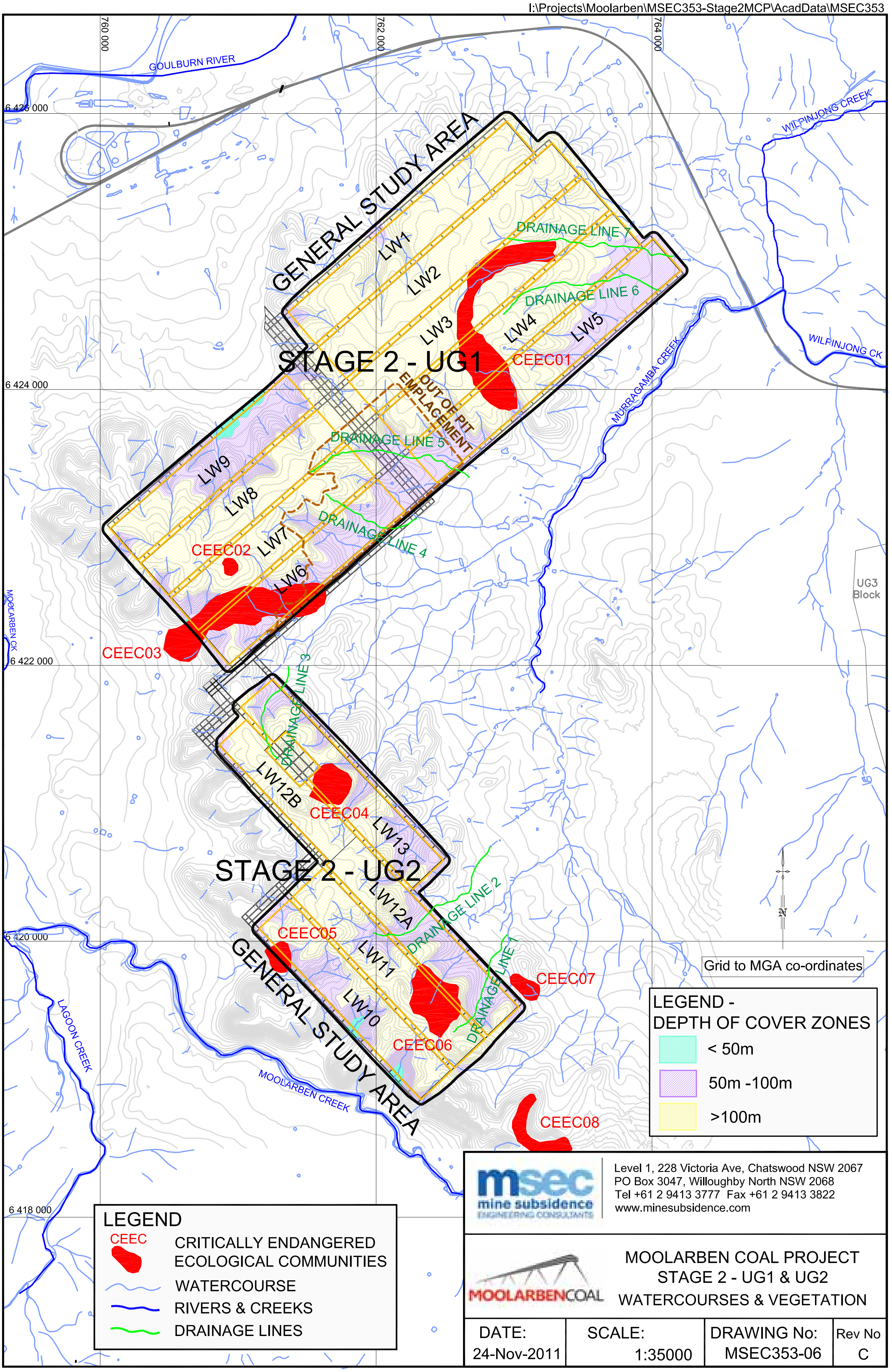
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764 000
6 426 000
6 424 000
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6 420 000
6 418 000
GOULBURN RIVER
WILPINJONG CREEK
WILPINJONG CK
MURRAGAMBA CREEK
MOOLARBEN CK
LAGOON CREEK
MOOLARBEN CREEK
GENERAL STUDY AREA
STAGE 2 - UG1
STAGE 2 - UG2
LW1
LW2
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12A
LW12B
LW13
OUT OF PIT EMPLACEMENT
DRAINAGE LINE 1
DRAINAGE LINE 2
DRAINAGE LINE 3
DRAINAGE LINE 4
DRAINAGE LINE 5
DRAINAGE LINE 6
DRAINAGE LINE 7
CEEC01
CEEC02
CEEC03
CEEC04
CEEC05
CEEC06
CEEC07
CEEC08
UG3 Block
Grid to MGA co-ordinates
LEGEND - DEPTH OF COVER ZONES
< 50m
50m -100m
>100m
LEGEND
CEEC
CRITICALLY ENDANGERED ECOLOGICAL COMMUNITIES
WATERCOURSE
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STAGE 2 - UG1 & UG2
WATERCOURSES & VEGETATION
DATE:
24-Nov-2011
SCALE:
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DRAWING No:
MSEC353-06
Rev No
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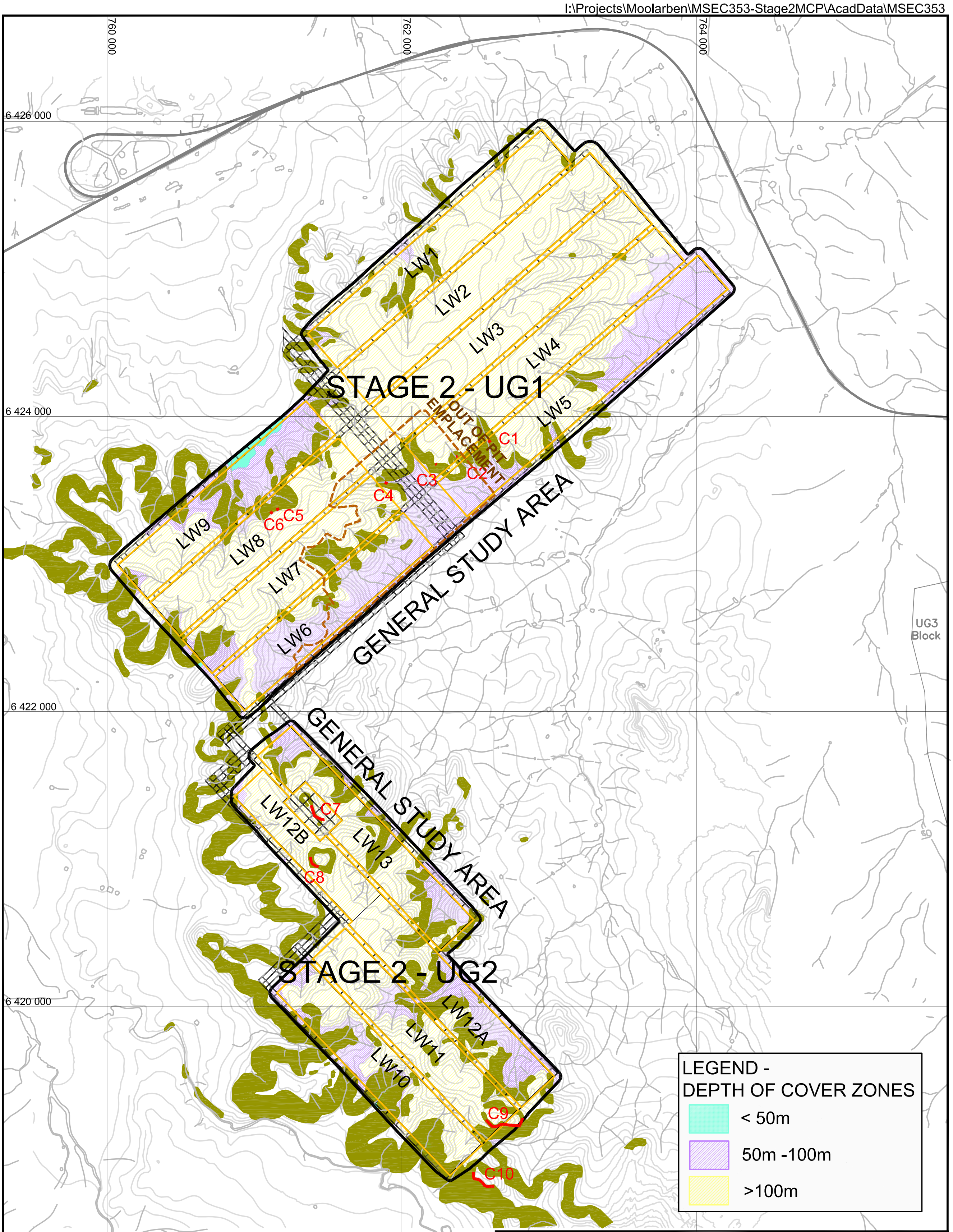

