MOOLARBEN COAL PROJECT

APPENDIX 8

Subsidence Impact Assessment

STRATA ENGINEERING

Consulting and Research Engineering

A.B.N. 26 074 096 263

MOOLARBEN COAL MINES PTY LTD

MOOLARBEN COAL PROJECT

Mine Subsidence Impact Assessment for the Proposed Longwall Panels LWs 1 to 14, No. 4 Underground Area, Moolarben Coal Project

SEPTEMBER 2006

Report No: 04-001-WHT/1

SUITE 7, LEVEL 1, 132-138 PACIFIC HIGHWAY
P O BOX 724
CHARLESTOWN NSW 2290
TEL: (02) 4946 2700 FAX: (02) 4946 2711
EMAIL: nsw@strataengineering.com.au

REPORT TO:

Mr Ian Callow
Project Manager
c/- Moolarben Coal Project
PO Box 205
EAST MAITLAND
NSW 2323

REPORT ON:

Mine Subsidence Impact Assessment for the Proposed Longwall Panels 1 to 14, No. 4 Underground Area, Moolarben Coal Project

REPORT NO:

04-001-WHT/1

REFERENCE:

Your letter dated 9/11/05

Rev	Date	Prepared	Checked	Status	Signature
A	19/02/06	J. Jiang/ S. Ditton	S. Ditton	Draft for comment	
B	17/04/06	S. Ditton	T. Watson	2nd Draft	
C	03/05/06	S. Ditton	T. Watson	3rd Draft	
D	07/09/06	S. Ditton	D.Hill	Final	

EXECUTIVE SUMMARY

A mine subsidence prediction and impact assessment has been completed for the proposed LWs 1 to 14 in the No. 4 Underground (No.4 UG) Area of the Moolarben Coal Project (MCP). Appropriate subsidence impact mitigation and management strategies have been assessed for the natural, man-made and Aboriginal heritage features present within the study area and guidance provided for the Subsidence Management Plan stage of the project.

The land above the proposed longwalls is largely undeveloped bush with several ephemeral drainage gullies or watercourses and 5 to 30 m high sheer to rounded sandstone cliff faces. Surface developments consist of gravel access roads, fire trails, small stock watering dams and residential dwellings on Westwood's private land holding in the northern area of No.4 Underground. It is understood that at the time of preparation of this report, Moolarben Coal Mines (MCM) had secured ownership of Westwood's land and it therefore unlikely that the residential dwellings will be inhabited during mining.

The Goulburn River National Park and "The Drip" are located outside a 26.5^{o} angle of draw from the proposed longwalls, as shown in **Figure 1.1**. The Gulgong to Sandy Hollow Railway, existing Ulan Mine groundwater bore field, Dronvisa's gravel and clay quarry, Ulan - Cassilis Road and associated cuttings, as well as the bridge across the Goulburn River, are also located outside the angle of draw limits of the proposed longwall blocks.

Forty-four aboriginal sites and one potential archaeological deposit have been recorded for the No. 4 UG area (refer to ARAS, 2006). The types of aboriginal sites recorded include 20 isolated finds, 8 artefact scatters, 15 rock shelters with artefacts and an axe grinding groove site. Two of the rock shelters contain hand paintings. The area also contains approximately 177 rock overhangs / potential rock habitation shelters have been identified along several of the cliff lines adjacent to the drainage gullies.

Reference to **Holla, 1991** and the measured subsidence above the 260 m wide longwalls at Ulan Mine, indicates that the Wollar Sandstone has significantly reduced subsidence above the longwalls compared to other mine sites in the Western Coalfields.

Therefore, subsidence impact parameter predictions have been made using Strata Engineering's empirically based subsidence prediction model, which allows the subsidence reduction potential of the Wollar Sandstone to be assessed.

The model was initially developed with ACARP funding in 2003 to address the issue of geology in the context of subsidence prediction methodology. The model links the likely effects of massive strata units and structure in the overburden to the predicted subsidence impact parameter outcomes - summary details of the model are presented in **Appendix A**.

Validation of the model using cross line and centre line data over Ulan Mine's LWs A, B and 1 to 19, indicates good agreement (i.e. >85% success rate) between the predicted Upper and Lower 95% Confidence Limits and measured subsidence, tilt and strain values.

Based on the outcomes of the study, it is considered that the predicted subsidence for the Moolarben No. 4 UG longwalls is likely to be higher than the measured subsidence above Ulan LWs 12 to 19, primarily due to the increased longwall face extraction height and greater subsidence above the chain pillars.

It is also apparent that the predicted subsidence values presented in this report are likely to be conservative because the Ulan subsidence profile data plotted well below the Upper 95% Confidence Limits predicted by the model, which has been used in this study to assess the impacts on the features in the study area.

There is, however, greater uncertainty in the prediction of maximum tilts and strains above the Moolarben longwalls, due to skewed subsidence profile development around ridges, secondary curvatures, strain concentrations due to cracking and variation of near surface lithology characteristics.

Nevertheless, previous success with the model over the past three years in all of the NSW Coalfields has provided enough confidence in the model to make predictions of subsidence, tilt and strain profiles with an allowance for the discontinuous behaviour issues previously mentioned. Any further increases in tilt or strain due to the increased extraction height of the Moolarben longwalls compared to the Ulan longwalls are not likely to significantly change the overall impacts assessed in this report.

Based on reference to transverse subsidence and strain data from Ulan Mine's LWs 12 to 19, it is considered that the prediction outcomes for Moolarben are still likely to be conservative if a multiplying factor of 10 m is applied to the curvatures to predict uniform 'smooth-profile' strains. The uniform strains may also be doubled or concentrated due to the likely effects of secondary curvature, cracking and the variation of near surface lithology ('beam') thickness.

The cover depth over the study area ranges from 85 to 215 m, with several massive sandstone units present above the Ulan Seam. The units range between 5 m and 75 m in thickness above the proposed longwalls and are located between 5 m and 125 m above the longwalls. It is assessed that the Wollar Sandstone will have 'High' Subsidence Reduction Potential above the longwalls planned below the elevated plateaux areas.

Credible worst-case (i.e. Upper 95% Confidence Limit) subsidence parameter predictions have been determined beneath the key surface features due to the extraction of the proposed Moolarben longwalls in the Ulan Seam.

Credible worst-case subsidence (S_{max}) over the longwalls is predicted to range between 1.81 m and 2.44 m for the range of cover depths. The predictions represent 0.4 and 0.6 times the proposed extraction height of 4.2 m.

The proposed chain pillars located between LWs 1 and 14 are 35 m wide and 3.5 m high, with predicted subsidence values above the pillars ranging between 0.19 m and 0.49 m for double abutment loading conditions (i.e. after longwalls have extracted coal from both sides of the pillars).

Maximum transverse and longitudinal tilts are estimated to range between 23 and 86 mm/m. The measured tilts above the Ulan longwalls ranged between 5 and 55 mm/m.

Maximum transverse and longitudinal uniform tensile and compressive strains are expected to range between 8 and 35mm/m with credible worst-case concentrated strains ranging from 14 to 41 mm/m predicted. The concentrated strains effectively double the uniform strains and are caused by the effects of cracking and variation of near surface beam thickness. The measured strains above the Ulan longwalls ranged between 3 and 25 mm/m, and are comparable to the proposed No.4 UG panels.

The predicted range of maximum tensile and compressive uniform strains indicate that surface crack widths of between 40 mm and 180 mm could occur within the limits of extraction (i.e. goaf) after mining is completed. In particular, significant cracks are most likely to occur above areas where surface rock exposures with widely spaced, adversely orientated or absent jointing, coincide with the peak strains (i.e. Terrain Units R1, R2 and R3).

Crack widths are expected to range between 40 mm and 90 mm above the deeper longwalls with cover depths of > 130 m. Crack widths ranging between 70 mm and 180 mm are estimated above the shallower areas where the cover depths are <130 m.

The crack widths have been estimated by multiplying the uniform strain by a distance of 10 m (based on the typical bay-length and crack widths observed in the field for the corresponding strains) and assuming that a single crack will occur in the given bay-length. In reality, several smaller cracks may develop or existing joints will open.

The cracks will probably be tapered and extend to depths ranging from 3 to 10 m and possibly deeper where massive near surface strata units exist. Repairs to cracks will probably be needed in the areas of the site where people and livestock are active.

Repairs to surface cracks will be required on an ongoing basis during mining to minimise long-term degradation to the surface and provide a seal over sections of panels where crack connectivity may occur between the surface and the longwalls.

Buckling or "upsidence" of between 130 and 230 mm is predicted above the proposed longwalls along the bases of two gullies between cliff lines CL4 and CL6. The combination of buckling and shear cracking of thin to medium bedded, near surface sandstone, is expected to result in localised areas of sub-surface flow paths developing along the affected watercourses. The surface flows are expected to 'day-light' again downstream of the affected areas.

The impact on the cliffs within the site has been assessed based on (i) mining subsidence deformation, (ii) public exposure to instability and aesthetics and (iii) instability due to natural weathering conditions as presented in **ACARP, 2002**. None of the cliffs above UG No. 4 are visible from public access ways around the site, such as the Ulan-Cassilis and Ulan-Wollar Roads, or the Goulburn River gorge to the north of the site (i.e. The Drip).

The cliffs outside of the longwall extraction limits have been assigned a 'very low' to 'low' impact rating, with a 'moderate' to 'high' impact rating assessed for the cliff lines above the longwalls. The cliffs above the longwalls will probably be damaged by localised cracking and spalling with further detailed stability studies required to assess the over impact of the proposed mining on the cliffs.

A rock fall hazard has been identified along the cliff lines. Even though public access will be restricted to the land, further risk analysis and management work will be required to provide appropriate controls to minimise exposure of mine site personnel and visitors to rock falls. Appropriate fencing and/or signage warning bush walkers to stay away from cliff lines will be erected around the boundaries of the No.4 Underground area.

In general, the surface drainage patterns are likely to function with minimal changes after subsidence trough development. However, some of the low-lying areas in the northern part of No. 4 UG could become poorly drained or boggy after the extraction of LWs 12 to 13 and drainage restoration works may be necessary. A small area of ponding may also develop up to 1 m in depth along a gully located above the northern end of LW 10. The ponding depth will also depend on surface cracking and soil percolation rates.

Sub-surface cracking above the longwalls may result in direct hydraulic connection developing with all of the coal seams above the workings, but this is unlikely to extend up into the Wollar Sandstone. It is possible that direct hydraulic connection to the surface could occur above LW1, where the depth of cover is < 100 m. Sub-surface monitoring will therefore be necessary to ascertain a suitable finishing point for this panel, if direct connection to the surface is not acceptable.

Far-field horizontal displacements have been predicted using an empirical data base of measured movements beyond the limits of longwalls in the Newcastle Coalfield with similar geometry to the Moolarben panels. Similar results have been obtained using a numerical model (Phase 2®) of full horizontal stress relief towards the extracted area. Based on the model, it is assessed that the impact of subsidence and far-field displacements on the cliffs in The Drip and along the Goulburn River National Park boundary line to the east of the No. 4 UG area, will be negligible.

Five Aboriginal sites, which include an artefact site, an axe grinding groove site and three rock shelters, are likely to be subject to tensile strains exceeding 0.5 mm/m or compressive strains > 3 mm/m at some stage during or after mining is complete. It has been assessed that there is a 'moderate' to 'high' likelihood that they will be damaged by cracking and spalling due to mine subsidence. The other sites are located outside the limits of the proposed longwall blocks and are assessed to have a 'low' to 'very low' likelihood of being damaged by mine subsidence. It is considered likely that the remaining rock shelters above the longwalls, that are not significant, will also be damaged by spalling and cracking due to subsidence.

Ulan Mine's groundwater bore-field infrastructure is located outside the predicted angle of draw with far-field displacements of < 20 mm predicted. Further consultation with Ulan Mine will be necessary to establish an appropriate operational agreement regarding to the potential impacts to the bore-field.

The memorial garden and grave site are located well outside the angle of draw to the proposed starting position of LW12. No impact to the site is expected.

The location of the old farmhouse on Ulan Mine land is unknown at this stage, but will probably be damaged if it is located above a longwall panel.

Three of the stock watering dams (D4, D6 and D12) are expected to be subject to tensile cracking of 20 to 40 mm width due to uniform tensile strains of 2 to 4 mm/m. This may result in subsequent loss off storage with repair works required to seal the cracks. The dams are also expected to be subject to temporary longitudinal deformations of similar magnitude to the transverse movements.

Dams (D11 and D13) may also be impacted to a similar degree by tensile strains associated with the transient longitudial deformations.The remaining five water bore dams are unlikely to be damaged with negligible tilt and strain predicted after longwall extraction.

The Ulan-Cassilis Road, associated cuttings and bridge over the Goulburn River are located outside the angle of draw, and are therefore not expected to be impacted directly by mine subsidence. However, the bridge and Cutting No 3 are located between 200 and 250 m from the NW corners of LWs 8 and 12 respectively and could therefore be subject to far-field horizontal displacements ranging between 26 mm and 57 mm. Cutting No.s 1 and 2, which are 350 m and 600 m west of LWs 1 and 8 respectively, are expected to experience no more than 9 mm and 4 mm of far-field horizontal displacement. Consultation with the Mid-Western Regional Council and the Roads and Traffic Authority (RTA) bridge engineers will be required, to develop appropriate monitoring and response plans to manage the consequences of this horizontal displacement.

The existing Dronvisa Pty Ltd gravel/clay quarry limits are currently outside the angles of draw to LWs 4 and 5 in No. 4 UG - South. Further consultation with the owners and an operational agreement will be required, before the quarry is extended further to the east.

Subsidence and strain monitoring along several cross lines and end of panel centre lines (i.e. panel start and finish locations) is suggested for subsidence parameter prediction and Subsidence Management Plan (SMP) review purposes. Monitoring programs around the surface features mentioned herein should be assessed based on the predictions provided in this report and mutually agreeable SMP's developed between individual stakeholders and the DPI.

To assess the impact of subsidence on sub-surface aquifers and deep alluvium at the surface, a sub-surface monitoring program is recommended, to determine heights of fracturing above LW 1. Cracking at the surface should be sealed off to limit the ingress of surface water and air (i.e. oxygen) into the goaf, to minimise the potential for a self-heating event.

Overall, it is considered that each of the long-term subsidence impacts due to the proposed Moolarben longwalls can be managed with the proposed mitigation and management measures presented.

TABLE OF CONTENTS

GLOSSARY

1.0 INTRODUCTION... 1

1.1 Overview... 1
1.2 Study Objectives... 1
1.3 Scope of Work 2
1.4 Report Structure.. 3

2.0 PROPOSED MINING GEOMETRY 5

2.1 General.. 5
2.2 Stability of Underground Workings 5

3.0 METHODOLOGY... 6

3.1 Subsidence Impact Parameter Predictions above Longwall Panels 6
3.2 Prediction of Subsidence Impact Parameters Using Regression Analysis Techniques 7
3.3 Prediction Model Uncertainty 7
3.4 Relevant Standards and Published Guidelines................................. 8
3.5 Work Program... 8

4.0 AVAILABLE DATA... 10

5.0 SITE CONDITIONS... 11

5.1 Site Surface and Sub-Surface Features Register 11
5.2 Geological Setting.. 13
5.3 Geotechnical Unit Properties in Roof and Floor of Proposed Workings........ 14
5.4 Overburden Lithology and Massive Sandstone Units 15
5.5 Geological Structure 16
5.6 Surface Conditions... 16
5.6.1 General 16
5.6.2 Land Use and Current Ownership 17
5.6.3 Cliff Line Conditions and The Drip 18
5.6.4 Aboriginal Rock Shelters 22
5.6.5 Significant Aboriginal Archaeological Sites 23
5.6.6 Residential Development.. 25
5.6.7 Stock Water Supply Dams.. 25
5.6.8 Memorial Garden and Grave Site 25
5.6.9 Old Farm House (circa 1920's) 26
5.6.10 Groundwater Bore Field Pumping Station and Dams.................... 26
5.6.11 The Dronvisa Gravel/Clay Quarry.................................. 26
5.6.12 Ulan-Cassilis Road.. 26
5.6.13 Gulgong to Sandy Hollow Railway.................................. 27
5.6.14 The Goulburn River National Park.................................. 27
5.7 Terrain Unit Evaluation... 27

6.0 SUBSIDENCE PREDICTION MODEL VALIDATION..................... 29

6.1 Ulan Mine Subsidence Data Review 29
6.2 Comparison Between Actual and Predicted Subsidence................. 30
6.3 Predicted v. Measured Profiles Above LWs 12 to 19....................... 32
6.4 Voussoir Beam Analysis 33

6.5 Validation Analysis Outcomes 36

7.0 SUBSIDENCE PREDICTIONS FOR THE PROPOSED LONGWALL PANELS 37

7.1 General 37
7.2 Subsidence Reduction Potential of Sandstone Units 37
7.3 Maximum Subsidence Predictions for the Proposed Longwalls 38
7.4 Subsidence Predictions above Chain Pillars 39
7.5 Differential Subsidence Predictions 44

8.0 CHAIN PILLAR STABILITY CONSIDERATIONS 45

9.0 MAXIMUM POSSIBLE SUBSIDENCE AFTER CESSATION OF MINING 47

10.0 PREDICTION OF ANGLES OF DRAW 48

11.0 POST-MINING SUBSIDENCE PROFILES AND SURFACE LEVEL CONTOUR PREDICTIONS 50

11.1 Transverse Subsidence Profiles 50
11.2 Longitudinal Subsidence Profiles 50
11.3 Predicted Surface Subsidence Contours 50

12.0 SUBSIDENCE IMPACT ASSESSEMENT AND MANAGEMENT STRATEGIES 51

12.1 Mechanisms of Damage 51
12.2 Surface Cracking 51
12.2.1 Predicted Impacts 51
12.2.2 Proposed Impact Mitigation and Management Strategies 52
12.3 Sub-Surface Cracking 53
12.3.1 Predicted Impacts 53
12.3.2 Proposed Impact Mitigation and Management Strategies 54
12.4 Ponding 54
12.4.1 Predicted Impacts 54
12.4.2 Proposed Impact Mitigation and Management Strategies 55
12.5 General Slope Stability and Erosion 56
12.5.1 Predicted Impacts 56
12.5.2 Proposed Impact Mitigation and Management Strategies 57
12.6 Cliff Line Stability Assessment 58
12.6.1 Impact Assessment Methods 58
12.6.2 Predicted Impacts Based on an Empirical Cliff Line Stability Assessment 59
12.6.3 Predicted Impacts based on an Analytical Cliff Line Stability Assessment 60
12.6.4 Rock Fall Hazard Mitigation and Management 61
12.7 Upsidence Along Creek Beds and Valleys 62
12.7.1 Predicted Impacts 62
12.7.2 Impact Mitigation and Management Strategies 63
12.8 Far-Field Horizontal Displacements 63
12.8.1 General 63
12.8.2 Predicted Impacts on the The Drip 64
12.8.3 Impact Mitigation and Management of Impacts to The Drip 65
12.9 Ulan-Cassilis Road, Goulburn River Bridge and Road Cuttings 67
12.9.1 Predicted Impacts due to Subsidence 67