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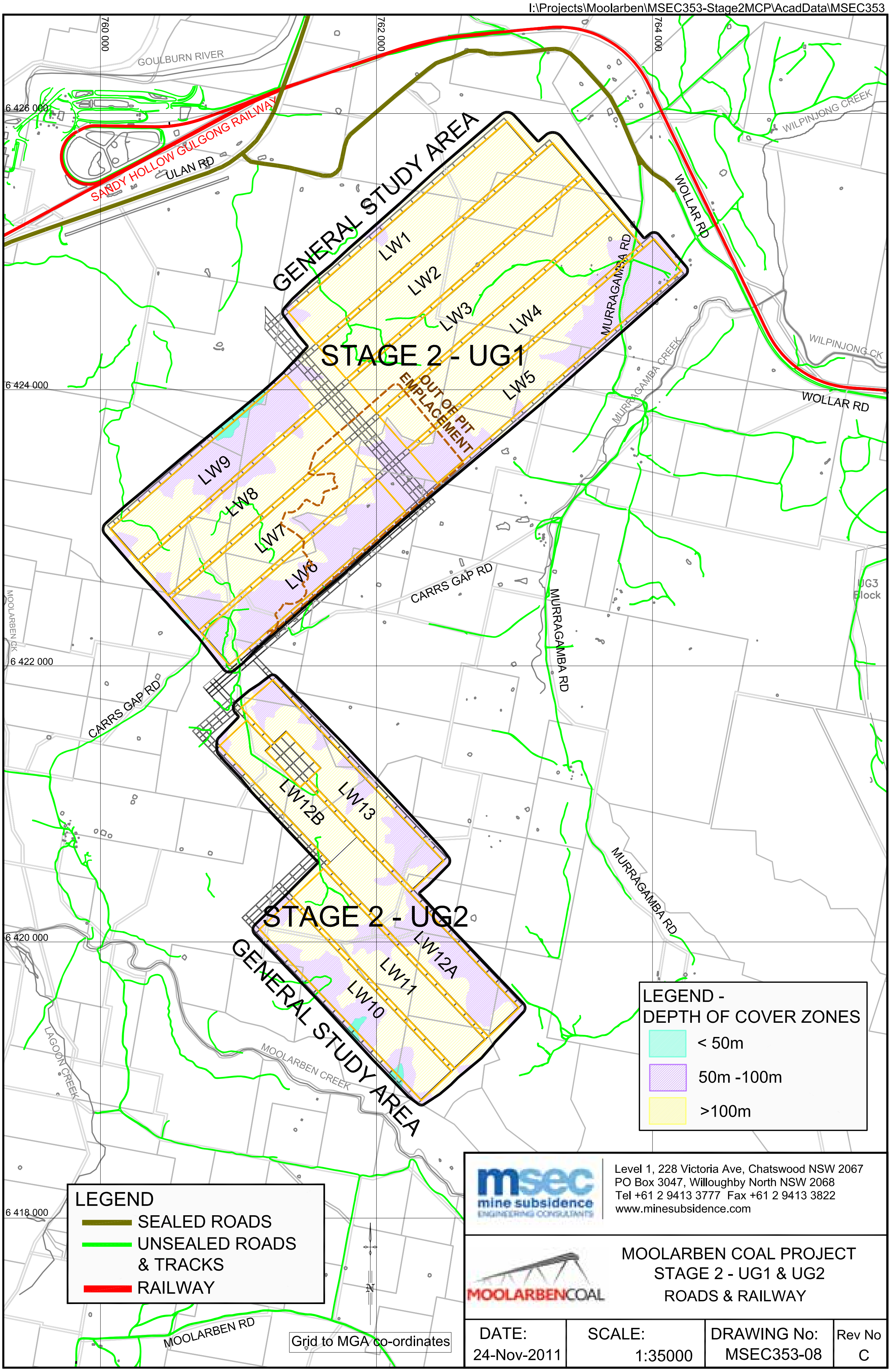
MOOLARBEN COAL PROJECT
STAGE 2 - UG1 & UG2
CLIFFS & STEEP SLOPES