12.9.2 Predicted Impacts due to Far-Field Horizontal Displacement........ 68
12.9.3 Impact Mitigation and Management of Impacts to the Ulan-Cassilis Road and Bridge.. 69
12.10 The Ulan Groundwater Bore-Field.. 70
12.10.1 Predicted Impact due to Subsidence 70
12.10.2 Predicted Impacts Due to Horizontal Displacement...................... 70
12.10.3 Impact Mitigation and Management Strategies............................. 71
12.11 The Dronvisa Gravel / Clay Quarry 71
12.11.1 Impacts Due to Subsidence.. 71
12.11.2 Impact Mitigation and Management Strategies............................ 72
12.12 The Goulburn River National Park.. 72
12.12.1 Predicted Impacts Due to Subsidence.. 72
12.12.2 Predicted Impacts Due to Horizontal Displacement...................... 72
12.12.3 Mitigation and Management Strategies 73
12.13 Groundwater Dependent Eco-Systems (GDEs) 73
12.13.1 Predicted Impacts... 73
12.13.2 Impact Mitigation and Management Strategies............................. 73
12.14 Aboriginal Heritage Sites.. 74
12.14.1 Predicted Impact Assessment Method 74
12.14.2 Impact Assessment Outcomes for Significant Archaeological Sites... 76
12.14.3 Impacts to Rock Shelters.. 78
12.14.4 Impact Mitigation and Management Strategies............................. 78
12.15 Residential Development 79
12.15.1 Tolerable Subsidence Limits and Predicted Impacts..................... 79
12.15.2 Impacts to Tony's House and Shed (B1/B2) 81
12.15.3 Impacts to Jim's House (B3).. 81
12.15.4 Impacts to the Remaining Huts and Sheds (B5-B9)...................... 82
12.15.5 Impact Mitigation and Management Strategies for Existing Residences... 82
12.16 Old Farm House (circa 1920's) 82
12.17 Water Storage Dams D1 to D13.. 83
12.17.1 Predicted Impacts... 83
12.17.2 Impact Mitigation and Management Strategies............................. 83
12.18 Gulgong to Sandy Hollow Railway 84
12.19 Moolarben Mine Site and Other Infrastructure... 84
12.20 Property Fences and Livestock 84
12.21 Memorial Garden and Grave Site.. 85

13.0 SUGGESTED SURFACE AND SUB-SURFACE MONITORING PROGRAM 86

13.1 Surface Monitoring Program 86
13.2 Surface Survey Accuracy.. 86
13.3 Sub-Surface Monitoring Program.. 87
13.4 Subsidence Development Rates 88

14.0 CONCLUSIONS.. 89

15.0 REFERENCES.. 95

APPENDICES

APPENDIX A - Strata Engineering's Empirical Mine Subsidence Prediction and Geological Influence Assessment Model

APPENDIX B - Rock Shelter and Significant Aboriginal Artefact Site Location and Subsidence Impact Details

APPENDIX C - Results of Cliff Line Stability Assessments

APPENDIX D - Laboratory Testing Results on Bore Core Samples from BHs WMLB34, WMLB78 and TB105

LIST OF FIGURES

Figure 1.1 Moolarben Coal Project - Stage 1 Layout and Ulan Seam Cover Depth Contours

Figure 5.1 Typical Lithological Section of Mine Workings in Ulan Seam (Based on BH C228)

Figure 5.2a Laboratory & Sonic UCS Data for BH WMLB34

Figure 5.2b Laboratory & Sonic UCS Data for BH WMLB78

Figure 5.2c Laboratory & Sonic UCS Data for Borehole TB105

Figure 5.3 Interpreted Lithological Section AB (East) for LWs 1-14

Figure 5.4 Interpreted Lithological Section CD (West) for LWs 1-14

Figure 5.5 Interpreted Unit 1 Sandstone Thickness Contours (m)

Figure 5.6 Interpreted Unit 1 Sandstone Distance Above the Proposed LWs 1-14 Contours (m)

Figure 5.7 Interpreted Unit 2 Sandstone Thickness Contours (m)

Figure 5.8 Interpreted Unit 2 Sandstone Distance Above the Proposed LWs 1-14 Contours (m)

Figure 5.9 Interpreted Unit 3 Sandstone Thickness Contours (m)

Figure 5.10 Interpreted Unit 3 Sandstone Distance Above the Proposed LWs 1-14 Contours (m)

Figure 5.11 Surface Level Contours and Features above the Proposed Moolarben UG4 LWs 1-14

Figure 5.12 Land Ownership Details fo No.4 UG Area

Figure 5.13 Photographs of Cliff Line CL1 above the Proposed LW 12 to 13

Figure 5.14 Photographs of Cliff Line CL2 above the Proposed LW 11

Figure 5.15 Photographs of Cliff Line CL3 above the Proposed LWs 13 and 14

Figure 5.16 Photographs of Cliff Line CL4 above the Proposed LWs 10 and 11

Figure 5.17 Photograph of The Drip Cliff Lines CL5 to North of Proposed LWs 12 to 14

Figure 5.18 Photographs of Cliff Line CL6 above the Proposed LW 6

Figure 5.19 Schematic Section of Typical Cliff Line Profiles in No. 4 Underground Area

Figure 5.20 Photograph of Significant Aboriginal Archaeological Site AS 1 (Refer to Figure 5.11 for Location)

Figure 5.21 Photograph of Significant Aboriginal Archaeological Site AS 2 (Refer to Figure 5.11 for Location)

Figure 5.22 Photograph of Significant Aboriginal Archaeological Site AS 4 (Refer to Figure 5.11 for Location)

Figure 5.23 Photograph of Significant Aboriginal Archaeological Site AS 5 (Refer to Figure 5.11 for Location)

Figure 5.24 Photograph of Significant Aboriginal Archaeological Site AS 6, 14 (Refer to Figure 5.11 for Location)

Figure 5.25 Photograph of Significant Aboriginal Archaeological Site AS 7 (Refer to Figure 5.11 for Location)

Figure 5.26 Photograph of Significant Aboriginal Archaeological Site AS 11 (Refer to Figure 5.11 for Location)

Figure 5.27 Photograph of Significant Aboriginal Archaeological Site AS 12 (Refer to Figure 5.11 for Location)

Figure 5.28 Photograph of Significant Aboriginal Archaeological Site AS 13 (Refer to Figure 5.11 for Location)

Figure 5.29 Photograph of Jim Westwood's House

Figure 5.30 Photograph of Tony's House on Westwood's Land

Figure 5.31 Photographs of Existing Westwood Huts (Building No.s 6,9) Above the Proposed LWs 12 and 13

Figure 5.32 Photographs of Existing Water Borefield Dams (Dam No.s 8-10) and Pump House West of the Proposed LWs 6 and 7

Figure 5.33 Photograph of Dronvisa Gravel/Clay Quarry - Northern Pit (Refer to Figure 5.11 for Location)

Figure 5.34 Photograph of Dronvisa Gravel/Clay Quarry - Southern Pit (Refer to Figure 5.11 for Location)

Figure 5.35 Photograph of Dronvisa Gravel/Clay Quarry - Geology and Man-Made Structures (Refer to Figure 5.11 for Location)

Figure 5.36 Photograph of Goulburn River Bridge and Cutting No.4 (Refer to Figure 5.11 for Location)

Figure 5.37 Photograph of Ulan Road and Cutting No.1 (Refer to Figure 5.11 for Location)

Figure 5.38 Photographs of Ulan Road Cutting No.s 2 and 3 (Refer to Figure 5.11 for Location)

Figure 5.39 Photographs of Southern Ridge and Alluvial Flats above the Proposed LWs 1 and 2

Figure 5.40 Pre-mining Surface level Contours and Ground Slopes above LWs 1-14

Figure 5.41 Interpreted Surface Terrain Units Above the Proposed Moolarben No. 4 UG LWs 8-14

Figure 5.42 Interpreted Surface Terrain Units Above the Proposed Moolarben No. 4 UG LWs 1-7

Figure 6.1 Predicted v. Measured SRP for Ulan Massive Sandstone Units Above LWs 1-19,A-B

Figure 6.2 Predicted v. Measured First S_{max}/T for Ulan Massive Sandstone Units Above LWs 1- 19,A-B

Figure 6.3 Measured Subsidence Over LWs 12 -18 Chain Pillars Subject to Double Abutment Loading Conditions

Figure 6.4 Predicted v. Measured Subsidence Profiles for Ulan LWs 12 - 19 (D Line)

Figure 6.5 Predicted v. Measured Tilt Profiles for Ulan LWs 12 - 19 (D Line)

Figure 6.6 Predicted v. Measured Curvature Profiles for Ulan LWs 12 - 19 (D Line)

Figure 6.8 Predicted Bridging Limits for Wollar Sandstone above Ulan LW10 using Voussoir Beam Theory

Figure 6.9 Predicted Bridging Limits for Wollar Sandstone above Ulan LW15D Using Voussoir Beam Theory

Figure 7.1 Conceptual Model of Overburden Above the Proposed LWs 32 to 37

Figure 7.2 Interpreted Subsidence Reduction Potential Due to Sandstone Units in the Overburden

Figure 7.3 Predicted Normalised Subsidence for Single LWs Proposed LW1-14 Predictions

Figure 7.4 Predicted Subsidence Over Chain Pillars Subject to Double Abutment Loading Conditions for LWs 1 - 14

Figure 10.1 Empirical Prediction Model for Goaf Edge Subsidence Prediction Above Panel Crossline

Figure 10.2 Empirical Prediction Model for Goaf Edge Subsidence Prediction Above Panel Centreline at End of LW

Figure 10.3 Empirical Prediction Model for Goaf Edge Subsidence Prediction Above Panel Cornerline

Figure 10.4 Empirical Prediction Model for Angle of Draw Outside Longwall Panel Sides, Ends and Corners

Figure 11.1 Predicted First and Final Subsidence Profiles at XL1, LW1 to LW7

Figure 11.2 Predicted First & Final Tilt & Horizontal Displacement Profiles at XL1, LW1 to LW7

Figure 11.3 Predicted First & Final Curvature & Strain Profiles at XL1, LW1 to LW7

Figure 11.4 Predicted First and Final Subsidence Profiles at XL4, LW1 to LW7

Figure 11.5 Predicted First & Final Tilt & Horizontal Displacement Profiles at XL4, LW1 to LW7

Figure 11.6 Predicted First & Final Curvature & Strain Profiles at XL4 LW1 to LW7

Figure 11.7 Predicted First and Final Subsidence Profiles at XL7, LW8 to LW14

Figure 11.8 Predicted First & Final Tilt & Horizontal Displacement Profiles at XL7, LW8 to LW14

Figure 11.9 Predicted First & Final Curvature & Strain Profiles at XL7 LW8 to LW14

Figure 11.10 Predicted First and Final Subsidence Profiles at XL10, LW12 to LW14

Figure 11.11 Predicted First & Final Tilt & Horizontal Displacement Profiles at XL10, LW12 to LW14

Figure 11.12 Predicted First & Final Curvature & Strain Profiles at XL10, LW12 to LW14

Figure 11.13 Predicted Final Subsidence Profiles at Start of LW1

Figure 11.14 Predicted Final Tilt and Horizontal Displacement Profiles at Start of LW1

Figure 11.15 Predicted Final Curvature and Horizontal Strain Profiles at Start of LW1

Figure 11.16 Predicted Final Subsidence Profiles at Finish of LW13

Figure 11.17 Predicted Final Tilt and Horizontal Displacement Profiles at Finish of XL6, LW13

Figure 11.18 Predicted Final Curvature and Horizontal Strain Profiles at Finish of LW13

Figure 11.19 Predicted Upper 95% Confidence Limit Subsidence Contours for the Proposed Moolarben LWs 1-14

Figure 11.20 Pre-Mining and Predicted Post-Mining Surface Level Contours for UG4 Area LWs 1-14

Figure 12.1 Empirical Subsurface Fracturing Prediction Model for NSW & QLD - Predictions for LWs 1 to14

Figure 12.2 Pre and Post Mining Surface Levels along Section A-A' Northern Region Water Course (Refer Figure 11.20)

Figure 12.3 Pre and Post Mining Surface Levels Along Section B-B' Northern Region - Saddlers Creek Road (Refer Figure 11.20)

Figure 12.4 Pre and Post Mining Surface Levels along Section C-C' Southern Region Water Course (Refer Figure 11.20)

Figure 12.5 Measured Far-Field Horizontal Movement Data Outside LW Panel Ends (Normalised to Key Mining Geometry)

Figure 12.6 Far-field Horizotal Displacement Results Predicted by Numerical Modelling (Phase 2 FEM)

Figure 12.7 Photographs of Large Wedge Failure from Southern Cliff Along 'The Drip' Outside of the Proposed LWs 12 and 13

Figure 13.1 Conceptual Model of Longwall Impacts on Hydro-Geological Conditions in the Overburden

Figure 13.2 Empirical Model for Predicting Subsidence Development

Figure 13.3 Example of Maximum Subsidence and Horizontal Displacement Increases after More LWs Are Extracted

GLOSSARY

First Workings	The tunnels or roadways driven by a continuous mining machine to provide access to the longwall panels in a mine (i.e. main headings and gateroads). The roof of the roadways is generally supported by high strength steel rock bolts encapsulated in chemical resin. Subsidence above first workings pillars and roadways is generally < 20 mm.
Longwall	The method of extracting a wide block of coal (which will be 260 m wide in the case of the MCM) using a coal shearer and armoured face conveyor. Hydraulic shields provide roof support across the face and protect the shearer and mine workers. The longwall equipment is installed along the full width of the block in an 8 to 10 m wide installation road at the start of the block before retreating 2 to 3 km back to the end of the block. The shields are progressively advanced across the full width of the face, as shearing continues in a sequence of backwards and forwards motions across the face. Depending on the geological and longwall equipment conditions, the longwall retreats at a typical rate of about 70 m/week.
Gate Roads	The tunnels or roadways driven down both sides of the longwall block (usually in pairs), to provide airways and access for men, materials, and the coal conveyor to the longwall face. The conveyor side of the block is called the 'maingate' and dust laden air and coal seam gases are exhausted on the opposite side (called the 'tailgate').
Goaf	The extracted area that the immediate roof or overburden collapses into, following the extraction of the coal. The overburden above the ‘goaf’ sags, resulting in a subsidence 'trough' at the surface.
Chain Pillar	The pillar of coal left between adjacent longwall panels. This forms a barrier that allows the goaf to be sealed off and facilitates tailgate roof stability.
Inbye	An underground coal mining term used to describe the relative position of some feature or location in the mine that is closer to the coal face than the reference location.
Outbye	An underground coal mining term used to describe the relative position of some feature or location in the mine that is closer to the mine entry point than the reference location.
Extraction Height	The height at which the seam is mined or extracted across a longwall face by the longwall shearer.

Development Height The height at which the first workings (i.e. the main headings and gateroads) are driven; usually equal to or less than the extraction height on the longwall face.

Panel Width The width of an extracted area between chain pillars.

Cover Depth The depth from the surface to the mine workings.

Subsidence The difference between the pre-mining surface level and the post-mining surface level at a point, after it settles above an underground mining area.

Angle of Draw The angle (normally no greater than 26.5^{o} from the sides or ends of an extracted longwall block) from the vertical of the line drawn between the limits of extraction at seam level to the 20 mm subsidence contour at the surface. The 20 mm subsidence contour is an industry defined limit and represents the practical measurable limit of subsidence.

Tilt The rate of change of subsidence between two points (A and B), measured at set distances apart (usually 10 m). Tilt is plotted at the mid-point between the points and is a measure of the amount of differential subsidence.

i.e. Tilt = (subsidence at point A - subsidence at point B)/(distance between the points) and is usually expressed in mm/m.

Curvature The rate of change of tilt between three points (A, B and C), measured at set distances apart (usually 10 m). The curvature is plotted at the middle point or point B and is usually concave in the middle of the panel and convex near the panel edges.

i.e. Curvature = (Tilt between points A and B - Tilt between points B and C)/(average distance between points A to B and B to C) and usually expressed in 1/km.

Radius of curvature is the reciprocal of the curvature is usually measured in km (i.e. Radius = 1/Curvature). The curvature is a measure of surface 'bending' and is generally associated with cracking.

Horizontal Displacement Horizontal displacement of a point after subsidence has occurred above an underground mining area within the angle of draw. It can be predicted by multiplying the tilt by a factor derived for the near surface lithology at a site (e.g. a factor of 5 or 10 is normally applied for the NSW Coalfields).

Far-Field Displacement Horizontal displacement outside of the angle of draw, associated with movement are due to horizontal stress relief above an extracted panel of coal. The strains due to these movements are usually < 0.5 mm/m and do not cause damage directly. Such displacements have been associated with differential movement between bridge abutments and dam walls in the Southern Coalfield, but generally have caused significant damage.

Strain	The change in horizontal distance between two points at the surface after mining, divided by the pre-mining distance between the points. i.e. Strain = ((post-mining distance between A and B) - (pre-mining distance between A and B))/(pre-mining distance between A and B) and is usually expressed in mm/m. Strain can be estimated by multiplying the curvature by a factor derived for the near surface lithology at a site (e.g. a factor of 5 or 10 is normally applied for the Newcastle Coalfield).
Tensile Strain	An increase in the distance between two points on the surface. This is likely to cause cracking at the surface if >2 mm/m. Tensile strains are usually associated with convex curvatures near the sides (or ends) of the panels.
Compressive Strain	A decrease in the distance between two points on the surface. This can cause shear cracking or steps at the surface if > 2mm/m. compressive strains are usually associated with concave curvatures near the middle of the panels.
Inflexion Point	The point above a subsided area where tensile strain changes to compressive strain along the deflected surface. It is also the point where maximum tilt occurs above an extracted longwall panel.
Transverse Subsidence Profile	Subsidence measured (or predicted) across a longwall panel or cross line.
Longitudinal Subsidence Profile	Subsidence measured (or predicted) along a longwall panel or centre line.
Subsidence Impact	The effect that subsidence has on natural or man-made surface and sub-surface features above a mining area.
Subsidence Control	Reducing the impact of subsidence on a feature by modifying the mining layout and set back distances from the feature (normally applied to sensitive natural features that can't be protected by mitigation or amelioration works).
Subsidence Mitigation/ Amelioration	Modifying or reducing the impact of subsidence on a feature, so that the impact is within safe, serviceable and repairable limits (normally applied to moderately sensitive man-made features that can tolerate a certain amount of subsidence).
Factor of Safety	The ratio between the strength of a structure divided by the load applied to the structure. Commonly used to design underground coal mine pillars.
Confidence Limits	A term used to define the level of confidence in a predicted subsidence impact parameter and based on a database of previously measured values above geometrically similar mining layouts.

Mean Values	The average value of a given impact parameter value (i.e. of subsidence, tilt and strain) predicted using a line of 'best fit' through a set of measured data points against key independent variables (e.g. panel width, cover depth, extraction height). The mean values are typically two-thirds to half of the credible worst-case values.
CWC Values	The Credible Worst-Case (CWC) prediction for the predicted impact Parameter and normally based on the Upper 95% or U99% Confidence Limit line determined from measured data and the line of 'best fit' used to calculate the mean value. The CWC values are typically 1.5 to 2 times the mean values.
Outlier	A data point well outside the rest of the observations, representing an anomaly (e.g. a measurement related to a structural discontinuity or fault in the overburden that causes a compressive strain concentration at the surface, in an otherwise tensile strain field).
Subsidence Management Plan	Refers to the approval process for managing mine subsidence impacts, in accordance with the Department of Primary Industry Guidelines. The mine must prepare a Subsidence Management Plan (SMP) to the satisfaction of the Director-General, before the commencement of operations that will potentially lead to subsidence of the land surface.