DATE:	SCALE:	DRAWING No:	Rev No
24-Nov-2011	1:35000	MSEC353-07	C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760 000
762 000
764 000
6 426 000
6 424 000
6 422 000
6 420 000
6 418 000
GOULBURN RIVER
SANDY HOLLOW GULGONG RAILWAY
ULAN RD
GENERAL STUDY AREA
WILPINJONG CREEK
WOLLAR RD
WILPINJONG CK
WOLLAR RD
LW1
LW2
LW3
LW4
LW5
MURRAGAMBA RD
STAGE 2 - UG1
OUT OF PIT EMPLACEMENT
MURRAGAMBA CREEK
LW9
LW8
LW7
LW6
CARRS GAP RD
MURRAGAMBA RD
UG3 Block
MOOLARBEN CK
CARRS GAP RD
LW12B
LW13
MURRAGAMBA RD
STAGE 2 - UG2
LW12A
LW11
LW10
GENERAL STUDY AREA
LAGOON CREEK
MOOLARBEN CREEK
LEGEND - DEPTH OF COVER ZONES
< 50m
50m -100m
>100m
LEGEND
SEALED ROADS
UNSEALED ROADS & TRACKS
RAILWAY
N
MOOLARBEN RD
Grid to MGA co-ordinates
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MOOLARBENCOAL
MOOLARBEN COAL PROJECT
STAGE 2 - UG1 & UG2
ROADS & RAILWAY
DATE: 24-Nov-2011
SCALE: 1:35000
DRAWING No: MSEC353-08
Rev No C

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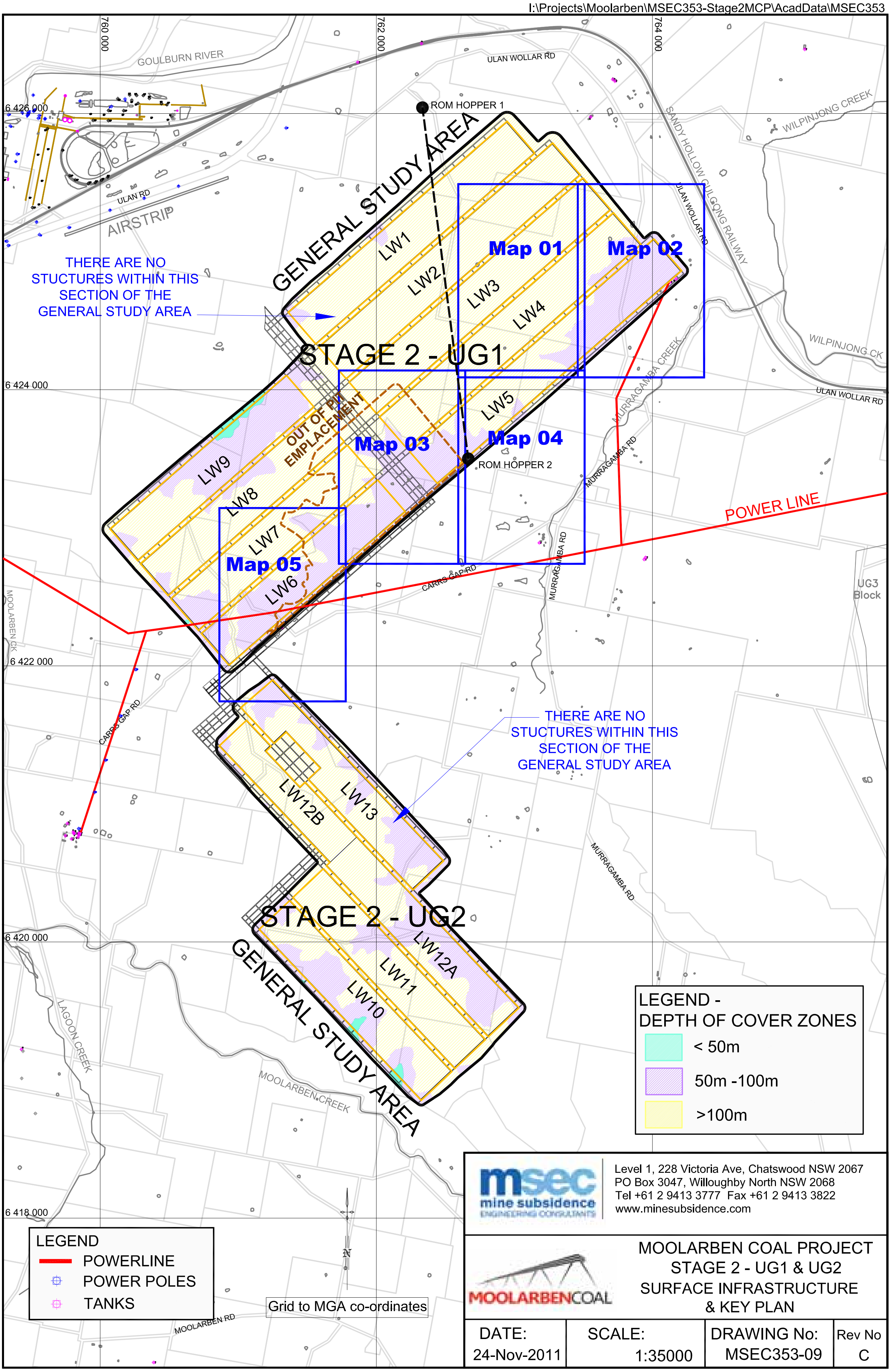

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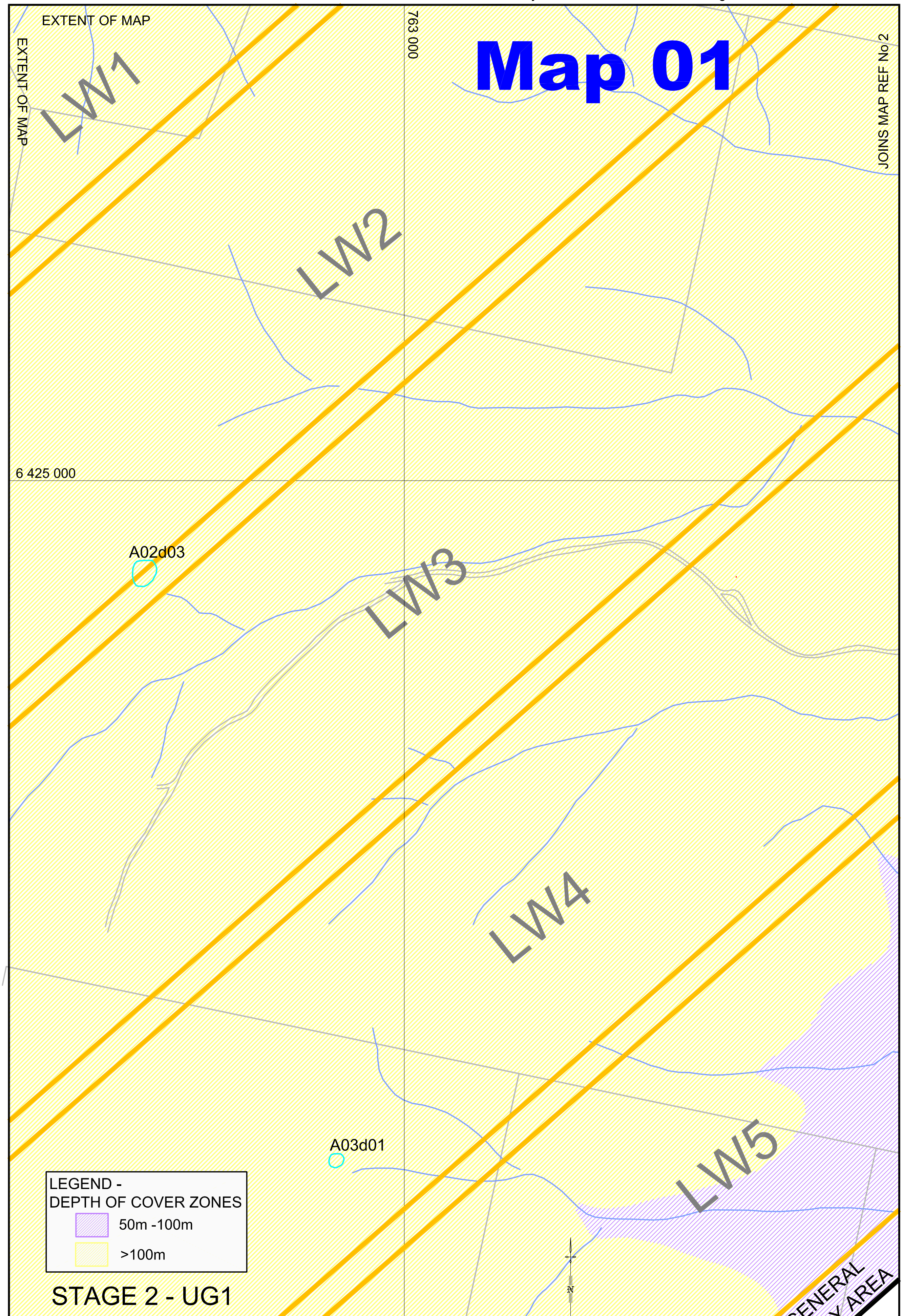