1.0 INTRODUCTION

1.1 Overview

This report provides estimates of the subsidence deformations expected above the proposed Longwalls 1 to 14 in the No.4 Underground Area (No.4 UG) at the Moolarben Coal Mine (MCM) and assesses the likely impacts on existing surface and sub-surface features within the zone of influence of the longwalls.

This report has been prepared pursuant to an application for approval for a new coal mine project under Part 3A of the Environmental Planning and Assessment Act 1979. A Subsidence Management Plan (SMP) will also be required under the mining lease for the Moolarben Coal Mine (MCM) and will be produced in accordance with relevant guidelines from the NSW Department of Primary Industries (DPI).

The proposed panel layouts are to be located within the central east part of Exploration Licence 6288 (EL6288). The study area is approximately 3 km east of the village of Ulan and is situated between the Goulburn River National Park and the existing Ulan Coal Mine. The study area is bounded by the Goulburn River to the north, Goulburn River National Park to the east; the Gulgong to Sandy Hollow railway to the south, and the Ulan - Cassilis Road to the west, refer to **Figure 1.1**.

The study area has been divided into two areas, (i) No.4 UG - South, which will be mined by the first seven longwall blocks (LWs 1 - 7) and (ii) No.4 UG - North, which will be mined by LWs 8 - 14. The pit top infrastructure and access drifts will be located in the south-west corner of the study area.

The longwalls in the No.4 UG-South area will be developed and extracted from east to west, with the No.4 UG-North area subsequently mined from north to south. The main headings will have six roadways abreast and developed along the western and southern sides of the South and North areas respectively.

1.2 Study Objectives

The main objective of this study is to predict and assess the subsidence impacts from the proposed Moolarben No.4 underground mine. In doing this the report:

(i) assesses the likely range of subsidence and associated impact parameter values for the surface and sub-surface features, and

(ii) identifies appropriate methods to control or mitigate subsidence impacts to acceptable and/or manageable levels.

This report provides the basis for assessing the Moolarben No. 4 UG mine's subsidence impact for the purposes of seeking approval under Part 3A of the Environmental Planning and Assessment Act, 1979. It will also provide the basis of future SMPs for the proposed mining lease that are required to be produced in accordance with the Department of Primary Industries (DPI) guideline, "*Guideline for Applications for Subsidence Management Approvals, 2003*".

1.3 Scope of Work

The natural surface and sub-surface features and existing development that have been assessed for impact, in regards to the proposed underground mining layout, are listed as follows:

- Cliff lines (between 5 and 30 m high) including the significant tourist site, "The Drip", which is located along the Goulburn River (a DIPNR Schedule 3 watercourse), to the north of the study area;
- The Goulburn River National Park along the eastern boundary;
- Aboriginal archaeological artefact sites and rock shelters;
- A grave, memorial garden and relic homesteads and stock yards, dating from the 1870's;
- Cleared, gently sloping grazing land and a horse training track above No.4 UG - North;
- A local public access road to an existing rural residential property (Imrie-Mullins) east of the No.4 UG - North boundary line;
- Two privately owned residential houses, four huts, two sheds, a horse stable and five livestock water supply (farm) dams are located on the Westwood property above No.4 UG - North;
- Five livestock water supply (farm) dams are located on the Ulan Mine owned land above No.4 UG - South;
- A groundwater bore-field to the west of No.4 UG - South, which consists of a water bore, three poly lined storage dams and pump house adjacent to Ulan - Cassilis Road. The water bore is presently used by Ulan Coal Mine, but the operational details are unknown;
- A privately owned (Dronvisa Pty Ltd) gravel/clay quarry to the west of No.4 UG - South;
- The Gulgong to Sandy Hollow Railway to the south of the study area;
- Proposed mine site infrastructure and No.4 UG mine entry drifts, located to the south of the study area;
- The proposed 330 kV Transgrid easement located to the south of the study area;
- The Ulan-Cassilis Road to the west of the study area;
- The Ulan-Wollar Road to the south of the study area;
- Several public access roads on the site, which are likely to be closed during mining;
- Ephemeral creek lines (DIPNR Schedule 1 watercourses) and associated groundwater systems (i.e. drainage impacts);

- Surface and sub-surface aquifers (i.e. the vertical extent of fracturing).

The significance of the credible worst-case values of the relevant subsidence parameters has been assessed for each of the abovementioned features and appropriate mitigation / management options provided.

The study outcomes include the first (i.e. subsidence after each longwall is extracted) and final (i.e. after mining is completed in the study area) surface deformation predictions to 95% Confidence Limits. *Note: The 95% Confidence Limits represent the practical limits of measured subsidence and differential subsidence values for the given range of mining geometries.*

The report has referred to government agency directives and various multi-disciplinary project consultant reports provided to MCM and publicly available reports associated with the Ulan No.2 Underground Subsidence Management Plan.

1.4 Report Structure

The structure of the report is based on the Director General Requirements (provided in a letter dated 16/03/06) and the DMR Guidelines for SMPs. A summary of the scope of each of the sections of the report is summarised below:

- Chapter 1 provides an overview of the project study and report structure;
- Chapter 2 discusses the proposed mining layout and describes the subsidence development process with regards to longwall mining;
- Chapter 3 provides a detailed description of the study methodology, the empirical subsidence prediction model and the method of defining the uncertainty of the model predictions in probabilistic terms;
- Chapter 4 discusses the available geotechnical, geophysical and subsidence data used to complete the study;
- Chapter 5 describes the surface and sub-surface conditions within the study area;
- Chapter 6 discusses the validation of the subsidence prediction model with Ulan longwall data;
- Chapter 7 discusses the subsidence impact parameter predictions for the Moolarben longwalls;
- Chapter 8 discusses the stability of the Moolarben chain pillars after mining;
- Chapter 9 deals with maximum possible subsidence for the Moolarben longwall panels, based on Chapters 7 and 8;
- Chapter 10 discusses predictions of angle of draw outside the limits of the Moolarben longwalls;
- Chapter 11 describes the subsidence contours and impact parameter profiles based on Chapters 7 to 10;

- Chapter 12 discusses the credible worst-case impacts of the predicted subsidence and provides mitigation strategies;

- Chapter 13 presents an overview of the required surface and sub-surface monitoring strategies to meet the obligations of the proposed impact management strategies;

- Chapter 14 presents conclusions regarding the general and specific findings of the study and provides recommendations for the SMP.

- Chapter 15 contains the reference list for the study.

2.0 PROPOSED MINING GEOMETRY

2.1 General

Moolarben Coal Mines propose to mine the D Top (DTP), D Working Section (DWS) and E Top (ETP) Sections of the 10.4 m to 13.6 m thick Ulan Seam using the longwall method of extraction. The longwalls will have a void width of 260 m and chain pillar width of 35 m (solid). The average longwall face extraction height will range from 4.2 m to 4.5 m. Development headings will be located in the D Section only (i.e. DTP + DWS) with mining heights ranging from 3.2 to 3.4 m, depending on seam thickness.

The cover depth over the study area ranges from 85 to 215 m as shown in **Figure 1.1** (Note: depths shown in **Figure 1.1** are measured to the floor of the ELW, i.e. the base section of the Ulan Seam, which is about 5 m below the proposed mine roof horizon. Cover depth generally increases from west to east.

Maximum roadway widths of 5.5 m have been assumed in this study.

The No.4 UG - South area will be mined by the first seven longwall blocks (LWs 1 - 7). The longwalls will be orientated E:W, to the east of N:S orientated main headings.

The No.4 UG - North area will subsequently be mined by LWs 8 - 14. These blocks are orientated N:S and located to the north of E:W main headings. The pit top infrastructure and access drifts will be located in the south-west corner of the study area.

The longwalls in the No.4 UG - South area will generally be developed in a south to north sequence, with the longwalls then retreated from east to west. The No.4 UG - North area will be developed generally from west to east, with the longwalls retreating from north to south.

2.2 Stability of Underground Workings

The study area will eventually consist of first and second workings in the Ulan Seam. The design intent of the workings and method of extraction is such that the first workings provide stable access to the longwall blocks, which are mined such that the overburden collapses (i.e. "goafs") in a controlled manner as the coal is removed. All of the subsidence movements at the surface are generally the result of a new equilibrium being achieved (i.e. chain pillars and overlying strata compress elastically and overburden caves and eventually ‘re-supports’ itself on bulked and broken ground).

The longwall blocks are also designed with barrier pillars at the ends of the blocks, to protect the adjacent first workings (main headings) pillars from significant abutment loading.

The chain pillars are usually only designed to provide serviceable gate roads for access and ventilation, and may yield or crush out after mining is completed.

3.0 METHODOLOGY

3.1 Subsidence Impact Parameter Predictions above Longwall Panels

The study has been based primarily on Strata Engineering's longwall subsidence and massive strata database for the Newcastle Coalfield, refer to **ACARP, 2003**. The original database has since been supplemented with data from the Hunter Valley (Wambo and United Coal Mines), Western Coalfield (Ulan, Springvale and Angus Place) and Southern Coalfield (Elouera and Appin) over the past three years.

A summary of the details of the subsidence database and prediction methodologies for each impact parameter discussed in this report is provided in **Appendix A**. Some of the methods presented in **ACARP, 2003** have since been updated and are further explained herein.

The database allows an assessment of the upper 95% Confidence Limit (credible worst-case) values to be determined, for a given mining geometry and geology.

The report provides predictions of first and final subsidence above a series of adjacent longwalls. The definitions of first and final S_{max} are as follows:

First S_{max} = The maximum subsidence at the middle of the longwall panel after the extraction of a panel, including the effects of previously extracted adjacent longwalls.

Final S_{max} = The final maximum subsidence above the middle of a longwall panel after at least two subsequent longwall panels have been extracted, or when mining is completed.

Predicted 'smooth' subsidence profiles have then been determined, based on cubic spline curve interpolation through a number of key points along the subsidence trough (i.e. maximum in-panel subsidence, inflexion point, goaf edge or rib-side subsidence, subsidence over chain pillars and 20 mm subsidence or angle of draw limit). These have been empirically derived from regression relationships between the variables and the geometry of the panels. Both transverse and longitudinal profiles have been derived in this manner.

The first and second derivatives of the fitted spline curves provide the 'smooth' or continuous subsidence profiles and values for tilt and curvature. Horizontal displacement and strain profiles were derived by multiplying the tilt and curvature profiles by an empirically derived constant associated with the bending surface beam thickness (and based on the linear regression relationship between the variables, as discussed in **ACARP, 2003**).

An allowance for the possible horizontal shift in the location of the inflexion point (within the 95% Confidence Limits of the database) has also been considered for the predictions of subsidence at surface features located over the goaf or extracted area.

Subsidence contours have been created based on empirically derived subsidence profiles along cross lines, centre lines and corner lines around the ends of the longwall panels. Contours were derived using geostatistical kriging techniques and the data processing software Surfer 8®. Vertical 'slices' were then taken through the contours where required to (i) determine the final CWC subsidence profiles, and (ii) assess the likely impacts on the relevant surface features.

Far-field horizontal displacements due to incremental horizontal stress relief with time were considered relevant with regards to “The Drip”, and have been assessed, based on measured and published data from the Newcastle and Southern Coalfields.

3.2 Prediction of Subsidence Impact Parameters Using Regression Analysis Techniques

Key impact parameters inside or outside the limits of extraction have been estimated using normalised longwall subsidence data from the Newcastle and Western Coalfields. This approach allows a reasonable assessment of the uncertainty of the predictions to be made using statistical regression techniques. A linear or non-linear regression line has been fitted to the database for each impact parameter, which has been normalised to easily measured parameters such as maximum subsidence, panel width and cover depth. The quality or significance of regression relationships is significantly influenced by the following parameters:

(i) the size of the database,

(ii) the presence of outliers, and

(iii) the physical relationship between the key parameters.

All models must be calibrated to field observations to validate their use for prediction or back analysis purposes. SEA has developed the regression techniques presented in the **ACARP, 2003** report by firstly assessing conceptual models of the mechanics and key parameter dependencies (based on established solid mechanics, subsidence and structural analysis theories) before generating the regression equations.

Estimates of the confidence limits were determined using the residual errors (i.e. the difference between the ‘line of best fit’ and the measured values. For some of the regression curves, the confidence limit lines have also been based on weighted non-linear regression techniques to provide a better fit to the databases (a valid approach considering the physical constraints that govern the behaviour of the overburden above and outside the limits of extraction).

3.3 Prediction Model Uncertainty

Provided that (i) there are enough data points in the model to cover the range of the prediction cases, and (ii) the impact parameter and independent variables have an established physical relationship based on solid or structural mechanics theories, it is considered unlikely that the regression line will be significantly biased away from the underlying physical relationship between the variables by the data set. On-going review of each of the **ACARP, 2003** regression equations used in this report over the past three years has not required significant adjustment to the model.

3.4 Relevant Standards and Published Guidelines

The following standards, published guidelines and technical papers have been referenced, to provide an indication of tolerable subsidence impact parameters:

- Mine Subsidence Board (MSB) Graduated Index Guidelines for Designing Buildings in Mine Subsidence Regions (**Appleyard, 2001**).
- AS2870 - 1996, **Residential Slabs and Footings**.
- Mine Subsidence in the Southern Coalfield, NSW (**Holla and Barclay, 2000**).
- AS3798 - 1996 Guidelines on Earthworks for Commercial and Residential Developments.
- ARRB Special Report No. 41 - Pavement Design Guidelines.
- Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys: Management Guidelines for Undermining Cliffs, Gorges and River Systems (**ACARP, 2002**).
- Preparation of Subsidence Management Plans (**DMR, 2003**).
- Management of Stream/Aquifer Systems in Coal Mining Developments - Hunter Region (Version 1) (**DIPNR, 2005**).
- Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation (**DEC**).
- Landslide Risk Management Guidelines (**AGS, 2000**).
- Far field horizontal displacements due to horizontal stress relief have been assessed by reference to measured and published data from the Newcastle and Southern Coalfields (**Holla and Barclay, 2000**, **Hebblewhite, 2001**, **Seedsman, 2001**, **Reid, 2001** and **Kay et al, 2006**).

Further consultation will occur with the individual stakeholders about acceptable tolerances during the preparation of *individual* SMP agreements.

3.5 Work Program

The study methodology and work program included deriving the following:

(i) Maximum subsidence predictions along several representative cross lines and centre lines above each of the proposed longwalls (i.e. a total of 14).

(ii) Maximum subsidence predictions over tailgate chain pillars (i.e. pillars left between the extracted longwall panels, subject to double abutment loading conditions).

(iii) The long-term Factor of Safety of the chain pillars after extraction is completed.

(iv) Maximum tilts and curvatures above the panels.

(v) Maximum horizontal displacements and strains above and outside of the panels (i.e. far-field effects).

(vi) The prediction of first and final cross line or transverse subsidence parameter profiles (i.e. tilt, curvature, strain and horizontal displacement) at the relevant site-specific locations.

(vii) Predicted centreline or longitudinal subsidence parameter profiles above the retreating longwall at the relevant site-specific locations.

(viii) Predicted final subsidence contours, based on the Upper 95% Confidence Limits.

(ix) Pre and post-mining surface level contours, based on the predicted subsidence contours.

(x) The prediction of continuous and discontinuous sub-surface fracture heights, to assess the likelihood of proposed longwalls will be addressed for the assessment of likelihood of surface and sub-surface aquifer adjustment.

A walkover field inspection by a Principal Geotechnical Engineer and Mining Engineer (17/01/06) of accessible site surface features. An assessment has been made of the likely impacts of the predicted subsidence movements on the existing natural and man-made surface features with damage mitigation measures likely to be required (including suggested monitoring line locations to provide impact management response data).

Before the subsidence predictions could be made the following preliminary studies were necessary:

(i) The development of a geological model, based on available borehole logs and regional structure location plans.

(ii) An assessment of massive conglomerate and/or sandstone unit thickness variations and the location of the unit(s) above the proposed longwall panels.

(iii) Assessment of massive strata Subsidence Reduction Potential (SRP) over each of the longwall panels, based on the available borehole data and subsidence measurements at Ulan Coal Mine.

(iv) Validation of the empirical prediction model with regard to the influence of the known sandstone and conglomerate units above the extracted longwall panel geometries at Ulan Coal Mine.

4.0 AVAILABLE DATA

The following data was requested by Strata Engineering for the purposes of undertaking this assessment:

- AUTOCAD® plans of the proposed longwall panel layouts;
- Electronic copies of various interpreted contour plans of surface topography, Ulan Seam thickness, cover depth and known geological structure over the proposed longwall panel layouts;
- Written and graphical lithological logs of boreholes in the study area;
- Laboratory strength and stiffness testing data from surface to Ulan Seam;
- Geophysical logging data of sonic velocity profiles from surface to Ulan Seam;
- A plan of the interpreted massive sandstone unit locations above the study area (namely the sandstone units above the Middle River Seam (Unit 3), Goulburn, Glen Davis and Irondale Seams (Sandstone units 2a, 2b and 2c) and Ulan Seams (Unit 1).

The location of the longwall panels, cover depth contours and available boreholes in the study area are presented in **Figure 1.1**. A summary of the available borehole log data used in this report is presented in **Table 4.1**.

Table 4.1 – Borehole Log Data Used to Assess Geological Conditions In the Study Area

Proposed Mining Domain	LW Panels	Boreholes Used
South	LWs 1 - 7	C204, C223, C224, C225, C226, C227, C228, C229, C230, C231, C232, C233, C236, C246, C248, C249, WD75, WD76, WD77, WD111, WD113, WD115, WD116, WD117, WD118, WD119, WD120, WD121, WD124, WD127, WD131, WD132, WD133, WD134, WMLB78, WMLB34.
North	LWs 8 - 14	C221, C234, C235, C237, C238, C239, C240, C241, C242, C243, C244, C245, C247, WD78, WD122, WD123, WD126, WD128, TB105.

The boreholes are spaced on a typical grid of approximately 300 to 500 m, which is considered adequate for the scope of this study.

5.0 SITE CONDITIONS

5.1 Site Surface and Sub-Surface Features Register

A register of the natural and man-made surface and sub-surface features within the study area is presented in **Table 5.1**, together with the relevant government agency/council responsible for the item, the number of the item present on site and the sections in the report that discuss the item.