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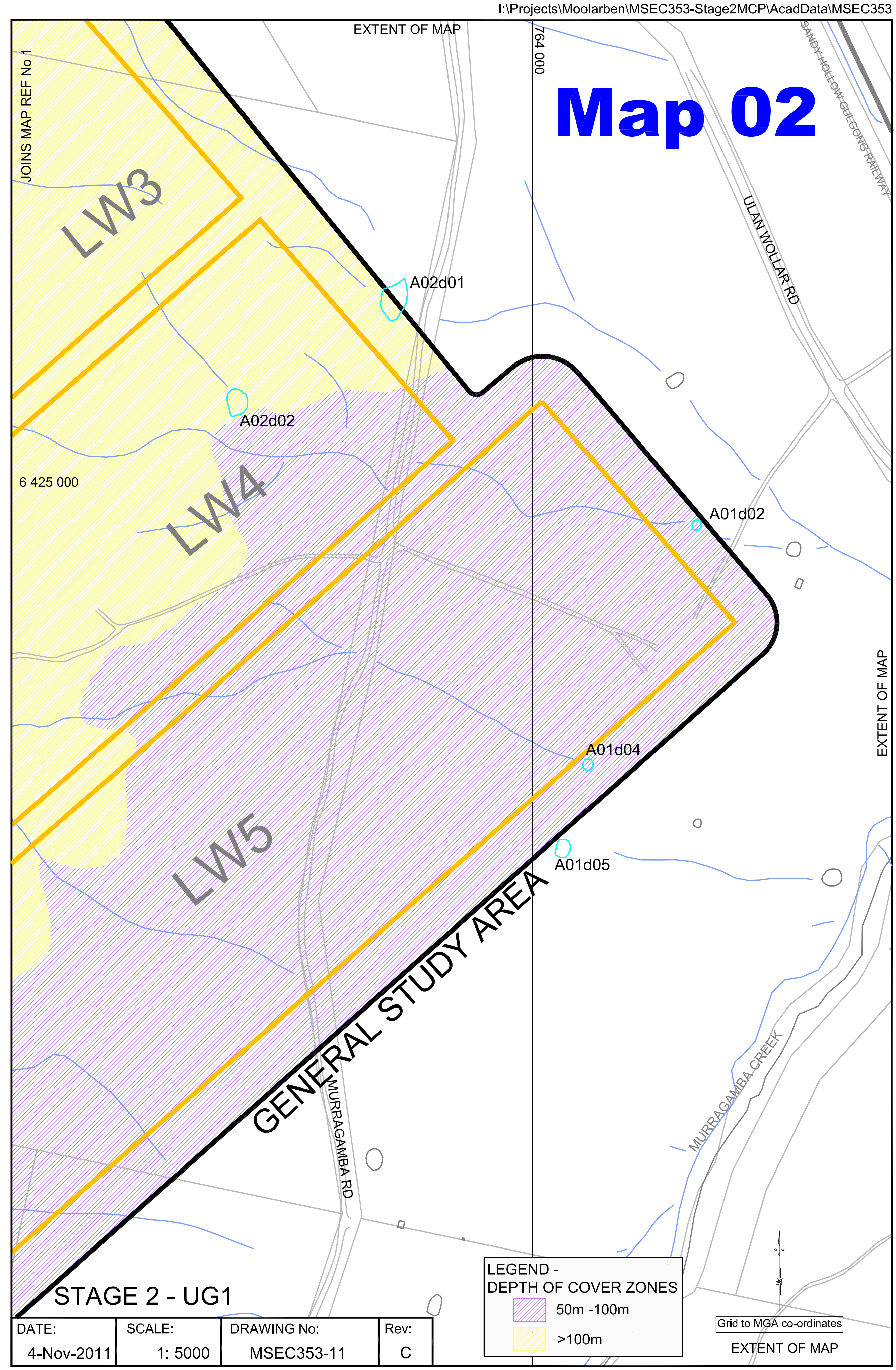
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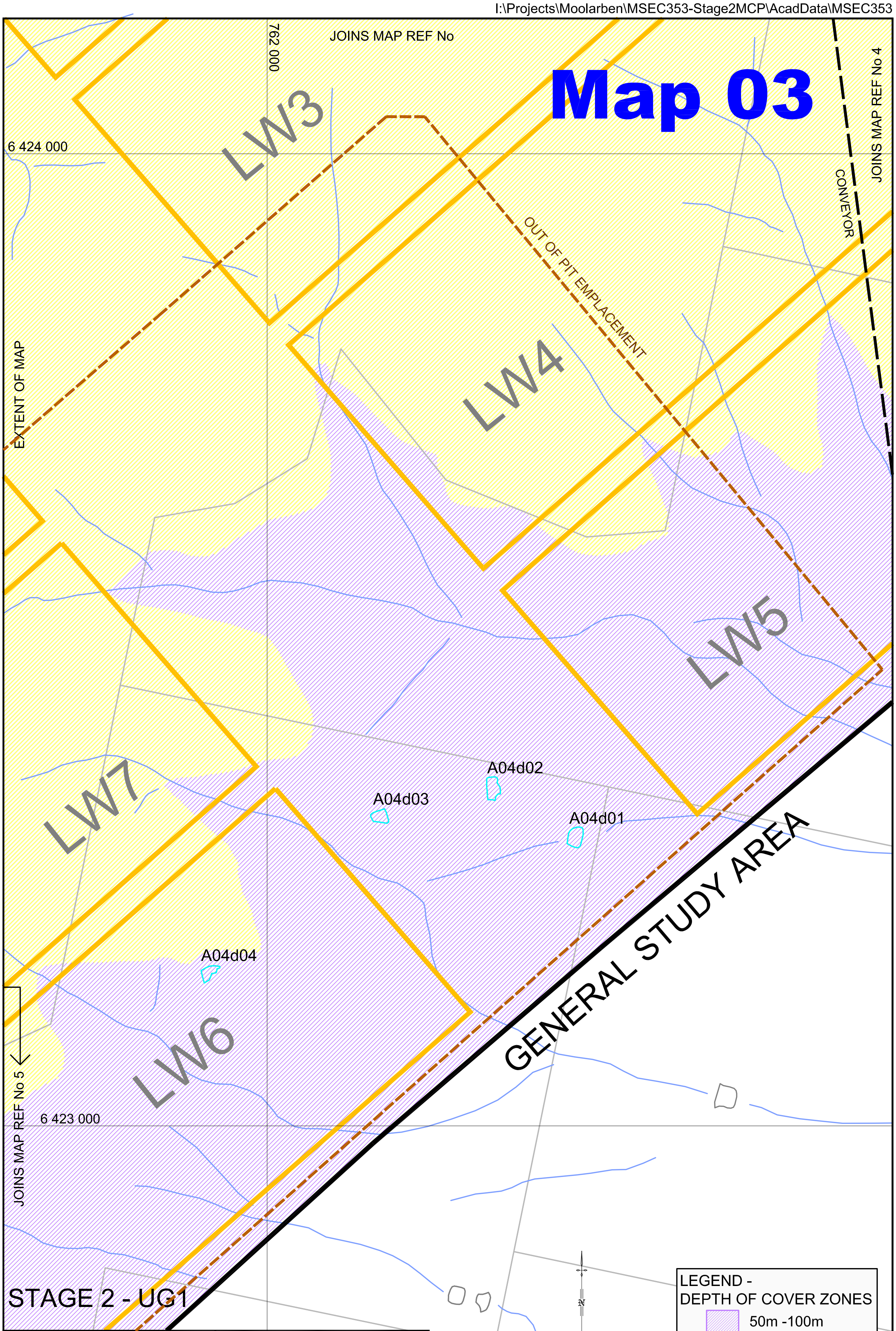
EXTENT OF MAP
764 000
Map 02
SANDY HOLLOW-GULGONG RAILWAY
ULAN WOLLAR RD
JOINS MAP REF No 1
LW3
LW4
LW5
A02d01
A02d02
6 425 000
A01d02
A01d04
A01d05
EXTENT OF MAP
GENERAL STUDY AREA
MURRAGAMBA RD
MURRAGAMBA CREEK
STAGE 2 - UG1
LEGEND -
DEPTH OF COVER ZONES
50m -100m
>100m
Grid to MGA co-ordinates
EXTENT OF MAP
DATE:
4-Nov-2011
SCALE:
1: 5000
DRAWING No:
MSEC353-11
Rev:
C



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4-Nov-2011	1: 5000	MSEC353-12	C

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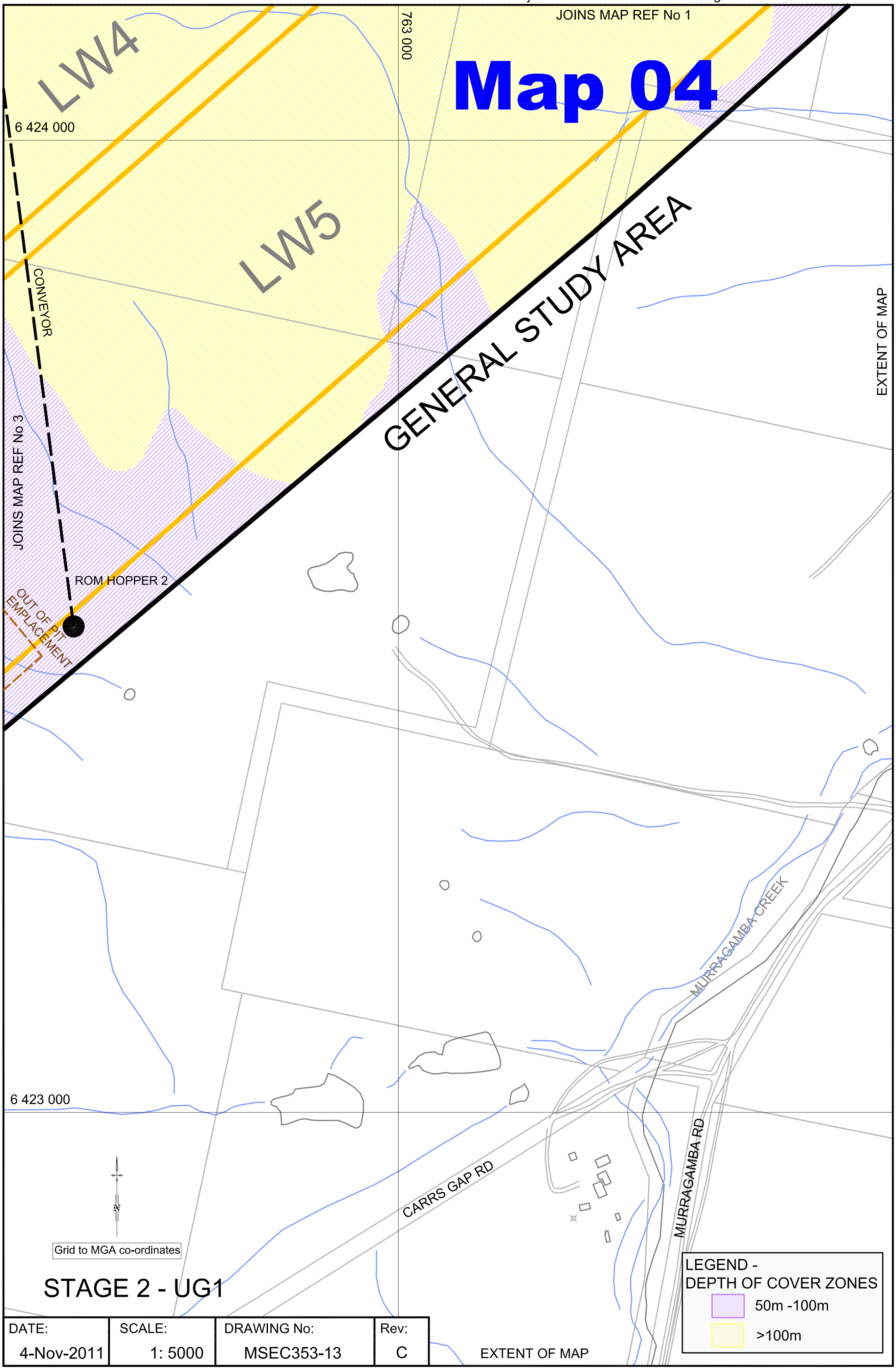

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4-Nov-2011	1: 5000	MSEC353-13	C

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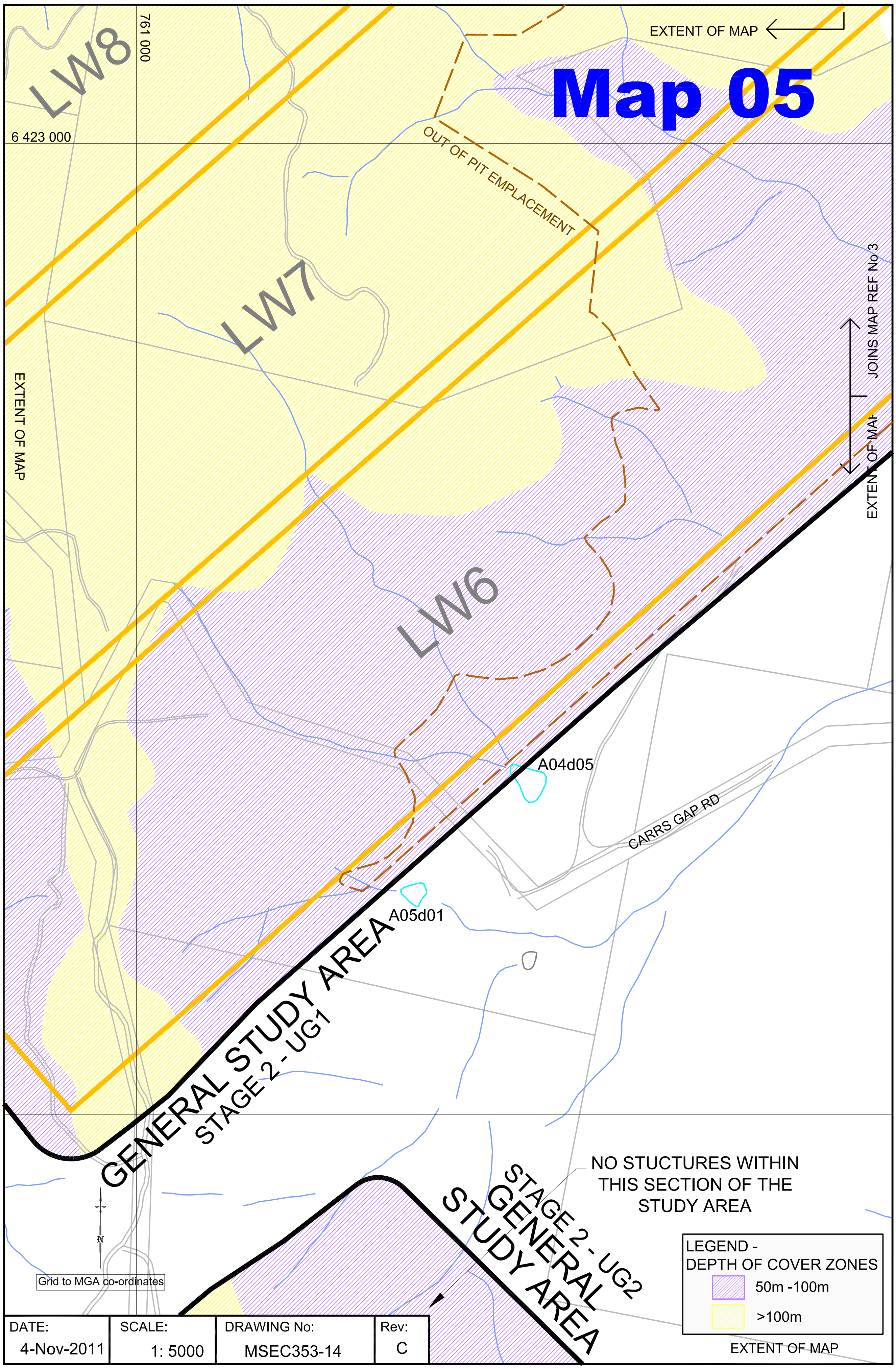