Table 5.1 - Register of Surface and Sub-Surface Features Identified in the Proposed Moolarben No.4 Underground Area

Description	Details	Local Council/State Government Agency and/or No. of items	Section No.s in this document in which item is discussed
(1) Natural Features			
1. Catchments and declared special features	The Drip	DNR, 1	5.6.2, 5.6.3, 12.8
2. National Park	Goulburn River National Park	DEC/NPWS	5.6.2, 12.2, 5.6.14
3. Rivers and creeks	Goulburn River, Schedule 1 Ephemeral Gullies	DNR, 2	5.6.1, 12.2, 12.4, 12.7
4. Aquifers, known groundwater resources	The Drip, Illawarra Coal Measures	DEC/DNR, 4	5.2, 12.3, 12.13, 12.10
5. Springs	The Drip, Cliff line base seepages	DEC/DNR, 2	5.6.3 ,12.6, 12.7, 12.8, 12.13
6. Cliffs	CL1-CL8 (refer to text)	DEC/DNR,	5.6.3, 12.6
7. Steep slopes	Associated with cliffs and plateaux	DEC/DNR, 4	5.6.1, 12.5
8. Swamps, wetlands, surface and groundwater dependent ecosystems (DGEs)	The Drip, minor localised	DEC/DNR	5.6.2, 5.6.3, 12.13,
9. Threatened and protected species	See ecological study report	DNR	-
10. Natural vegetation	Dry schlerophyll forrest	DNR	5.6.1
11. Soil Erosion	Alluvium, colluvium, residual	DEC	5.6.1, 12.5
(2) Public Utilities			
12. Roads	Ulan - Cassillis Road	MWRC, 1	5.6.12, 12.9
	Ulan - Wollar Road	MWRC, 1	5.6.12, 12.9
	Private access	2	5.6.2, 12.2, 12.4
	Bush tracks, fire Trails	3-4	5.6.2, 12.2
13. Road Cuttings	3 to 4 m High, 30 - 45^{o} Batters	MWRC, 3	5.6.12, 12.9
14. Bridges	Goulburn River	1	5.6.12, 12.9
15. Electricity Transmission Lines	Transgrid 330 kV line	1	5.6.2, 12.18
	Supply to individual properties	1	-
16. Railway Lines	Gulgong-Sandy Hollow	1	5.6.13, 12.17
17. Telecommunication lines	Fibre Optic Cable	N/A	-
	Standard Copper Lines	2	5.6.6, 12.15

Table 5.1 (Cont...) - Register of Surface and Sub-Surface Features identified in the Proposed Moolarben No. 4 Underground Area

Feature	Details	Local Council/ State Government Agency and/or No. of Items	Section No.s in this document in which item is discussed
(3) Farmland and Facilities			
18. Agricultural Utilisation	Horses and cattle	20	5.6.2, 12.2
19. Sheds and Stables	Westwood's stable	1	5.6.6, 12.15
20. Groundwater Bores	Ulan Mine Bore field (Not registered)	DNR,1	5.6.10, 12.10
21. Fences	Westwood's/Ulan Mine/Crown Land Property	~20	5.6.2, 5.6.6, 12.19
22. Farm dams	Earth embankments 1-2 m high, <1 ML storage	10	5.6.7, 12.16
23. Irrigation systems	N/A	0	-
(4) Industrial, Commercial, and Business Establishments			
24. Workshops	N/A	0	-
25. Business equipment and premises	Dronvisa Gravel/Clay Quarry	1	5.6.11, 12.11
(5) Existing Undergound Mining Areas			
26. Abandoned Workings	N/A	DPI, 1	-
(6) Archaeological Sites			
27. Areas of Archaeological and/or Heritage significance	Aboriginal Sites	DEC, 14	5.6.4, 5.6.5, 12.14
	European	N/A	-
(8) Other			
28. Westwood's Memorial Garden	Minnie Josephine Westwood's ashes & grave of Mr Raymond Perry (Aboriginal friend)	Merriwa Shire Council (1979), 1	5.6.8, 12.20
29. Farm House	> 50 years old (circa 1920's)	TBA	5.6.9, 12.19
30. State Survey Control	None	Lands D, 0	-
(7) Residential Establishments			
31. Residences	Total Residences:	6	5.6.6, 12.15
	Single storey brick veneer	1	5.6.6, 12.15
	Single storey fibro	3	5.6.6, 12.15
	Single storey timber/metal	2	5.6.6, 12.15
32. On-site waste water disposal systems	Westwood residences have on-site waste water disposal systems-trenches/pit	MWRC, 6	5.6.6, 12.15
33. Water tanks	Residents are dependent on tank water	MWRC, 6	5.6.6, 12.15
34. Swimming pools	N/A	0	-
35. Driveways/landscaping	N/A	0	-
36. Ancillary sheds	small sheds	3	5.6.6, 12.15

Notes:
MWRC - Mid-Western Regional Council.
DEC - Department of Environmental Conservation.
DPI - Department of Primary Industries.
N/A - Not Available.
DNR - Department of Natural Resources.
HO - Heritage Office.
Lands D - Lands Department.

5.2 Geological Setting

Refering to the 1:100,000 Geological Sheet for the Western Coalfield (**DMR, 1998**), the Moolarben Coal Project EL area is located predominantly within the Triassic Narrabeen Group (Wollar Sandstone) and underlying Permian Illawarra Coal Measures on the western margin of the Sydney-Gunnedah Basin. Carboniferous granite basement rocks (Ulan Granite) and Rhylstone Volcanics are noted to the west and east of the lease respectively.

The Illawarra Coal Measures are generally 100 to 120 m thick and comprise interbedded sandstone, siltstone, tuffaceous claystone/mudstone and dull/banded coal. The Ulan Seam is regarded as the only seam of economic importance in the measures at this location. Other seams that are present within the Permian sequences above the Ulan Seam (in ascending order) include the Irondale Seam (27 to 41 m above the proposed workings), the Glen Davis Seam (55 to 65 m above the proposed workings), the Goulburn Seam (70 to 73 m above the proposed workings) and the Middle River Seam (82 to 95 m above the proposed workings). The seams in the overburden are generally less than 3 m thick and are not considered to be significant sub-surface aquifers (refer to the groundwater consultant's report for further details).

In the elevated areas of the No 4 Underground, the Illawarra Coal Measures are overlain by up to 60 m of plateau (the “Moolarben Plateau”), formed of Wollar Sandstone. The Wollar Sandstone is generally finer grained and lithic in the lower sections, with coarse grained quartzose lithology existing in the upper sections.

The contact between the Permian and Triassic groups at the site is marked by an erosional unconformity above the Middle River Coal Seam, whereby the Farmers Creek Formation has been largely removed. The cover depth above the Ulan Seam ranges between 85 and 215 m, with the shallow cover located along the western and south-western foot slopes of the Moolarben Plateau.

Along the valley floor to the south of the Moolarben Plateau, the upper section of the coal measures has been eroded; with deep Quaternary Alluvial deposits (up to 35 m deep) comprising sandy gravels and clayey sands are indicated by borehole logs.

The Moolarben Plateau itself consists of deeply incised gullies and sub-vertical cliff lines created by differential weathering along persistent joint sets and weaker fine grained, lithic sandstones along the cliff bases. Numerous sandstone boulders/talus exist along the cliff bases due to natural weathering processes. Shallow alluvial/slope wash-filled gullies and flats exist between the broad, prominent ridges.

According to the MCM geologist's report (**Johnstone, 2005**), the structural setting of the area is relatively simple. Rock mass bedding generally dips at 2 to 3 degrees towards the NE, with some superimposed rolling dips and undulations expected in the Ulan Seam.

No significant geological structure is indicated on the DMR Geological Sheet, with the NNE trending Spring Gully Fault Zone (strike-slip) to the west and the NW trending Curra and Green Hills Faults (graben-horst) located to the north.

The major horizontal stress is likely to be oriented NE:SW (**Strata Engineering, 2005**).

5.3 Geotechnical Unit Properties in Roof and Floor of Proposed Workings

The proposed longwalls are to be located within the D and E sections of the Ulan Seam (which consists of A to E Sections in total). The longwalls will extract the DPT, DWS and ETP Sections with development headings driven in the DTP and DWS sections only, see **Figure 5.1**.

The coal seam sections to be mined are of ‘low’ strength, with Unconfined Compressive Strength (UCS) values ranging from 10 to 15 MPa. Some ‘low’ strength claystone bands up to 0.15 m thick are present within the coal seam, with UCS values ranging between 15 and 25 MPa, see **Figures 5.2a to 5.2c**. Note that the following references to rock strength are based on the classification system presented in **ISRM, 1981**.

The immediate roof of the proposed mining horizons will consist of 5 to 7 m of coal (Ulan Seam UA, UB, UC and UCL Sections) with some tuffaceous claystone and carbonaceous shale beds up to 0.35 m thick (i.e. the C Marker or CMK unit is the thickest claystone bed and is approximately 0.85 m above the DTP Section). The Ulan Seam is overlain by several metres of interbedded siltstone and sandstone (i.e. laminite) with ‘medium’ strength (UCS of 22 to 48 MPa). Some isolated thin bands of siderite with 'very high' strength (UCS up to 107 MPa) exist in the finer grained strata.

The immediate floor of the proposed workings consists of 1.6 m to 2.7 m of ‘low’ strength dull/banded coal (i.e. Ulan Seam EBT and EL Sections) with some ‘low’ strength tuffaceous claystone and carbonaceous mudstone bands up to 0.15 m thick. The Ulan Seam is underlain by up to 1 m of ‘low’ strength (i.e. UCS 14 - 20 MPa) shale and siltstone with ‘medium’ strength (i.e. UCS 20 - 50 MPa) sandstone units underlying the finer grained beds.

The UCS and stiffness properties of the immediate roof and floor materials have been derived from laboratory and point load strength test results, plus *in-situ* geophysical testing data from borehole WMLB78. Good correlation is apparent between laboratory derived and *in-situ* sonic UCS results (see **Figures 5.2a to 5.2c**).

Typical ranges of material strength and stiffness properties are summarised in **Table 5.2**.

Table 5.2 – Strength Property Estimates for Ulan Seam, Roof and Floor Lithology

Lithology	Unit Thickness Range (m)	UCS Range (MPa)	Unit Elastic Moduli Range(GPa)*	Poisson’s Ratio
Interbedded Sandstone/ Siltstone, with some minor coal seams, above Ulan Seam	>10	22 - 48	3.3 - 14	0.13 - 0.19
Immediate Coal Roof with some tuff (UA-UCL,CMK)	4.8 - 7.7	10 - 20	1.5 - 6	N/A
Ulan Seam Coal Pillars and Mudstone Bands	3.2 - 3.4	10 - 20	1.5 - 6	N/A
Immediate Coal Floor with some mudstone (UEPT-UEL)	1.6 - 2.7	10 - 20	1.5 - 6	N/A
Siltstone/Sandstone below Ulan Seam	>10	45 - 60	6.75 - 18	0.23

Note:* - Young’s Modulus (E) derived from sonic UCS data, E = 150 to 300 x UCS (units are in MPa).

5.4 Overburden Lithology and Massive Sandstone Units

Subsidence prediction for the proposed longwalls requires an assessment of massive sandstone/conglomerate unit thickness and location in the overburden. The lateral persistence of the members is also a factor assessing the bridging or Subsidence Reduction Potential (SRP). Where there are no significant sandstone units, or significant faulting is present, a low SRP is assumed (see **Section 6** for further subsidence model definition details).

Reference to the borehole logs within the study area indicates, that there are three potential subsidence-reducing sandstone beds (henceforth referred to as Units 1 to 3) in the overburden. The beds are generally thickly bedded to massive and separated by thinly bedded sequences of shale, siltstone, mudstone and coal beds that would be expected to shear and readily cave below bridging massive units after extraction.

The SRP of each unit is assessed separately; they are assumed to be acting independently of one another in the overburden. The sandstone unit with the highest SRP is then adopted as the key unit for subsequent subsidence predictions (refer to **Section 6**).

Interpreted sandstone unit thicknesses and locations above the proposed longwalls are shown in long section in **Figures 5.3** and **5.4**. Units 1 and 2 are located within the Illawarra Coal Measures but the dominate sandstone unit (Unit 3) is considered to be the Triassic Wollar Sandstone.

- Unit 1 is a sandstone unit 5 to 30 m thick, approximately 8 to 37 m above the Ulan Seam. The unit is located between the Ulan and Irondale Seams and is relatively persistent laterally, crossing all of the panels in the study area.

- Unit 2 is a sandstone unit of 1 to 37 m thick, with its base 24 to 88 m above the Ulan Seam. Unit 2 is represented by several sub-units that are intermittently distributed over the study area, between the Irondale and Middle River Seams (i.e. Units 2a, 2b and 2c). Unit 2 is generally relatively thin compared to Units 1 and 3, but increases in thickness towards the southern end of the study area.

- Unit 3 is a 9 to 68 m thick massive sandstone and conglomerate (i.e. the Wollar Sandstone), with its base located approximately 85 to 137 m above the Ulan Seam. The unit is significantly thicker than the other two units. However, its upper section has been extremely weathered in some areas, to depths ranging from 5 to 34 m. The unit thickness has also been effectively reduced by the deeply incised gullies between the surface ridges. In general, Unit 3 will have a significant impact on subsidence reduction.

Unit 1 has a higher compressive strength than that of Unit 3, according to available data. However, due to its limited thickness and distance from the Ulan Seam, it will have minimal impact in terms of subsidence reduction (i.e. a low SRP).

Although the weathering of the upper portion of Unit 3 has reduced its strength, it is still considered to have significant SRP in the entire area except above the southern end of LWs 1-7 (i.e. No.4 UG-South), where Unit 2 is considered to have greater SRP than Unit 3.

The SRP assessment for Units 1 to 3 is further discussed in **Section 6**.

The thickness and location of the sandstone units are summarised in **Table 5.3**.

Table 5.3 – Summary of Massive Sandstone Units above LWs 1-14 in the Study Area

Sandstone Unit	Unit Location	Strata Unit Thickness (m)	Distance above Extraction Horizon (m)	Depth to top of Unit* (m)
1	Sandstone located above the US but below ICS	5 - 30	8 -37	110 - 130
2 (a,b,c)	Sandstone above ICS but below the MRS	1 - 37	24 - 88	50 - 80
3	Sandstone above MRS	9 - 68	85 - 137	0 - 10

Note:
US = Ulan Seam; ICS = Irondale Seam; MRS = Middle River Seam
*- based on the cover depth ranges in the boreholes.

Contours of individual unit thickness and location above the workings are shown in **Figures 5.5** to **5.10** for Units 1, 2 and respectively.

5.5 Geological Structure

As mentioned earlier, there is no known regional-scale structure present within the study area.

Surface joint patterns measured on the sandstone cliff lines and outcrops around the site consist primarily of two sub-vertical, widely spaced, planar to wavy, persistent joint sets striking at 005º (N:S) and 075º (ENE:WSW). A third sub-vertical joint set striking between 105º and 145º (NW:SE to WNW:ESE) is also present. The trend of the cliff faces is similar to the primary and secondary joint sets.

A forth, joint set was observed, dipping at 50º to 60º (mid-angled) towards the north-west and persistent through the cliff lines. Several failed wedges associated with this joint set were observed along north-west corners of the cliffs within the study area.

5.6 Surface Conditions

5.6.1 General

The No 4 Underground area is approximately 3 km east of the village of Ulan and is situated between the Goulburn River National Park and the existing Ulan Coal Mine.

The site is bounded by the Gulgong to Sandy Hollow rail-line to the south and the Ulan - Cassilis Road defines the western boundary. The Goulburn River gorge, known as “The Drip”, and the Goulburn River National Park form the northern and eastern boundaries respectively, refer **Figure 1.1**.

The surface topography in the study area is shown in **Figure 5.11** and ranges between undulating ridge-affected terrain and broad, shallow alluvium and slope-wash filled gullies and valleys. Topographic relief is about 90 m from RL 410 m (AHD) to RL 500 m (AHD).

Landforms on the site include wooded upland ridges, and dissected plateaux associated with the Goulburn River. In the southern area, the ridges grade down to a cleared valley. Access to the valley floors is good, whilst road access to the more rugged plateaux is limited to a few tracks and fire trials.

Ground slopes generally range between 10° and 20° on the ridges and decrease to between 0° and 10° on the ridge crests, foot slopes and in valley floor areas.

Sandstone and conglomerate outcrops and cliff lines ranging from 5 to 30 m high define the plateau / ridge crests. Numerous loose boulders or talus exist on the mid-slopes and foot slopes of the ridges and cliff lines.

The lithic to quartzose sandstone and conglomerate exposures are grey to orange-brown in colour, cross bedded and have low to high material strength.

The soil profile on the upper to mid-slopes of the ridges is judged to comprise residual gravelly, sandy clays, overlying extremely to highly weathered sandstone and conglomerate.

5.6.2 Land Use and Current Ownership

The current land titles in place for No.4 Underground are presented in **Figure 5.12** and summarised below:

- The entire northern area (No.4 UG - North) is freehold land, which is understood to have been acquired by MCM from Westwood's. Several residential dwellings/huts and livestock watering dams exist in the cleared area to the north, with the structures located above the proposed LWs 11 to 13.

- An unsealed gravel access road off Ulan-Cassilis Road traverses LWs 12 to 14 and provides access to the Westwood residents, as well as a private property (Imrie-Mullins), immediately to the east of the study area.

- The remainder of the property is generally undeveloped bush land with several access tracks.

- The Goulburn River has a gorge approximately 250 to 450 m north of proposed longwalls 12 to 14, known as "The Drip". The Drip is a public nature reserve that has high local value (refer to NSW Heritage Office (HO) Site Recording Form No. 23). It is frequented by tourists and the local community and is a popular bush-walking route. The reserve starts at a picnic area adjacent to Ulan-Casilis Road and extends for approximately 1.6 km downstream, past several distinct natural cliff lines and aboriginal heritage sites. It is a requirement of the NSW HO that public access to the site is maintained.

- The Goulburn River National Park boundary is located 150 to 270 m to the east of the proposed longwall blocks.

- The southern area (No.4 UG - South) is predominately land owned by Ulan Coal Mines Pty Ltd with a portion of Crown Land, located in the north-eastern corner of this area. The land is generally undeveloped bush land with some cleared areas used for grazing and watering livestock. Several small earth embankment dams exist at the heads of gullies.

- A Ulan Mine owned and operated groundwater bore-field with three polymer lined earth embankment dams and pumping station exists above the proposed main headings to the east of the LW7 extraction limits, see **Figure 5.11**.

- A privately leased gravel/clay quarry (Dronvisa Pty Ltd) operates to the south of the groundwater bore-field and is located on Ulan Mine owned land. The quarry is located just outside the proposed extraction limits of LWs 4 and 5, see **Figure 5.11**. The company hold several mining licenses over the area.

- The Ulan-Cassilis Road is under the care and control of the Mid-Western Regional Council, with funding assistance provided by the NSW Roads and Traffic Authority (RTA).

- The Gulgong to Sandy Hollow Railway is owned by the NSW state government and maintained by a rail service provider.

- The proposed surface infrastructure for the underground mine is to be located 200 m south of LW 1. The infrastructure proposed includes the main office and bath house, workshops, water management storage and treatment structures, substation, product stockpile, CHPP, Rail Load-out Bin and rail loop. The proposed 330 kV transmission line and the Ulan-Wollar Road re-alignments will be 250 m to 500 m south of LW1.

5.6.3 Cliff Line Conditions and The Drip

There are eight areas with cliff lines in the study area, 5 areas (CL1 - 5) in the northern region (LWs 8 to 14), including The Drip (CL 5), and 3 areas (CL6 - 8) in the southern region (LWs 1 to 7). The location of the cliffs is shown in **Figure 5.11**.

The majority of the cliff lines are located over proposed longwall panels, except for CL5, which is about 250 m to 450 m north and east of LWs 12 to 14.

The cliff faces above the proposed longwalls are sheer to rounded in shape and range in height between 5 and 30 m. Their lengths range from 10 m to 200 m or more. The cliff faces slope between 60^o and 85^o, with numerous small overhangs or rock shelters along their bases. The overhangs are 2 to 4 m deep and typically 10 m long. Several large overhangs of 5 to 7 m depth also exist and some have collapsed beds of sandstone within them.

Some of the cliff faces also have several tiers with occasional pagoda type formations up to 5 m high. Some of the overhangs have been categorised as archeologically significant rock shelters, and will be furthered discussed in **Section 5.6.4**.

Ground slopes above and below the cliffs dip between 5^o and 20^o, with numerous talus cobbles and boulders present on the foot slopes. The maximum dimension of the talus ranges between 1 and 10 m. The cliff lines appear to be well drained with no excessive erosion or seepages noted around the cliffs. Vegetation above and below the cliffs is generally sparse to dense, consisting of mature trees and scrub growth.