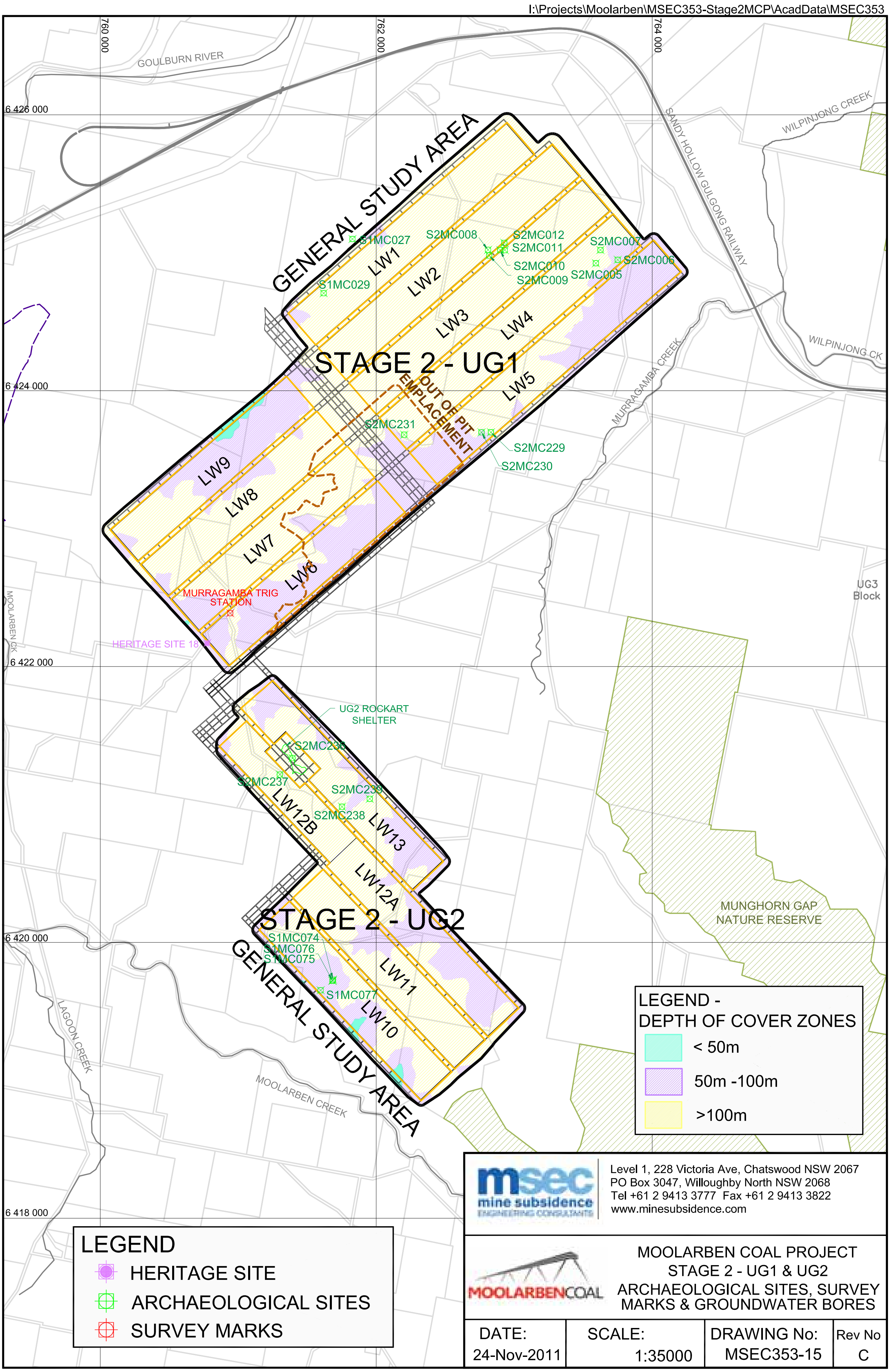

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760 000
762 000
764 000
6 426 000
6 424 000
6 422 000
6 420 000
6 418 000
GOULBURN RIVER
SANDY HOLLOW GULGONG RAILWAY
WILPINJONG CREEK
WILPINJONG CK
MURRAGAMBA CREEK
MOOLARBEN CK
LAGOON CREEK
MOOLARBEN CREEK
GENERAL STUDY AREA
STAGE 2 - UG1
STAGE 2 - UG2
OUT OF PIT EMPLACEMENT
LW1
LW2
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12A
LW12B
LW13
S1MC027
S1MC029
S2MC008
S2MC012
S2MC011
S2MC010
S2MC009
S2MC007
S2MC006
S2MC005
S2MC231
S2MC229
S2MC230
MURRAGAMBA TRIG STATION
HERITAGE SITE 18
UG2 ROCKART SHELTER
S2MC236
S2MC237
S2MC239
S2MC238
S1MC074
S1MC076
S1MC075
S1MC077
UG3 Block
MUNGHORN GAP NATURE RESERVE
LEGEND - DEPTH OF COVER ZONES
< 50m
50m -100m
>100m
LEGEND
HERITAGE SITE
ARCHAEOLOGICAL SITES
SURVEY MARKS
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MOOLARBENCOAL
MOOLARBEN COAL PROJECT
STAGE 2 - UG1 & UG2
ARCHAEOLOGICAL SITES, SURVEY MARKS & GROUNDWATER BORES
DATE: 24-Nov-2011
SCALE: 1:35000
DRAWING No: MSEC353-15
Rev No C