Active natural cliff line instability processes are evident in the study area and are dominated by block, wedge or toppling failures along persistent rock mass structure (i.e. joints). Block and toppling failures appear to be initiated by the faster weathering rates of the weaker, fine grained, lithic sandstones and shales that are present along the cliff line bases. This has resulted in the undercutting and eventual failure of overhanging quartzose sandstone units.

The wedge or sliding failures tend to occur in a similar way to the undercutting/overhang failure mechanism, when mid-angled structure, sub-parallel to the cliff face was exposed by an active undercut.

The specific details of each cliff line will now be summarised below with details of the mine impact rating assessments presented in **Appendix C**.

Cliff Line, CL1:

CL1 is located above and outside the north-west corner of LW12, see **Figure 5.11**. The area has relatively steep slopes with several orthogonal, south to west facing sub-vertical cliffs and overhangs. The cliffs are approximately 3 to 15 m high with slopes of 60^o to 85^o. The cliff faces strike at 010^o, 075^o and 165^o (i.e. NNE, ENE and NNW).

The overhangs along the cliffs are 2 to 7 m deep, 3 to 4 m thick and up to 10 m long. Cobble to boulder-sized sandstone talus was present in front of and down slope from the cliffs.

The lithology of the cliffs and overhangs are predominantly thickly bedded, fine to coarse grained, quartzose sandstone, grey-yellow brown, with medium to high strength. Some thinly bedded, fine grained, lithic sandstone and laminated shale beds with low strength, have been undercut and form the back walls of the overhangs.

Most of the cliffs in this area have widely spaced sub-vertical joints striking normal to the cliff faces at 2 to 3 m spacing. Some of the overhangs with a depth of 4 to 5 m had partially collapsed where a joint that was sub-parallel to the overhang face, coincided with the back wall of the undercut. Occasional, very widely spaced, mid-angled and persistent joints dipping at 50^o towards the north-west have resulted in wedge failures near the corners of the west facing cliffs.

The ground slopes behind and below the cliff lines range between 5^o and 10^o with medium dense to sparse vegetation consisting of mature trees and scrub.

Photographs of two cliffs (with overhangs) that are typical of this area are shown in **Figure 5.13**.

Cliff Line, CL2:

CL2 is located above LWs 11 and 12, see **Figure 5.11**. The cliffs strike at approximately N:S and face towards the west. The cliffs are stepped with 3 to 5 m high tiers and an overall height of 12 to 15 m. The cliffs in this part of No. 4 UG do not have well developed overhangs and some of them are pagoda type with ironstone indurations at bedding parting boundaries.

The lithology of the cliffs is predominantly medium to high strength sandstone, thickly bedded, grey-yellow brown, fine to coarse grained, with some thin beds of claystone present. Most of the cliffs have widely spaced sub-vertical joints which are normal to or at moderate angles to the cliff faces. Sandstone cobble to boulder-sized talus was present in front of the cliffs and further down slope.

The ground slopes behind and below the cliff lines range between 5^o and 10^o with medium dense to sparse vegetation consisting of mature trees and scrub.

Photographs of two cliffs typical of this area are shown in **Figure 5.14**.

Cliff Line, CL3:

CL 3 is located above LWs 13 and 14, see **Figure 5.11**. The cliff lines at this location range in strike from 045°: 225° (NE:SW) to 145°:325° (SE:NW) and face towards the north-west, west and south-west respectively. The cliffs are 10 to 30 m high, with 5 m to 10 m deep overhangs that are 60 to 70 m in length. The cliff faces slope at 80° to 85° near the crests and then dip back into the face at about 70° at mid-height (due to previous overhang failures).

The upper sections of the cliffs consist of high to medium strength sandstone and pebbly sandstone, fine to coarse grained, orange - brown, with ironstone indurations along bedding partings. The lithology of the back walls of the overhangs / undercuts is cross-bedded, lithic sandstone, fine to medium grained with low strength. Irregular cross bedding with river stones exist in the lithic sandstone along the lower half of the cliff lines at this location.

Visible joints are widely spaced, sub-vertical and normal to or at moderate angles to the cliff faces. Numerous sandstone boulders and cobble sized talus exist along the base of the cliffs and downslope of the cliffs in this area.

The ground slopes behind and below the cliff lines range between 5° and 15° with medium dense to sparse vegetation consisting of mature trees and scrub.

Photographs of two cliffs typical of this area are shown in **Figure 5.15**.

Cliff Line, CL4:

CL 4 is located above LWs 10 and 11, see **Figure 5.11**. The cliffs are oriented at 315°/135° (NW:SE) and 000°/180° (N:S). The cliffs in this part of No. 4 UG do not have well developed overhangs. Most of the cliffs are 5 to 10 m high, and have 1 m to 2 m deep overhangs that are 2 to 3 m thick and 5 m long.

The lithology of the cliffs is predominantly medium to high strength sandstone, thickly bedded, grey-yellow brown, fine to coarse grained, with some thin beds of claystone present. Most of the cliffs have widely spaced sub-vertical joints which are normal to or at moderate angles to the cliff faces. Sandstone cobble to boulder-sized talus was present in front of the cliffs and further down slope.

The ground slopes behind and below the cliff lines range between 5° and 15° with medium dense to sparse vegetation consisting of mature trees and scrub.

Small, localised groundwater seepages from open joints in the rock mass, sustain the growth of flora (non-threatened species) along the bases of some of the cliffs.

Photographs of the cliffs typical of this area are shown in **Figure 5.16**.

Cliff Line, CL5 (The Drip):

CL5 refers to the northern cliff face of "The Drip" and is located a minimum distance of 250 m beyond the northern ends of LWs 12 and 14, see **Figure 5.11**. The Drip is a distinctive gorge with northern and southern sandstone cliff faces formed by the Goulburn River (which flows towards the east).

The northern cliffs are sheer sub-vertical faces that are 30 to 40 m high and more than 300 m in length. Groundwater seepages from the north discharge down the cliff face and have resulted in the development of groundwater dependant ecosystems (GDEs), see reports by the MCP's groundwater and ecological consultants.

The southern face of The Drip has lower, rounded cliffs with heights of about 10 to 20 m and are similar to the drier cliffs found above the No. 4 UG area. The northern cliffs of The Drip are located approximately 250 m to 470 m north of the ends of the proposed starting positions of LWs 12 to 14. Where the gorge NE corner of LW14 The river and gorge runs parallel to the ends and sides of the above LWs before diverging away to the east at about 300 m in from the start of LW14. The base of the gorge is about 50 m wide with sandy river sediment, rock pools and riparian vegetation.

There are numerous fallen boulders/wedges with side dimensions of up to 10 m along the gorge, that have been generated by similar weathering processes to those noted along cliff lines to the south.

The cliffs along the gorge have widely spaced sub-vertical joints which are normal to or at moderate angles to the cliff faces.

Another significant feature along the gorge is a thin ‘dyke-like’ upstand rock structure (“The Bread Knife”) that is located above the northern cliff face to the north of LW 14.

Photographs of the northern cliffs of The Drip and The Bread Knife are shown in **Figure 5.17**. The southern cliffs are shown in **Figure 12.7**.

Cliff Line, CL 6:

CL 6 is located above LW6, see **Figure 5.11**. The E:W and NW:SE trending, sub-vertical cliffs are approximately 5 to 15 m high, with some overhangs that are 2 to 10 m deep, 1 to 5 m thick and 10 to 20 m long.

The lithology of the cliffs and overhangs is predominantly medium to high strength sandstone, thickly bedded, grey-yellow brown, fine to coarse grained. Undercutting at the base of the cliffs is occurring in weak, thinly bedded, fine grained, silty sandstone.

Several visible E:W striking joints with about a 2 m spacing are sub-parallel to some of the cliffs where some spalling of sandstone blocks along joints.

The slopes below the cliffs range between 15^{o} and 17^{o} for 10 to 15 m, with numerous blocks of sandstone talus accumulating down the slope. The slopes then break to more gently sloping terrain, associated with alluvial and slope wash-filled gullies.

Photographs of the cliffs in this area are shown in **Figure 5.18**.

Cliff Line, CL 7 :

CL 7 is located to the east of LWs 5 and 6; see **Figure 5.11**. The cliff lines are generally N:S to E:W trending with overall heights ranging from 15 to 35 m. The cliff faces are sub-vertical and approximately 5 to 15 m high with overhangs that are 2 to 7 m deep, 1 to 10 m thick and 10 to 20 m in length.

The lithology of the cliffs and overhangs is predominantly medium to high strength sandstone, thickly bedded, grey-yellow brown, fine to coarse grained. The undercutting at the base of the cliffs is occurring in fine-grained, thinly bedded silty sandstone with low strength. Some large, loose sandstone blocks were noted along the toe and crests of the cliff lines.

The slopes below the cliffs range between 15^{o} and 17^{o} for 10 to 15 m with numerous blocks of sandstone talus accumulating down the slope. The slopes then break to more gently sloping terrain.

On-going spalling and collapse of overhanging sandstone (formed by preferential weathering of low strength, silty sandstone beds) was evident at some locations with visible E:W striking joints that were sub-parallel to the cliff faces and a minimum spacing of 2 m.

Photographs of the cliffs in this area are shown in **Figure 5.24**.

Cliff Line, CL 8:

CL 8 is located above LWs 1 and 5, see **Figure 5.11**. These cliff lines could not be accessed during the fieldwork. However, based on reference to the surface slopes derived from the topography contours (refer to **Figure 5.13**), it is assessed that the cliffs are generally N:S trending, with heights ranging between 5 and 15 m. It has been assumed for the purposes of this report, that CL 8 will have similar characteristics as CL 4. This assumption will need to be verified before undermining occurs.

A schematic section of the typical characteristics of the cliff lines and overhangs is presented in **Figure 5.19**.

5.6.4 Aboriginal Rock Shelters

According to information provided by the project heritage consultant, there are 177 overhangs identified in the study area that are assessed to have been used in the past by the aboriginal people as rock shelters (RS1-177), see **Figure 5.11**. The overhangs that have been classified as rock shelters have evidence of previous aboriginal habitation due to the presence of scattered artefacts, grinding grooves and hand paintings.

The majority of the rock shelters are located along cliff lines CL1 to 4 and CL 6 to 7. Eight of the rock shelters are considered archeologically significant, six are above UG4 - North and two are above UG4 - South.

The majority of the rock shelters have overhangs that are 2 to 4 m deep and 2 to 4 m thick. The exceptions are the shelters at CL3, which have several large overhangs of around 10 m deep and 20 to 25 m thick. See **Section 5.6.3** for details of rock shelter geological characteristics.

Rock shelter location details and the numbering system adopted for the purpose of this study are provided in **Appendix B**.

5.6.5 Significant Aboriginal Archaeological Sites

There are 14 significant aboriginal archaeological sites in the study area (AS 1 to 14); see **Figure 5.11**. Ten of the sites are rock shelter (two with hand paintings) and artefact sites; three are artefact scatters and one has several axe grinding grooves on a sandstone rock 'bar'. There is also a site considered to be a potential archaeological deposit (PAD).

Significant archaeological site location details are provided in **Appendix B** and summarised in **Table 5.4**. Photographs of several of the significant sites are shown in **Figures 5.20** to **5.28**.

The likelihood of significant damage to the above sites, due to the impact of longwall mining is assessed in **Section 12**.

Table 5.4 – Summary of Specific Aboriginal Archaelogical Site Details for Mining Impact Assessment

AS No	S1 MC No.	Type	LW No	Location Relative to LW (m)*		Overhang or Rock Bar Geometry				Comment On Current Condition**
				Side	Start	Depth (m)	Height (m)	Length (m)	Cliff Strike	
1	254	Artefact Scatter (Figure 5.20)	13	101	1005	N/A	N/A	N/A	N/A	Residual soils /slopewash
2	256	Rock Shelter (Figure 5.21)	13	-39	47	3-4	3-4	10-15	N-S	Joints @ 3-5 m spacing
3	261	Rock Shelter (Figure 5.21)	11	0	25	3-4	3-4	10-15	N-S	Joints @ 3-5 m spacing
4	264	Grinding Grooves (Figure 5.22)	9	60	64	15-20 rock bar	N/A	15-20	N/A	High strength sandstone, joints @ 5-10 m spacing
5	267	Rock Shelter (Figure 5.23)	6	87	66	2-3	2-3	5-7	N-S	Joints @ 3-5 m spacing
6	271	Rock Shelter (Figure 5.24)	5	-54	53	2-3	3-5	5-7	E-W	Joints @ 3-5 m spacing
7	280	Rock Shelter (Figure 5.25)	3	60	905	5-6	3-5	15-20	N-S	Partially collapsed, joints @ 5-10 m spacing
8	281	Artefact Scatter	12	-88	-125	N/A	N/A	N/A	N/A	Residual soils /slopewash
9	282	Artefact Scatter	12	-103	-116	N/A	N/A	N/A	N/A	Residual soils /slopewash
10	283	Rock Shelter	12	-40	-92	2-3	3-5	5-8	E-W	Joints @ 3-5 m spacing
11	284	Rock Shelter with hand paintings (Figure 5.26)	12	-77	-34	4-7	3-5	10-15	E-W	Partially collapsed, joints @ 3-5 m spacing
12	285	Rock Shelter (Figure 5.27)	12	-47	116	4-5	3	10	N-S	Joints @ 3-5 m spacing
13	286	Rock Shelter (Figure 5.28)	12	-82	124	2-3	3-4	10	N-S& E-W	Joints @ 3-5 m spacing
14	PAD 11	Rock Shelter (Figure 5.24)	5	100	-132	5-7	5-10	10-15	E-W	Joints @ 3-5 m spacing

Notes:
AS = Strata Engineering numbering system as shown in figures.
S1MC = Heritage Consultant numbering system.
*- Negative values indicate location is outside the limits of LW extraction.
** - Visible joints are generally normal to the cliff faces.

5.6.6 Residential Development

Within the study area, there are two small dwellings, four 'huts', two sheds and one horse stable. The buildings have been assigned a number B1 to B9 on **Figure 5.11**. It is understood that all of the houses and huts were inhabited at the time of the field work.

Details of the dwellings are described as follows:

Jim Westwood's Residence (Building No. B3):

The residence is a single storey 12 m x 11 m brick house with a galvanised iron roof and timber post frame as shown in **Figure 5.29**. There is a timber post/galvanised iron clad shed and a water tank on posts near the house. The house is in a flat area with 1 - 2^{o} slope.

There are several trees up to 5 m high in front of the house.

Tony's Residence (Building No. B1):

The residence is a 10 m x 16 m fibro clad, timber framed house with galvanised iron roof. The house is built on brick/pad footings as shown in **Figure 5.30**. A fibro clad shed exists to the south of the residence.

Associated Huts and Sheds (Building No.s B2, B4 to B9):

There are four 4 m x 5 m single room huts that are all built on timber, concrete or rock boulder slabs. The huts have either timber or steel post frames and are clad with galvanised iron, weather board or sheet metal. Most of the huts have equipped with water tanks on timber posts. All the huts have glass windows and one has stone and mortar chimney. **Figure 5.31** shows two of the huts.

A 20 m x 8 m horse stable (B5) is built of timber posts and sheet metal cladding.

5.6.7 Stock Water Supply Dams

There are ten stock water supply dams in the study area as shown in **Figure 5.11**. Five of the dams (D1-D5) are located in the No.4 UG - north region associated with Jim Westwood's house. The dams are small earth embankment water supply dams, with a storage capacity of about 0.1 - 0.2 ML (10 m to 20 m x 10 m x 1 m deep).

The other five dams (D6, D7 and D11 to D13) are located in the No. 4 UG - South region. The size of the dams is considered to be in a similar rage to those in the north region.

5.6.8 Memorial Garden and Grave Site

The memorial garden for Minnie Josephine Westwood's ashes and the remains of an Aboriginal family friend (Mr Ray Perry) and is located near relic stockyards and artefact sites AS8 and AS9, see **Figure 5.11**. The garden also includes eleven trees planted to represent Minnie's children.

The garden is located approximately 150 to 170 m north of the north-west corner of LW12.

5.6.9 Old Farm House (circa 1920's)

The remnants of a farmhouse exist on Ulan Coal Mine owned land in the southern area of UG 4. The condition of the house is recorded as being 'poor' by the Heritage Office, who also recommends *in-situ* conservation of the site is to be conducted if the house is not to be disturbed by mining.

5.6.10 Groundwater Bore Field Pumping Station and Dams

The ground water bore-field owned and operated by Ulan Coal Mine is located in the No.4 UG - South region and is 200 to 300 m west of the proposed finishing position of LW7, see **Figure 5.11**.

The field consists of a ground water bore, pumping station and three polymer sheet lined, earth embankment storage dams. The dams range in size from 20 ML (80 m x 120 m x 2 m deep) to 2.5 ML (20 m x 60 m x 2 m deep) and are shown in **Figure 5.32**.

The characteristics of the facility and operational details are unknown at this stage. However, it is possible that the bore extends down to the Ulan Seam and is used for mine de-watering purposes.

5.6.11 The Dronvisa Gravel/Clay Quarry

The Dronvisa Pty Ltd quarry is located 20 to 150 m west of the proposed finishing positions of LWs 4-5, see **Figure 5.11**. It is understood that the quarry may extend out over the longwall extraction limits at some time in the future. However, this issue cannot be assessed until further details of the proposed quarry layout are provided.

Therefore, this report has only assessed the impact of the proposed mining layout on the quarry in its present state.

The batters at the quarry range between 20 to 25 m high, with batter slopes of around 30^o to 35^o. The upper sections of the batters expose weathered Triassic conglomerate and sandstone, associated with the Wollar Sandstone. This material is generally ripped, crushed and graded to make road base materials.

The lower sections of the batters contain mudstone and shale, which is generally used for clay brick manufacture.

Several steel framed, sheet-metal clad sheds with reinforced concrete slab footings exist on site and are generally in good condition.

Photographs of the quarry batters and on-site buildings are shown in **Figure 5.33** to **5.35**.

5.6.12 Ulan-Cassilis Road

Approximately 5 km of the Ulan-Cassilis Road is located along the western boundary of the proposed No.4 UG Area, see **Figure 5.11**. The cover depth along the western side of the proposed LWs 1 to 12 ranges from 85 m to 155 m.

Approximately 2 km of the Ulan-Cassilis Road is orientated NNW:SSW and located 360 to 370 m west of the proposed finishing points of LWs1 - 7 in No.4 UG - South (i.e. the longwall blocks are orientated orthogonally to the road).

A 2.5 km section of the road is also adjacent to No.4 UG - North and is orientated generally NE:SW, which has resulted in the starting position for N:S orientated longwall blocks being constrained by the road. The road is located at a distance of 50 to 90 m from the NW corners of proposed LWs 8 to 11. The road is approximately 120 to 240 m from the sides at a point where maximum subsidence is expected (i.e. about 150 m from the start of each longwall).

Four cuttings (No.1 to 4) ranging from 3 to 15 m deep with 25° to 35° batters in weathered sandstones and shales, as well as a reinforced concrete bridge (over the Goulburn River) exist along the section of road in the study area, see **Figure 5.11**.

Cutting No.1 is 2 to 10 m deep and is about 360 m from the end of LW1. Cutting No. 2 is about 15 m deep and is 620 m west of LW8. Cutting No. 3 is 3 to 4 m deep and is located approximately 120 m from the north-west corner of the proposed LW8.

The Goulburn River Bridge and Cutting No. 4 (which is 3 to 4 m deep) are 250 m and 300 m respectively from the north-west corner of LW12.

Photographs of the current condition of the road, cuttings and bridge are shown in **Figures 5.36** to **5.39**.

5.6.13 Gulgong to Sandy Hollow Railway

The Gulgong to Sandy Hollow Railway line run E:W approximately 500 m south of the proposed side rib of LW1 and is orientated E:W.

5.6.14 The Goulburn River National Park

The Goulburn River National Park boundary is located 150 m to 270 m to the east of the proposed longwall blocks. The cover depth along the eastern boundary ranges between 150 m and 210 m, such that the boundary is located outside a 26.5° angle of draw (i.e. half cover depth).

5.7 Terrain Unit Evaluation

The surface has been separated into geotechnical distinct natural or man-made terrain unit categories, in a similar manner to the method described in **Aitchison and Grant, 1967**. The method allows efficient regional appraisal of the terrain in a study area by allowing (i) rapid assessment of significant geotechnical features, and (ii) identification of areas that may require more detailed investigation relevant to a particular project.

For this study, the natural terrain units have been described in terms of their topographical location, typical ground slopes, drainage conditions and geomorphic origin, which are considered the key parameters for assessing likely subsidence impacts. A plan showing the ground slopes within the study area is presented in **Figure 5.40**.

A description of each terrain unit is presented in **Table 5.5** and their location within the north and south regions of the study area is shown in **Figures 5.41** and **5.42**.

The surface impacts of the expected subsidence magnitudes within the study area will generally be influenced by the type of surface terrain and near surface lithology. This issue will be further discussed in **Section 12**.

Table 5.5 - Surface Terrain Unit Description Summary

Terrain Unit Category	Unit No.	Topographic Location	Ground Slope(°)	Comment*
Residual	R1	Ridge Crests	0 - 5	Rock outcrops, shallow residual soil profile < 1 m deep.
	R2	Upper Slopes Above Cliff Lines	5 - 20	Some rock outcrop and loose boulders, shallow soil cover.
	R3	Cliff Lines (CL1-8)	60 - 85	Triassic Sandstone cliffs, 5 -30 m high with significant overhangs due to active natural undercutting of weaker lithic sandstone and shale.
	R4	Foot Slopes Below Cliff Lines	5 -20	Loose boulders (talus), colluvium overlying residual soil profile 1- 3 m deep.
Alluvial	A1	Valley/Gully Floors (general)	0 - 5	Gently undulating terrain, shallow alluvial/slope-wash deposits < 3 m.
	A2	Broad Erosion Gully /Bora Creek	0 - 10	Gently undulating terrain, deep alluvial/slope-wash deposits up to 35 m (see Borehole WD75).
Infrastructure/ Developments	D8-D10	Ulan Mine water bore field dams	0 - 5	Three dams with 10 to 20 ML storage capacity and brick borehole pumping station building.
Domestic/ Commercial Structures	B1-9	Residential Development	0 - 10	Single storey residences. Weatherboard or brick veneer houses, equipment sheds and horse stable.
	D1-5 and D11-13	Livestock Watering Dams	0 – 15	Non-engineered earth fill embankment dams < 2 m high for livestock water supply.
	Quarry	Clay/gravel Quarry	5 - 20	25^{o} to 35^{o} batter slopes. Cut heights up to 25 m with some steel framed sheds.
Aboriginal Heritage	RS1-177	Possible Artefact Sites	0 - 20	Mainly rock shelters along cliff lines.
	AS1-14, PAD1	Significant Sites	0 - 20	Rock shelters with hand paintings, scattered artefacts and axe grinding grooves.
Other	North of AS 8 & 9	Memorial Garden and grave site on the Westwood Property	0-1	Plaque with Minnie Josephine Westwood's ashes and grave site of an Aboriginal family friend (Mr Ray Perry). Eleven trees planted to represent her children.
		Relic Stock yards (circa 1879)	0-1	Remnants of original fence posts. Public access to be maintained.
Natural Environment/ Tourist Destination	CL5	The Drip to the north, Goulburn River National Park to the east.	80-85	The Drip is a gorge on the Goulburn River - 1.6 km of reserve to be maintained for public access.

* - Based on surface observations only

6.0 SUBSIDENCE PREDICTION MODEL VALIDATION

6.1 Ulan Mine Subsidence Data Review

A review of subsidence data presented in **SCT, 2005**, measured along several cross and centre lines for Ulan Coal Mine's LWs A, B and 1 to 19, was completed before making predictions for the proposed Moolarben longwalls.

The measured subsidence and associated parameters (i.e. maximum tilt, curvature, strain, horizontal displacement, goaf edge subsidence and angle of draw to the 20 mm subsidence contour) have been compared to predicted parameters derived using the prediction methodology in **ACARP, 2003**.

The geometries and measured maximum subsidence for the Ulan longwalls are summarised in **Table 6.1**.

Table 6.1 - Ulan Longwall Geometry and Measured Maximum Subsidence Summary

Parameter	Value
Longwall Panel No.s	A, B, 1-19
Panel Void Width, W (m)	160 - 260
Cover Depth, D (m)	67 - 260
Extraction Height, T (m)	2.9 - 3.2
Development Height, h (m)	2.9 - 3.2
W/D range	0.89 - 3.1
Maximum Panel Subsidence*, S_{max} (m)	0.13 - 1.5
S_{max}/T Range	0.04 - 0.52
Chain Pillar Width, w_{cp} (m)	24.8 m
Roadway width (m)	5.2 m
Chain Pillar Subsidence (m)	0.09 - 0.57

The subsidence above Ulan Mines longwalls is strongly influenced by the stiffness of the overburden and the chain pillars. The maximum subsidence generally occurs at mid-panel with 10 to 50 % of the maximum subsidence occurring over the chain pillars. This behaviour is typical of sub-critical width longwalls in the Western Coalfield, however the magnitude of subsidence relative to the extraction height is significantly lower than other mines that do not have massive sandstone in the overburden.

The overburden for the Ulan longwalls (located in the lower 3.2 m of the Ulan Seam) appears to be similar to the Moolarben No.4 UG areas, in that there are similar sandstone members within the Illawarra Coal Measures and Triassic Wollar Sandstone. The Illawarra Coal Measures extend for 85 to 95 m above the Ulan Seam and contain several laterally persistent sandstone units up to 20 m thick.

The thickness of the quartzose units of the Triassic Wollar Sandstone member is assessed to range between 24 m and 130 m, at a distance of about 90 m above LWs 5 to 19. There are no Triassic sandstones above LWs A, B and 1 to 3.

The Subsidence Reduction Potential (SRP) of the sandstone units above the Ulan longwalls were assessed by plotting the thicknesses of the units for the given panel widths in **Figure 6.1**.

The threshold lines that have been bolded in **Figure 6.1** indicate that the assessed Triassic and Permian sandstone units described above the longwalls all had 'High' SRP for the 160 m to 260 m wide longwalls. Based on the SRP assessment, the range of subsidence for the 'High' SRP limit lines was determined from the subsidence prediction curves shown in **Figure 6.2**, as discussed in **Section 6.2**.

6.2 Comparison Between Actual and Predicted Subsidence

Maximum longwall panel subsidence measurements for the Ulan Coal Mine's LWs A, B and 1 to 19 have been compared to predicted values. The outcomes are summarised in **Table 6.2** and include the Upper 95% Confidence Limits for the first (i.e. subsidence after each longwall is extracted) and final (i.e. after all mining is completed in each area) S_{max} predictions.

Table 6.2 – Ulan Coal Mine's LWs A, B and 1 to 19 Predicted vs. Measured Subsidence

LW Panel	Predicted Final S_{max} Upper 95%CL (m)	Measured S_{max} (m)	LW Panel	Predicted Final S_{max} Upper 95%CL (m)	Measured S_{max} (m)
A	1.43	**1.2**	11C	1.86	**1.4**
B	1.26	**0.93**	11X	1.86	**1.4**
1	1.68	**1.5**	12D*	1.46	**1.3**
5	1.30	**1.0**	13D	1.60	**1.3**
6	1.34	**0.13**	14D	1.66	**1.1**
7	1.68	**1.0**	15D	1.86	**0.96**
8	1.68	**1.0**	16D	1.86	**1.1**
9	1.86	**1.2**	17D	1.86	**1.2**
10	1.86	**1.3**	18E	1.86	**1.1**
11	1.86	**1.4**	19E	1.62	**1.2**

Notes:
- The extraction height, T varies from 2.9 m to 3.2 m.
- The measured values are final subsidence.
* - The affects of LW11 were not measured.
Bold - Measured values are within prediction limits.
Italics - Prediction limits greater than measured values.

Measured subsidence for all of the Ulan longwalls presented in **Table 6.2** are within the predicted Upper 95% Confidence Limits. The measured values were generally much lower than the Upper 95% Confidence Limit of the model, which indicates that the predictions are conservative. It is also possible that further subsidence may have occurred (but was not measured) due to previous or subsequent longwalls (refer to **SCT, 2004**). This could have increased the measured values by between 10 and 20%, due to goaf reconsolidation and chain pillar compression effects.

A similar exercise was also conducted on the transverse differential subsidence (i.e. tilt) and strain measurements for the Ulan Mine longwalls and the results are summarised in **Tables 6.3** and **6.4**.

Table 6.3 - Ulan LWs A,B and 1 to 19 Predicted vs. Measured Tilt

LW Panel	Predicted T_{max} Final Upper 95%CL (mm/m)	Measured T_{max} (mm/m)	LW Panel	Predicted T_{max} Final Upper 95%CL (mm/m)	Measured T_{max} (mm/m)
A	22	35	11C	35	**30**
B	17	25	11X	35	**32**
1	63	**54**	12D	19	**18 -** 44
5	18	20	13D	20	**20**
6	22	**5**	14D	22	**20**
7	29	***30***	15D	28	**17**
8	24	**15**	16D	27	**17**
9	32	**20**	17D	26	**14**
10	30	**20**	18E	26	**11**
11	33	**32**	19E	27	**13**

Notes:
Bold - measured values are within prediction limits.
Italics - measured value < 5% outside the confidence limit range.

Based on **Table 6.3**, 85% of the measured maximum tilts were within the predicted Upper 95%CL ranges. This outcome is considered to be a reasonable fit to the data considering that some of the profiles were effected by 'skewed' or kinked subsidence profiles, which appear to have increased the measured tilts locally, see **Section 6.4**. At 3 out of 21 locations, the maximum measured tilts have been under-predicted by 1.5 to 1.9 times the final Upper 95%CL value.

Table 6.4 – Ulan LWs A, B and 1 to 19 Predicted vs. Measured Strain

LW No.	Predicted Final Uniform Strain (mm/m)	Predicted Final Concentrated Strain (mm/m)	Measured E_{max} (mm/m)	LW No.	Predicted Final Uniform Strain (mm/m)	Predicted Final Concentrated Strain (mm/m)	Measured Final E_{max} (mm/m)
A	4 - 10	18	20	11C	4 - 13	20	**4**
B	2 - 8	15	**10**	11X	4 - 13	20	**6**
1	6 - 18	31	N/A	12D	3 - 9	16	**14**
5	3 - 8	15	**10**	13D	3 - 9	18	**14**
6	3 - 12	20	**3**	14D	4 - 10	19	25
7	3 - 10	18	**7**	15D	3 - 9	17	**7**
8	3 - 5	15	**9**	16D	2 - 6	13	**9**
9	4 - 12	17	**9**	17D	2 - 8	15	**7**
10	5 - 15	22	**8**	18E	3 - 8	16	**6**
11	4 - 12	20	**20**	19E	3 - 9	16	**3**

Notes:
- Uniform strains have been determined by multiplying the curvature by 10 (see **Section 6.3**).
- Concentrated strain values have been estimated based on the formulae presented in **Appendix A**.
- **Bold** - measured values are within prediction limits.

Based on **Table 6.4**, the results of the empirical analysis indicate that 85% of the measured strains fall within the predicted smooth and concentrated strain limits. Fifty eight percent of the measured strains were within the upper 95%CLs for the uniform or 'smooth' surface profile strains when a strain to curvature ratio of 10 is applied. The remainder of the measured strain values exceed the predicted Upper 95% Confidence Limit and mean strain values by about 1.5 and 2 times respectively. This issue will be further discussed in **Section 6.3**.

6.3 Predicted v. Measured Profiles Above LWs 12 to 19

Predictions of subsidence, tilt, curvature and strain profiles have been assessed for Ulan Mines LWs 12 and 19 based on data presented in **SCT, 2004**. The prediction methodology requires the assessment of single panel subsidence and subsidence above the 24.8 m wide chain pillars under double abutment loading. As discussed previously, the (relatively low) measured subsidence above the longwall panels indicates that the Wollar Sandstone exhibits High SRP, for the range of cover depths above the panels.

The subsidence above the chain pillars has been plotted against the Chain Pillar Subsidence Index (see **Section 7.4** for definition), see **Figure 6.3**. The calculated FoS for the Ulan chain pillars ranged between 1.1 and 1.5, which infers that the chain pillars are likely to be in the yield zone of the pillars.

It is noteworthy that the measured subsidence above the panels and chain pillars plot in the lower end of the longwall database. This may be due to the higher coal and overburden stiffness properties compared to the average database conditions. A similar outcome is apparent for several of the Newstan Colliery longwalls, which had massive conglomerate channels (i.e. the Teralba Conglomerate member) above the West Borehole and Young Wallsend Seams.

Predicted and measured cross line subsidence and associated parameter profiles for LWs 12 to 19 along Crossline D are presented in **Figures 6.4** to **6.7**. The predicted profiles are based accordingly on the Lower 95% Confidence Limits of the model database, as inferred by the measured Ulan chain pillar and mid-panel subsidence values.

The results indicate that the prediction methodology is generally conservative with regards to subsidence, tilt and curvatures. However random 'kinks' in the measured subsidence profiles result in localised increases or secondary tilt and curvatures which have exceeded the expected smooth profile predictions by about 2 times (and sometimes more). The manner in which the random increases can be addressed is further discussed below and in **Section 6.5**.

Before predictions of strain can be made, the relationship between the measured curvatures and strain must be understood. As discussed in **ACARP, 1993** and **ACARP, 2003**, structural and geometrical analysis theories indicate that strain is linearly proportional to the curvature of an elastic, isotropic bending 'beam'. This proportionality actually represents the depth to the neutral axis of the beam, or in other words, half the beam thickness. **ACARP, 1993** studies returned strain over curvature ratios ranging between 6 and 11 m for NSW and Queensland Coalfields.

ACARP, 2003 continued with this approach and introduced the concept of secondary curvature and strain concentration factors due to cracking. The mean peak strain / curvature ratio for the Newcastle Coalfield was assessed to equal 5.2 m with strain concentration effects increasing the ‘smooth-profile’ strains by 2 to 4 times.

Near surface lithology strata unit thickness and jointing therefore dictate the magnitude of the proportionality constant between curvature and strain.

The strain / curvature ratio for Ulan data was estimated by dividing the measured maximum strain peaks (tensile and compressive) by the corresponding curvature at the same location. The values were then assessed statistically to derive the appropriate ratio to be used for the Moolarben longwalls.

The results of a statistical analysis of 33 measured strain / curvature ratios above LWs 12 to 19, are summarised in **Figure 6.7**. Measured strain peaks ranged between 1.4 and 37 mm/m, with an average strain of 9 mm/m. Measured curvature peaks ranged between 0.2 km^{-1} and 4.5 km^{-1}, with an average curvature of 1.1 km^{-1}.

The results indicate that the median ratio of the measured ratio for peak strains over the corresponding curvature is 9 m for Ulan data. The mean ratio is 11 m. Twenty percent of the ratio data ranges between 15 and 35, with one outlier of 54. The Ulan data therefore indicates that near surface beam thicknesses of about 20 m would be expected to develop during subsidence for the Moolarben longwalls with a corresponding strain / curvature ratio of 10 m.

6.4 Voussoir Beam Analysis

To further understand the outcomes of the previous empirically-based analysis, it is important to understand the physical relationships between the variables applied.

The empirical models used in this report are expressed by a 'best fit' or regression equation (linear or non-linear) between the observed set of dependent and independent variables.

The main limitations of with empirical models are (i) the quantity and quality of the data covering the range of proposed mining cases, and (ii) whether the physical relationships between the variables are adequately defined by the statistical relationships in the empirical model.

Analytical and numerical models however, also require assumptions with regard to material strength, stress distribution and loading patterns etc. Engineering judgement and some form of calibration are therefore necessary to assess the likely variability of the ‘unknowns’ in both approaches.

The empirical SRP threshold lines presented in **Figure 6.1** were based on analytical linear arch or Voussoir beam theory, to justify their form physically. A Voussoir beam model (ROOFSTAB) adapted from the model presented in **Brady and Brown, 1985** has been used to evaluate the minimum rock beam thicknesses required to span or bridge over the extracted panels.

Voussoir beam theory allows a quantitative assessment of a jointed rock beam’s spanning capability by arching action over an extracted longwall panel. The model assesses the Factor of Safety (FoS) against instability of the rock beam due to (i) abutment crushing, (ii) shear failure and (iii) buckling.

The model is essentially indeterminate, in that the number of unknown variables is greater than the number of equilibrium equations and boundary or beam end-support conditions; a solution therefore requires assumptions regarding internal stress distribution and thrust line location. The Voussoir beam model was validated by comparison with results from the discrete block numerical model, UDEC.

The Voussoir beam model described above was also used qualitatively to provide an indication of the minimum beam thickness required to ‘span’ the 250 m wide Ulan longwall panels (LWs 10 and 15D) and so produce **High** SRP, as indicated by the measured Ulan data presented in **Figure 6.1**.

The following input data was used to provide an indication of the minimum Voussoir beam thickness required to ‘span’ the Ulan Coal Mine’s LWs 10 and 15D.

- Cover depth, D = 140 m and 175 m.
- Panel width, W = 250 m.
- UCS values, minimum = 22 MPa, mean = 35 MPa and maximum = 48 MPa.
- Massive strata unit location above the workings, y = 107 m and 112 m. (i.e. y/D = 0.76 and 0.64).
- Abutment angle = 19º (based on a W/D ratio of 0.7 for deep to shallow beam transition behaviour of the overburden, refer to **ACARP, 2003**).
- Rock mass density = 2.5 t/m^3
- Average elastic modulus = 150 x UCS (MPa)
- Horizontal stress / vertical stress ratio = 2.

The analysis of also required assumptions regarding the following:

(i) the effective span width for the massive strata unit above the workings,

(ii) the resultant vertical load acting on the massive unit, and

(iii) the rock mass strength and yielding criteria.

The yielding criteria assumed in the model defines an effective Young’s Modulus which decreases linearly to 0.25 x the elastic modulus, when the assessed FoS against abutment crushing decreases from 1 to 0.5. At an FoS of 0.5, full collapse is considered to have occurred. The predicted sag for the beam is been based on the elastic formulae for a simply supported beam, ignoring goaf edge compression (estimated to be < 0.1 m for the cases assessed), with the effective modulus defined above applied in the ‘yielded’ zone. For the collapsed beam case, the surface subsidence is considered to be equal to the maximum empirical subsidence (0.58 x extraction height).

The results of the Voussoir beam analysis are summarised in **Table 6.5** and summarised in **Figures 6.8** and **6.9**.