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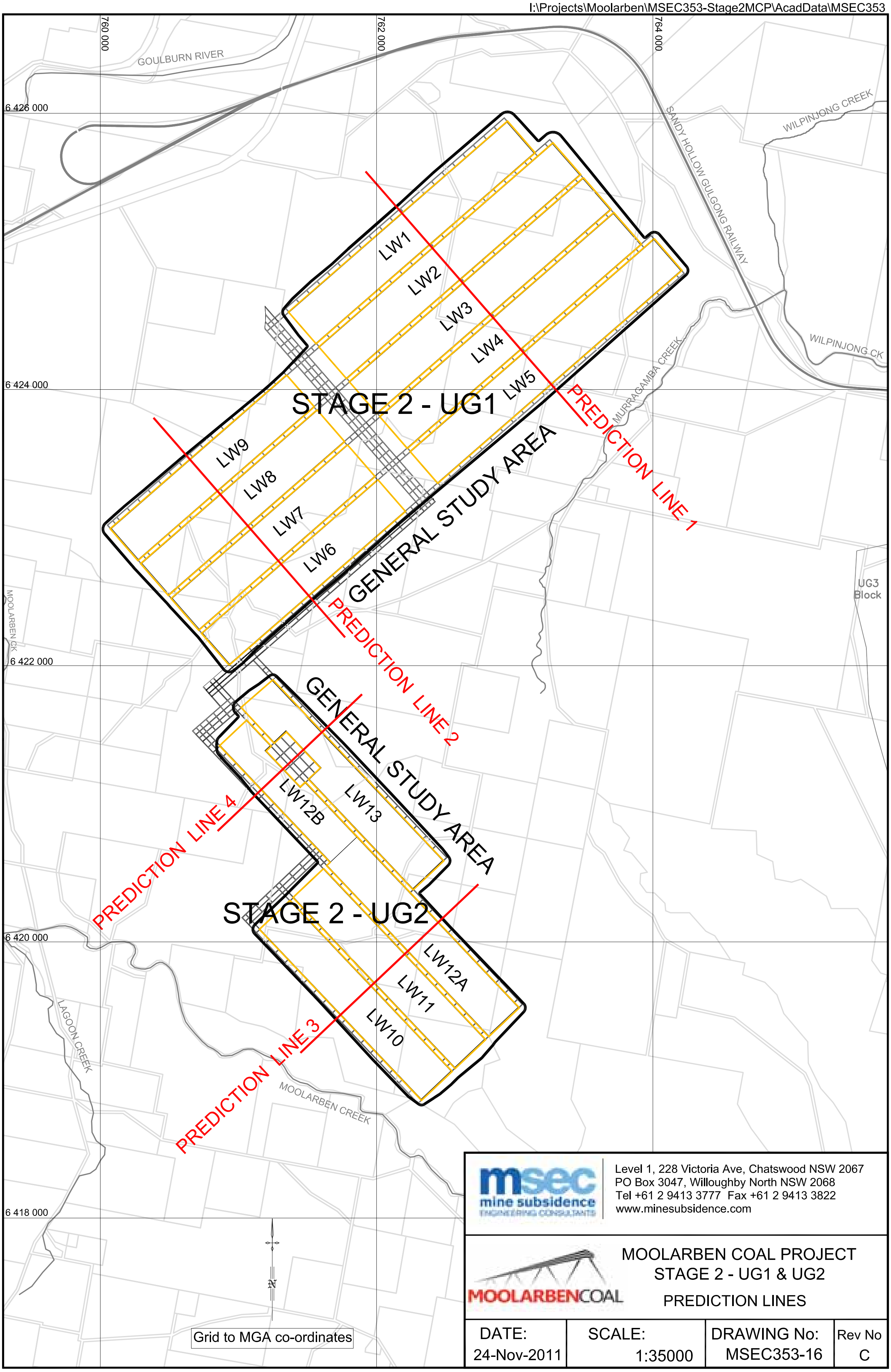

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MOOLARBENCOAL

MOOLARBEN COAL PROJECT
STAGE 2 - UG1 & UG2
PREDICTION LINES

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24-Nov-2011	1:35000	MSEC353-16	C

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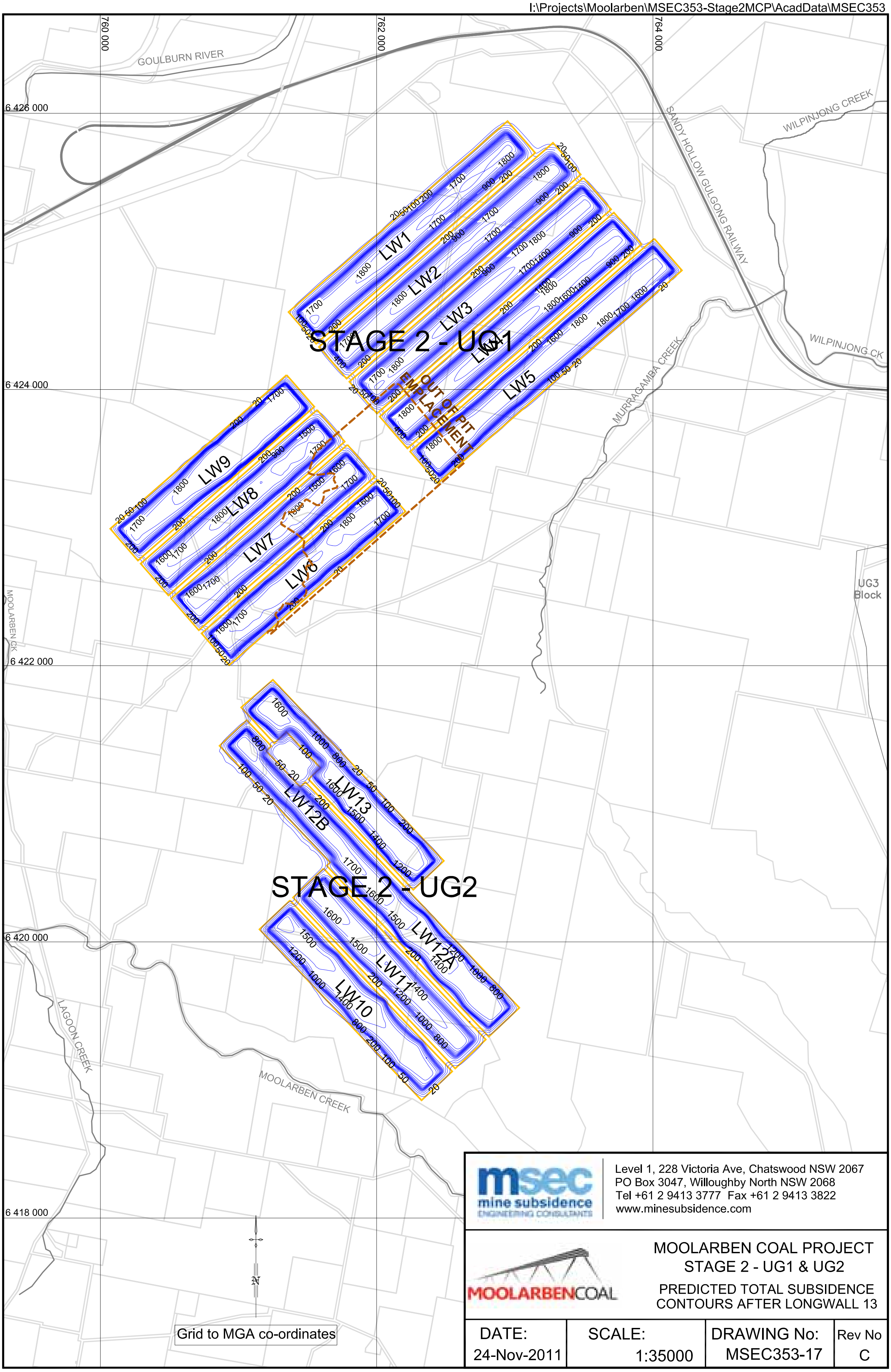

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