Table 6.5 – Predicted Minimum Beam Thickness Required for Ulan LWs 10 and 15D Using Voussoir Beam Theory

Overburden Sandstone Strength Range UCS (MPa)	Minimum Thickness for High SRP (m)		Predicted Subsidence for a Simply Supported Elastic Beam (m)	Predicted Subsidence for Voussoir Elastic Beam (m)
	LW10 (D=140m)	LW15D (D=175m)	LW10 (D=140m)	LW15D (D=175m)
22	>33m	48	N/A	0.42
35	29	39	0.65	0.47
48	25	34	0.74	0.56

The above values have been plotted against the empirical model values on **Figure 6.1**. All values plot above the High SRP threshold limit lines for beams located between a y/D of 0.5 and 0.9, indicating a consist outcome between the analytical and empirical methods.

It is also of interest to note that the calculated deflection of the beams increase with increasing UCS. As the elastic modulus is normally assumed to equal 300 times the UCS values and the deflection is inversely proportional elastic modulus, Voussoir and elastic beam theory formulae indicate that the deflection is also inversely proportional to the thickness squared (i.e. the beam thickness dominates the deflection behaviour).

From the measured subsidence of 0.96 m and 1.3 m for LWs 10 and 15D, some yielding of the rock mass is assessed to have occurred, based on (i) the predicted sag of 0.4 to 0.7 m for theoretical (Voussoir and elastic) beam behaviour and (ii) the expected subsidence of about 1.7 m for the fully collapsed cases. It should be understood that the definition of 'High' and 'Moderate' SRP includes partly yielded beam behaviour, as it still results in subsidence reduction, when compared to fully collapsed cases (those with 'Low' SRP).

Based on the above, the minimum theoretical and empirically derived beam thickness required for High SRP are comparable and therefore considered to be reasonable for the overburden in the study area.

Further, the various assumptions required to be made for the analytical model indicates that it is unlikely that it will produce results that have a better accuracy than the empirically based model (which is linked to a credible mechanistic conceptual model of overburden behaviour).

The Voussoir beam analysis also helps to demonstrate that the overall depth of cover and relative location of a massive unit within the overburden are important factors (along with the beam thickness, effective span, beam surcharge and material strength), when assessing its SRP at a given panel width.

6.5 Validation Analysis Outcomes

Based on the results of the validation analysis it is concluded that:

(i) There do not appear to be significant differences in the subsidence-reducing behaviour of the massive Western Coalfield sandstone units of a similar thickness and strength, as compared to the conglomerate units in the Newcastle Coalfield.

(ii) The empirical model can be used to make credible subsidence and associated deformation predictions for LWs 1 to 14 at the Moolarben UG No. 4 Mine.

Regardless of the details of the mechanisms involved, the empirical database and methodology enable realistic long-term subsidence predictions to be made, reducing speculation over the input parameters required for alternative analytical or numerical modelling techniques.

To allow for the possibility of 'skewed' subsidence profile or concentration effects on strain, the following allowances should be made when making subsidence impact parameter predictions for the Moolarben No.4 UG panels:

a) Increase predicted maximum tilts above a longwall panel by a factor of 1.5 to 2, when making predictions in undulating terrain in the vicinity of a sensitive surface feature (i.e. a cliff).

b) Assume the expected and credible worst-case uniform profile strains provided in **Tables 7.5** and **7.6** and the subsequent impact studies, could be increased by 2 times due to strain concentration (from cracking) or variations in near surface lithology thickness.

7.0 SUBSIDENCE PREDICTIONS FOR THE PROPOSED LONGWALL PANELS

7.1 General

Taking cognisance of the favourable outcomes of the validation work in **Section 6**, the Strata Engineering models were used to predict maximum subsidence and associated tilt, curvature and strain over the proposed longwalls. The predictions include the effects of chain pillar and strata compression, due to the extraction of a series of longwall panels.

A summary of the subsidence parameter ranges for LWs 1 to 14 is presented in **Table 7.1**.

Table 7.1 - Longwall Panel Geometry and Geology Ranges

Parameter	Proposed LW Panels 1 - 14	Model Database
Panel Void Widths, W (m)	260	34 - 260
Cover Depth Range, D (m)	85 - 215	45 - 350
Panel W/D Ratio	1.21 - 3.06	0.21 - 5.8
Average Working Height, T (m)	4.2	1.05 - 4.9
Development Height (m)	3.5	1.8 - 3.5
Development Roadway Width, r (m)	5.5	4.8 - 6.0
Chain Pillar or Barrier Pillar Width, w_{cp} (m)	35	18 - 215
Massive Strata Unit Thickness, t (m)	12 - 70	<5 - 80
Strata Unit Distance Above Workings, y (m)	50 - 125	1 - 350
Strata Unit Location Ratio (y/D)	0.41 - 0.89	0.0 - 0.9

Based on **Table 7.1** the geometries of the proposed longwall panels are all within the limits of the database.

7.2 Subsidence Reduction Potential of Sandstone Units

As previously discussed, the influence of overburden lithology on subsidence predictions for the proposed panels has been assessed from cover depth contours and interpretative contouring of other key parameters obtained from boreholes in the study area. The accuracy of the interpretative contours is a function of the borehole spacing and the variation of the terrain between the boreholes.

Based on a review of the available borehole logs, there are three significant sandstone units ranging in thickness between 5 and 70 m and located 5 to 125 m above the Ulan Seam. A conceptual model of the SRP of massive strata units present above the proposed 260 m wide No. 4 Underground panels is presented in **Figure 7.1**. Details of the SRP assessment of the sandstone units are summarised in **Table 7.2**.

Table 7.2 - Summary of Subsidence Reduction Potential (SRP) of Sandstone Units 1, 2 and 3 above the Proposed LWs

LW Panel No.	Panel Void Width W (m)	Cover Depth D (m)	Sandstone Unit No.	Unit Thickness t (m)	Unit Height above LW y (m)	Unit Location Factor (y/D)	Unit SRP
1 - 7	260	85 - 180	1 2 3	5 - 30 1 - 37 9 - 86	9 - 37 24 - 79 85 - 130	0.14 - 0.22 0.26 - 0.45 0.57 - 0.94	L - M L - H L - H
8 -14	260	120 - 170	1 2 3	5 - 20 5 - 17 12 - 68	8 - 27 73 - 88 100 -137	0.05 - 0.18 0.50 - 0.60 0.56 - 0.83	L - M L - M L - H

Notes:
L = Low, M = Moderate, H = High

The results in **Table 7.2** indicate the following general SRP rules with regard to Sandstone Units 1, 2 and 3 above the 260 m wide panels:

- Unit 1 has 'Low' to 'Moderate' SRP. Unit thickness is ≤ 30 m at a y/D range of 0.05 to 0.22.

- Unit 2 will generally have 'Low' to 'Moderate' SRP where unit thickness is < 35 m at a y/D range of 0.26 to 0.60; 'High' SRP is predicted in a limited area where its thickness is ≥ 35 m.

- Unit No. 3 will generally have 'Low' to 'Moderate' SRP where its thickness is < 25 m; at a y/D range of 0.56 to 0.94; 'High' SRP if ≥ 25 m.

Sandstone Unit No. 3 (i.e. the Wollar Sandstone) is expected to govern the development of subsidence in the plateaux areas of the site with 'High' SRP expected.

'Low' to 'Moderate' SRP is generally expected above areas with Illawarra Coal Measures rocks only, or where incised gullies or weathering decrease the effective unit thickness significantly. The thickness of the Unit 2 sandstone in the Illawarra Coal Measures results in ‘High SRP’ in the south-western end of LW2, however there is no apparent decrease to subsidence expected because the panel is supercritical at this location (i.e. the W/H = 2.4).

The distribution of 'Low', 'Moderate' and 'High' SRP overburden for the proposed longwalls is therefore largely governed by the thickness of the Wollar Sandstone Unit contours are presented in **Figure 7.2**.

7.3 Maximum Subsidence Predictions for the Proposed Longwalls

The Subsidence Reduction Potential (SRP), and credible worst-case subsidence for each longwall, as a single isolated panel (i.e. Single S_{max}), have been determined.

Subsidence over a series of adjacent panels has then been estimated by adding a proportion of the predicted subsidence above the chain pillar (when subject to double abutment loading) to the predicted maximum subsidence for a single (i.e. isolated panel).

Normalised single panel subsidence predictions for the assessed SRP ranges in the study area are shown in **Figure 7.3.**

First and final S_{max} each panel were then predicted by adding the increment related to subsidence over the chain pillars. Prediction of subsidence above the chain pillars when subject to double abutment loading is presented in **Figure 7.4**.

Credible worst-case (CWC) (i.e. the upper 95% Confidence Limits) first and final subsidence values are summarised in **Table 7.5**.

After the extraction of longwalls 1 to 14, predicted CWC subsidence values are estimated to conservatively range from 1.81 to 2.44 m, for cover depths of 215 and 85 m respectively. The predictions represent 0.43 and 0.58 times the proposed extraction height of 4.2 m.

7.4 Subsidence Predictions above Chain Pillars

Maximum subsidence generally occurs above chain pillars when the pillars are subject to double abutment loading conditions (i.e. goaf on both sides).

Based on extensive studies of NSW longwall mines, the measured subsidence above chain pillars is considered to be strongly influenced by the following key parameters:

- The volume of the rock prism (i.e. the load) acting on the pillar and immediate roof and floor strata (W'D). *Note: this has been conservatively estimated for an assumed caving angle of 21 degrees.*
- The longwall face extraction height (T).
- The pillar width and development height (w and h).

The coal pillar and column of rock above and below the seam will behave either elastically or plastically (depending on their strength and stiffness properties) under double abutment loads.

The subsidence above the pillars is a function of the following combination of these key parameters:

S_p = f (T, W'H/w, h/w)

or $S_p/T = f(W'Hh/w^2)$ = the "Chain Pillar Subsidence Index" (CPSI)

where:

T = the extraction height (or sometimes the seam height) is applied instead of the pillar development height as this approximates to the column of coal that is subject to maximum pillar stresses.

W'H/w = a pillar stress index

w/h = a pillar strength index.

The **ACARP, 2003** model for estimating chain pillar subsidence has been updated in **Figure 7.4**. The revised approach compares the Chain Pillar Subsidence Index (CPSI) to the measured subsidence, normalised to (S_p/T). The CPSI and FoS have been determined by assuming a caving angle of 21 degrees for the assessment of the prism of rock above the chain pillar. The chain pillar strength has been determined based on **ACARP, 1998**.

The predicted first CWC subsidence values above the chain pillars are presented in **Table 7.5** and range between 0.19 m and 0.49 m. Final pillar subsidence could increase a further 20% after subsequent longwalls are extracted (i.e. could ultimately total 0.23 m to 0.59 m).

Table 7.5 - Predicted First and Final Subsidence Impact Parameters (Credible Worst-Case)

LW Panel No.	Distance from Start LW (m)	Cover Depth D (m)	Chain Pillar Width w_{cp} (m)	Maximum Massive Strata Unit Thickness t (m)	Strata Unit Height above Seam y (m)	W/D Ratio	Unit Location Factor (y/D)	SRP	MG First Goaf Edge S_{ge} (m)	First Panel S_{max} (m)	First Pillar S_p (m)	Final S_{max} (m)	Final Max Tilt T_{max} (mm/m)	Final Max Curv (km^{-1})	Final Maximum Strain (mm/m)* Uniform	Concentrated
1.1	1740	95	35	27	40	2.74	0.42	L	0.18	*2.44*	0.19	2.44	*86*	3.49	34	41
1.2	1340	120	35	25	50	2.17	0.42	L	0.18	*2.44*	0.23	2.44	*58*	1.96	20	25
1.3	940	130	35	28	55	2.00	0.42	L	0.18	*2.44*	0.27	2.44	*52*	1.67	17	23
1.4	535	145	35	35	60	1.79	0.41	L	0.17	*2.44*	0.31	2.44	*44*	1.34	13	20
1.5	130	150	35	35	65	1.73	0.43	L	0.17	*2.44*	0.32	2.44	*46*	1.43	14	21
2.1	1812	110	35	25	70	2.36	0.64	H	0.18	*2.44*	0.21	2.44	*65*	2.32	23	26
2.2	1412	130	35	20	95	2.00	0.73	L	0.18	*2.44*	0.27	2.44	*52*	1.67	17	23
2.3	1012	150	35	25	100	1.73	0.67	H	0.14	2.06	0.32	2.28	*37*	1.20	12	19
2.4	607	155	35	48	110	1.68	0.71	H	0.13	2.02	0.35	2.27	*34*	1.12	11	18
2.5	202	160	35	28	125	1.63	0.78	H	0.13	1.98	0.36	2.24	*32*	1.03	10	17
3.1	1884	130	35	17	115	2.00	0.88	L	0.18	2.44	0.26	2.44	*52*	1.67	17	23
3.2	1484	150	35	40	100	1.73	0.67	H	0.14	2.06	0.32	2.28	*37*	1.20	12	19
3.3	1084	160	35	50	97	1.63	0.61	H	0.13	1.98	0.37	2.24	*32*	1.04	10	17
3.4	679	170	35	50	100	1.53	0.59	H	0.12	1.93	0.40	2.22	*29*	0.90	9	15
3.5	274	170	35	40	125	1.53	0.74	H	0.12	1.93	0.40	2.22	*29*	0.91	9	15
4.1	1956	140	35	30	110	1.86	0.79	H	0.15	2.17	0.29	2.36	*39*	1.26	13	19
4.2	1556	160	35	60	100	1.63	0.63	H	0.13	1.98	0.35	2.22	*32*	1.03	10	17
4.3	1156	175	35	70	100	1.49	0.57	H	0.12	1.89	0.40	2.19	*28*	0.86	9	14
4.4	751	180	35	70	105	1.44	0.58	H	0.12	1.90	0.42	2.21	*28*	0.86	9	14
4.5	350	180	35	50	115	1.44	0.64	H	0.12	1.90	0.42	2.21	*28*	0.86	9	14
5.1	2028	150	35	50	100	1.73	0.67	H	0.14	2.06	0.30	2.26	*36*	1.20	12	19
5.2	1628	160	35	50	105	1.63	0.66	H	0.13	1.98	0.33	2.22	*32*	1.02	10	17
5.3	1228	175	35	50	125	1.49	0.71	H	0.12	1.92	0.38	2.20	*28*	0.86	9	15
5.4	823	180	35	60	115	1.44	0.64	H	0.12	1.90	0.40	2.20	*28*	0.86	9	14
5.5	420	180	35	60	110	1.44	0.61	H	0.12	1.91	0.41	2.21	*28*	0.87	9	14

Table 7.5 (Continued) - Predicted First and Final Subsidence Impact Parameters (Credible Worst-Case)

LW Panel No.	Distance from Start LW (m)	Cover Depth D (m)	Chain Pillar Width w_{cp} (m)	Maximum Massive Strata Unit Thickness t (m)	Strata Unit Height above Seam y (m)	W/D Ratio	Unit Location Factor (y/D)	SRP	MG First Goaf Edge Sge (m)	First Panel S_{max} (m)	First Pillar S_p (m)	Final S_{max} (m)	Final Max Tilt T_{max} (mm/m)	Final Max Curv (km^{-1})	Final Max Strain (mm/m)*	
															Uniform	Concentrated
6.1	2100	140	35	40	95	1.86	0.68	H	0.15	2.18	0.26	2.34	39	1.26	13	19
6.2	1700	150	35	40	105	1.73	0.70	H	0.14	2.08	0.30	2.28	37	1.20	12	19
6.3	1300	160	35	30	125	1.63	0.78	H	0.13	1.99	0.33	2.22	32	1.03	10	17
6.4	895	170	35	40	115	1.53	0.68	H	0.12	1.94	0.37	2.21	29	0.90	9	15
6.5	500	175	35	40	105	1.49	0.60	H	0.12	1.93	0.39	2.22	28	0.87	9	15
7.1	2172	120	300	35	95	2.17	0.79	H	0.18	*2.44*	0.01	*2.44*	51	1.80	18	24
7.2	1772	140	300	30	105	1.86	0.75	H	0.15	2.17	0.01	2.17	34	1.16	12	19
7.3	1372	145	300	20	110	1.79	0.76	L	0.17	*2.44*	0.01	*2.44*	43	1.32	13	21
7.4	967	160	300	25	110	1.63	0.69	M	0.16	*2.44*	0.02	*2.44*	38	1.15	12	19
7.5	565	170	300	30	100	1.53	0.59	H	0.12	1.92	0.02	1.92	24	0.78	8	15
8.6	400	140	35	20	110	1.86	0.79	L	0.17	*2.44*	0.34	*2.44*	47	1.44	14	21
9.6	330	145	35	32	100	1.79	0.69	H	0.14	2.20	0.34	2.38	37	1.19	12	18
9.7	785	155	35	25	125	1.68	0.81	M	0.16	2.38	0.40	*2.44*	44	1.33	13	20
10.6	260	140	35	20	100	1.86	0.71	L	0.17	*2.44*	0.34	*2.44*	47	1.44	14	22
10.7	715	160	35	25	125	1.63	0.78	M	0.16	2.40	0.42	*2.44*	42	1.26	13	19
10.8	1340	160	35	25	100	1.63	0.63	M	0.16	2.37	0.42	2.20	31	1.01	10	16
11.6	200	150	35	30	100	1.73	0.67	H	0.14	2.10	0.38	2.37	39	1.25	13	19
11.7	655	170	35	24	105	1.53	0.62	M	0.16	2.37	0.45	*2.44*	39	1.11	11	18
11.8	1280	165	35	35	105	1.58	0.64	H	0.12	1.88	0.44	2.31	32	1.00	10	16
12.6	140	160	35	40	95	1.63	0.59	H	0.12	1.94	0.42	2.32	34	1.08	12	17
12.7	592	170	35	50	100	1.53	0.59	H	0.12	1.86	0.47	2.32	31	0.95	10	15
12.8	1217	170	35	45	105	1.53	0.62	H	0.12	1.86	0.44	2.30	31	0.94	10	15
12.9	1717	150	35	20	125	1.73	0.83	L	0.17	*2.44*	0.37	*2.44*	46	1.43	14	21
12.10	2212	140	35	12	100	1.86	0.71	L	0.17	*2.44*	0.34	*2.44*	47	1.44	14	21

Table 7.5 (Continued) - Predicted First and Final Subsidence Impact Parameters (Credible Worst-Case)

LW Panel No.	Distance from Start LW (m)	Cover Depth D (m)	Chain Pillar Width w_{cp} (m)	Maximum Massive Strata Unit Thickness t (m)	Strata Unit Height above Seam y (m)	W/D Ratio	Unit Location Factor (y/D)	SRP	MG First Goaf Edge Sge (m)	First Panel S_{max} (m)	First Pillar S_p (m)	Final S_{max} (m)	Final Max Tilt T_{max} (mm/m)	Final Max Curv (km^{-1})	Final Maximum Strain (mm/m)*	
															Uniform	Concentrated
13.6	74	170	35	45	95	1.53	0.56	H	0.12	1.86	0.45	2.30	31	0.94	10	15
13.7	529	180	35	55	100	1.44	0.56	H	0.12	1.81	0.49	2.31	30	0.91	9	15
13.8	1154	165	35	40	115	1.58	0.70	H	0.12	1.87	0.42	2.28	32	1.00	10	16
13.9	1654	150	35	30	105	1.73	0.70	H	0.14	2.10	0.37	2.36	38	1.25	13	19
13.10	2149	150	35	20	105	1.73	0.70	L	0.17	2.44	0.38	*2.44*	46	1.43	14	21
14.6	0	170	300	40	100	1.53	0.59	H	0.12	1.86	0.02	1.94	24	0.79	8	15
14.7	454	180	300	50	100	1.44	0.56	H	0.12	1.81	0.02	1.91	23	0.75	8	15
14.8	1079	160	300	40	110	1.63	0.69	H	0.12	1.94	0.02	2.00	27	0.92	9	17
14.9	1579	150	300	30	100	1.73	0.67	H	0.14	2.10	0.02	2.08	32	1.09	11	19
14.10	2074	155	300	25	100	1.68	0.65	M	0.16	2.40	0.02	*2.44*	40	1.24	12	20

Notes:
- SRP = Subsidence Reduction Potential of the massive strata unit (i.e. L = Low, M = Moderate, H= High).
- First S_{max} = maximum subsidence over a longwall panel after it is first extracted (including previous chain pillar effects).
- Final S_{max} = maximum final subsidence for a given panel (including subsequent chain pillar effects), after adjacent panels have been extracted.
- *Italics:* Final S_{max} does not exceed 0.58 x Extraction Height (T).
- Curvature and strain magnitudes are the maximum values derived for compressive zones. Convex curvatures and tensile strains may be 1 to 2/3 times these values.
* - Uniform strains: 'smooth profile' strains, which are relatively even or uniform between pegs (i.e. no cracking).
* - Concentrated strains: When cracking occurs the uniform strains can increase by up to 2 times. Cracks usually occur when uniform strain exceeds 2 mm/m.

7.5 Differential Subsidence Predictions

The Upper 95% Confidence Limits (i.e. credible worst-case) predictions of tilt and strain are presented in **Table 7.5**.

The parameters have been derived from a database of measured subsidence and strain profiles over several longwalls in the Newcastle Coalfield and include measured maximum tilt, curvature, horizontal displacement and strains along several longwall panel cross lines and centre lines that have been correlated with S_{max}, panel width (W) and cover depth (D).

The credible worst-case tilts are estimated to range between 23 and 86 mm/m. Measured tilts above the Ulan longwalls ranged between 5 and 55 mm/m, a good indication that the predictions for the Moolarben panels are reasonable.

Maximum CWC compressive and tensile strains for the longwall panels are estimated to range between 10 and 20 mm/m for 'smooth' surface profiles with 14 to 31 mm/m for a single 10 m bay-length due to strain concentration effects. Measured strains above the Ulan longwalls ranged between 3 and 25 mm/m, a good indication that the predictions for the Moolarben panels are reasonable.

Predicted uniform strains are generally for a surface with a deep soil cover and is likely to have a relatively even or uniform strain distribution. Tensile or shear cracks may also develop, and usually when strain exceeds 2 mm/m and near surface rock exposures are present. Strain tends to 'concentrate' at cracks or natural joints. The apparent increase in strain could also be due to variations in bending strata thickness at the surface.

Based on the outcomes of the validation analysis, predictions of concentrated strain may be determined by multiplying the uniform strains by up to 2 for the credible worst-cases.

8.0 CHAIN PILLAR STABILITY CONSIDERATIONS

The results of the pillar stability assessment are summarised in **Table 8.1**. The results indicate that the chain pillars have Factors of Safety (FoS) of between 2.13 and 5.07, for the range of panel widths and cover depths considered. Based on reference to the data presented in **Figure 7.4**, significant increases in subsidence above the chain pillars only start to occur when FoS fall below 1.6 or the CPSI is >70.

It is assessed that none of the chain pillars proposed for Moolarben No. 4 Underground are likely to yield in the long-term.

Table 8.1 - Chain Pillar Factor of Safety Summary

LW Panel No.	Cover Depth, D (m)	Pillar Width, w (m)	Pillar Stress, P Under DA+ (MPa)	Pillar Strength, S (MPa)	Pillar FoS+ (S/P)
1.1	100	35	6.2	31.4	5.07
1.2	120	35	8.1	31.4	3.87
1.3	130	35	9.6	31.4	3.27
1.4	145	35	10.9	31.4	2.89
1.5	150	35	11.5	31.4	2.74
2.1	110	35	7.5	31.4	4.19
2.2	130	35	9.6	31.4	3.27
2.3	150	35	11.5	31.4	2.74
2.4	155	35	12.3	31.4	2.55
2.5	160	35	12.7	31.4	2.48
3.1	130	35	9.2	31.4	3.42
3.2	150	35	11.5	31.4	2.74
3.3	160	35	12.9	31.4	2.43
3.4	170	35	14.0	31.4	2.25
3.5	170	35	14.0	31.4	2.25
4.1	140	35	10.3	31.4	3.05
4.2	160	35	12.2	31.4	2.57
4.3	175	35	14.1	31.4	2.23
4.4	180	35	14.8	31.4	2.13
4.5	180	35	14.8	31.4	2.13
5.1	150	35	10.6	31.4	2.97
5.2	160	35	11.8	31.4	2.67
5.3	175	35	13.4	31.4	2.35
5.4	180	35	14.3	31.4	2.20
5.5	180	35	14.5	31.4	2.16
6.1	140	35	9.1	31.4	3.45
6.2	150	35	10.6	31.4	2.97
6.3	160	35	11.5	31.4	2.72
6.4	170	35	13.0	31.4	2.42
6.5	175	35	13.9	31.4	2.27
8.6	140	35	10.1	31.4	3.12
9.6	145	35	10.2	31.4	3.07
9.7	155	35	11.8	31.4	2.66
10.6	140	35	10.3	31.4	3.05

Table 8.1 (continued) - Chain Pillar Factor of Safety Summary

LW Panel No.	Cover Depth, D (m)	Pillar Width, w (m)	Pillar Stress, P Under DA+ (MPa)	Pillar Strength, S (MPa)	Pillar FoS+ (S/P)
10.7	160	35	12.7	31.4	2.48
10.8	160	35	12.4	31.4	2.53
11.6	150	35	11.5	31.4	2.74
11.7	170	35	13.5	31.4	2.33
11.8	165	35	13.1	31.4	2.40
12.6	160	35	12.7	31.4	2.48
12.7	170	35	14.0	31.4	2.25
12.8	170	35	13.2	31.4	2.38
12.9	150	35	11.0	31.4	2.85
12.10	140	35	10.3	31.4	3.05
13.6	170	35	13.5	31.4	2.33
13.7	180	35	14.8	31.4	2.13
13.8	165	35	12.6	31.4	2.50
13.9	150	35	11.0	31.4	2.85
13.10	150	35	11.2	31.4	2.80

Note:
- Chain pillar length is 95 m.
+ - DA = double abutment loading on pillar

9.0 MAXIMUM POSSIBLE SUBSIDENCE AFTER CESSATION OF MINING

The maximum subsidence measured above Ulan Mine's LWs 1-19 ranged between 4 % and 52 % of the average extraction height (T) of 3.2 m, at face widths up to 260 m and panel width/cover depth ratios ranging between 0.89 and 2.41.

The Holla curves for the Newcastle and Western Coalfield predict maximum subsidence of 0.55 T and 0.65 T for super-critical longwalls in the respective coalfields. These values are based on older established empirical relationships derived from combined total pillar extraction panels and longwall databases, refer to **Holla, 1987** and **1991**.

A review of maximum measured subsidence above longwalls in the Newcastle and Western Coalfields, indicates that the maximum possible subsidence for a super-critical longwall panel (i.e. W/D ratios of 1.4 to 1.6 for Low SRP cases) ranges between 0.58 and 0.65 times the extraction height respectively. It is considered that the behaviour/performance (in subsidence terms) of the geology above the Moolarben longwalls, is likely to be similar to the conglomerate/sandstone dominated geology of the Newcastle Coalfield.

Overall, it is considered practically impossible that maximum long-term subsidence will exceed 0.6 x Extraction Height (T), for the range of mining geometries proposed for Moolarben No. 4 Underground.

10.0 PREDICTION OF ANGLES OF DRAW

Based on **ACARP, 2003**, angles of draw (AoD) around the sides, ends and corners of the longwall block are related to the subsidence above the limits of extraction (i.e. the goaf edge) and the maximum in-panel subsidence. The model used for predicting subsidence above the sides, ends and corners of the longwall blocks is presented in **Figures 10.1** to **10.3**.

Using the predictions of goaf edge subsidence, the associated AoD from the goaf edge to the 20 mm subsidence limit for the proposed LWs 1 to 14 can be derived from the relationship presented in **Figure 10.4**. A summary of goaf edge subsidence and AoD predictions is presented in **Table 10.1**.

Table 10.1 - Summary of Predicted Goaf Edge Subsidence and Credible Worst-Case (U95% CL) Angle of Draw Limits to the 20 mm Subsidence Contour, for the Four Geographical Corners of the Study Area

Parameter	**Units**	**NW (LW12)**	**NE (LW14)**	**SW (LW1)**	**SE (LW1)**
Cover Depth	m	140	157	95	150
Predicted S_{max}	m	2.44	2.40	2.44	2.44
Predicted Side Goaf Edge,S_{gx}	m	0.17	0.16	0.18	0.17
Predicted Angle of Draw from LW Side	^{o}	20.8	19.8	21	20.7
Predicted Distance from Side	**m**	**53.1**	**56.5**	**36.4**	**56.7**
Predicted End Goaf Edge,S_{ge}	m	0.18	0.19	0.18	0.17
Predicted Angle of Draw from LW End	^{o}	20.7	21.0	20.8	18.8
Predicted Distance from End	**m**	**52.9**	**60.2**	**36.1**	**51.1**
Predicted Corner Goaf Edge Subsidence	m	0.030	0.028	0.033	0.03
Predicted Angle of Draw from LW Corner	^{o}	8.7	8.7	8.7	8.7
Predicted Distance from Corner	**m**	**21.4**	**24**	**14.5**	**23.0**

Other published data for the Newcastle Coalfield and Ulan Mine, indicates that angles of draw are unlikely to exceed the values presented in **Table 10.2** with over 80% of the Ulan angle of draw data < 26.5^o with a mean value of 18^o.

However, three angle of draw values of 29^o, 30^o and 39^o were measured for LWs 8, 15D and 16D for cover depths ranging between 160 m and 185 m (i.e. 0.55 to 0.8 times the cover depth) and may be due to the bridging behaviour of the massive sandstone overburden or topographic influences.

Table 10.2 - Maximum Practical Angle of Draw Limits for 20 mm Subsidence, based on Published Newcastle Coalfield and Ulan Data

Location Relative to Longwall (LW) Panel Sides, Ends and Corners	Maximum Draw Angle to 20 mm Subsidence Contour (degrees)	Maximum Draw Angle to 20 mm Subsidence Contour (Ratio to Cover Depth) (z/D)
LW Side*	26.5 (39)+	0.5
LW End above Centre Line	26.5	0.5
LW Corner (45º Diagonal)	14	0.25

* - Relative to the maximum panel subsidence, which occurs at a distance approximately equal to 0.5 times the panel width from the start and ends of the panels.
+ - observed outside the limits of Ulan LW 16 D Cross line, where the cover depth was 180 m.

The values in **Table 10.2** are considered to be the maximum practical limit for the angle of draw outside of the Moolarben panels and have been plotted on **Figures 1.1** and **11.19** for reference. Should the higher than expected measured angle of draw values occur again in Moolarben No.4 UG, surface features such as The Drip and Goulburn River National Park, would still be located outside the limit of subsidence. It is not considered reasonable at this stage to increase the AoD above 26.5^{o} until survey data for Moolarben suggests otherwise. It is also considered less likely that the higher AoD values will occur at the ends of the proposed longwalls.

11.0 POST-MINING SUBSIDENCE PROFILES AND SURFACE LEVEL CONTOUR PREDICTIONS

11.1 Transverse Subsidence Profiles

Transverse subsidence and associated differential subsidence profiles have been determined along cross lines 1 to 10 as shown in **Figure 1.1**. Selected cross lines 1, 4, 7 and 10 are presented in **Figures 11.1** to **11.12** respectively and have been referred to for the purposes of surface impact analysis.

11.2 Longitudinal Subsidence Profiles

Differential subsidence profiles will develop in the longitudinal direction, at the ends of the panels and above the retreating longwall face. The magnitudes of centreline tilt, curvature and strain at the starting and finishing points of the panels will be of a similar magnitude to the transverse parameters presented in **Table 7.5**.

The magnitudes of the tilt, strain and curvature above the retreating longwall face are likely to be about 25 to 50% of the transverse parameters, due to ‘dynamic’ or travelling wave effects. This phenomenon has been measured above numerous longwall faces and generally occurs when retreat rates are greater than 30 m / week. Dynamic profiles are similar to final (static) subsidence profiles, when retreat rates are less than 30 m / week.

The credible worst-case longitudinal subsidence, tilt and curvature profiles above the starting or finishing point centrelines of proposed LWs 1 and 13 are presented in **Figures 11.13** to **11.18**. These cover the typical range of depths.

11.3 Predicted Surface Subsidence Contours

Credible worst-case post mining subsidence and surface level contours for LWs 1 to 14 have been plotted. These are presented in **Figures 11.19** and **11.20**. The post-mining contours and levels have been used to subsidence parameter values for surface features that do not necessarily follow the cross lines and centre lines of a given panel. The impacts of the estimated credible worst-case subsidence parameters are assessed in **Section 12.**

12.0 SUBSIDENCE IMPACT ASSESSEMENT AND MANAGEMENT STRATEGIES

12.1 Mechanisms of Damage

In areas where longwall mining is proposed, the potential impacts of the following subsidence and subsidence-related damage mechanisms on natural and man-made features have been assessed:

(i) subsidence (primarily tilt and strain)

(ii) surface (and sub-surface) cracking,

(iii) ponding,

(iv) general slope instability and erosion,

(v) stability of cliff lines,

(vi) uplift along creeks and river valleys,

(vii) far-field displacements,

Discussions of likelihood of impact occurrence in the following sections generally refer to the qualitative measures of likelihood described in **Table 12.1**, and are based on reference to **AGS, 2000** and **Vick, 2002**.

Table 12.1 - Qualitative Measures of Likelihood

Likelihood of Occurrence	Event Implication	Indicative Relative Probability
Almost Certain	The event is expected to occur.	0.9-0.99
Very Likely	The event is expected to occur, although not completely certain.	0.75-0.90
Likely	The event will probably occur under normal conditions.	0.5-0.75
Possible	The event could occur under normal conditions.	0.1-0.5
Unlikely	The event is conceivable under adverse conditions.	0.05-0.1
Very* Unlikely	The event probably won't occur even under adverse conditions.	0.01-0.05
Not Credible	The event is inconceivable or practically impossible.	<0.01

Notes:
** - Equivalent to the credible worst-case or U95%CL subsidence impact parameter.

12.2 Surface Cracking

12.2.1 Predicted Impacts

Maximum tensile and compressive strains of 8 to 35 mm/m for the proposed panels indicate that surface crack widths of between 40 mm and 180 mm can be expected within the limits of extraction (i.e. goaf). In particular, significant cracks are likely to occur above areas in which surface rock exposures with widely spaced, adversely orientated (or no) jointing, coincide with peak strains (i.e. Terrain Units R1, R2 and R3).

Crack widths are expected to range between 40 mm and 90 mm above longwalls at cover depths > 130 m. Crack widths ranging between 90 mm and 180 mm are expected above the shallower areas, where the cover depths are <130 m.

The crack widths have been estimated by multiplying the mean uniform strain (typically half the CWC strain) by a distance of 10 m (based on the typical bay-length and crack widths observed in the field for the corresponding strains) and assuming that a single crack will occur in the given bay-length. In reality, several smaller cracks may develop or existing joints will open.

Cracks will also probably develop 20 or 30 m behind the retreating longwall face. The majority of these cracks are expected to close after mining is complete.

Cracks in the tensile zones will probably be tapered and extend to depths of about 3 to 10 m, possibly deeper where massive near surface strata units exist. Cracks caused by compressive or buckling/shear failures in the compressive zones are likely to dip at 20 to 30^{o} to the horizontal and be less persistent.

Cracks within drainage gullies or creek beds are only likely to impact sections where sandstone outcrops exist. These could result in sub-surface re-routing of surface flows during storm periods (i.e. when the ephemeral drainage gullies are likely to flow).

12.2.2 Proposed Impact Mitigation and Management Strategies

Where relatively deep sediment deposits exist along ephemeral watercourses (i.e. Terrain Units A1 to A2), cracking is unlikely to impact significantly on water flows directly, due to the self-sealing capability of sandy beds after cracks develop by ongoing natural geomorphic processes.

Similar in-filling of cracks will be much slower in drainage gullies in the R1 and R2 terrain units (i.e. with sandstone exposures). Post-mining crack repairs may be necessary to mitigate against significant sub-surface flows.

Surface crack repair works will need to be implemented around the site, focusing particularly on damage to drainage gullies, access roads, farm dams and livestock grazing paddocks.

Cracking impacts on cliffs, overhangs, gullies and residential structures are discussed in specifically in subsequent sections of this report.

12.3 Sub-Surface Cracking

12.3.1 Predicted Impacts

Sub-surface fracturing has been assessed by reference to the empirical sub-surface fracturing model presented in **ACARP, 2003**, in the context of the predicted subsidence deformations.

Continuous sub-surface cracking refers to fracturing above a longwall panel that would provide a direct flow-path or hydraulic connection to the workings, if a sub-surface aquifer were intersected. The presence sub-surface aquifers above the workings and within the continuous fracture zone could therefore result in increased water makes at seam level during longwall extraction.

Discontinuous fracturing refers to the additional extent above a longwall to which there could be a general increase in horizontal and vertical permeability, due to bending or curvature deformation of the rock mass. This type of fracturing does not provide a direct flow path or connection to the workings and is more likely to interact with surface cracks or joints. This type of fracturing may therefore result in an adjustment of surface and sub-surface flow paths and storage magnitudes within the rock mass, but may not result in a significant change to the groundwater or surface water resource in the long-term.

Predicted upper 95% Confidence Limits (credible worst-case) for continuous and discontinuous sub-surface cracking heights are summarised in **Table 12.2**.

Table 12.2 - Summary of Predicted Credible Worst-Case Sub-Surface Fracturing Heights

LW #	D (m)	Single Panel S_{max} (m)	Single Panel E_{max} Uniform Tensile Strain (mm/m)	Predicted Fracture Heights Above LWs	
				Continuous (m)	Discontinuous (m)
1 - 2	90	2.44	10	**82**	**90**
	160	1.75	3	94	**153**
3 - 6	130	2.39	5	96	**130**
	180	1.54	2	96	165
7	120	2.44	5	90	**120**
	170	1.59	2	93	157
8 - 10	140	2.32	5	97	**145**
	160	1.65	3	94	**153**
11 - 14	150	1.75	4	84	**148**
	170	1.59	3	93	158

Notes:
* - Fracture heights, see **Appendix A** for details.
Bold - sub-surface fracturing are considered likely to interact with surface cracks if they extend to within 10 m of the surface.

The data presented in **Table 12.2** is illustrated in **Figure 12.1**. Further details of the model are provided in **Appendix A**.

Based on the lithological profiles and the predicted fracture heights, it is assessed that it is possible that sub-surface aquifers within 100 m of the workings (i.e. all of the Permian coal seams) will be susceptible to continuous fracturing.

The likelihood of a direct connection with the surface is assessed to be highly unlikely to practically impossible (i.e. < 1% probability) for the areas where the depth exceeds 100 m.

At depths of 85 to 100 m, a direct hydraulic connection with the surface is considered possible (i.e. a likelihood of 10 to 50%), particularly if major geological structure and/or deep alluvium are present (e.g. 35 m of alluvium over the outbye 300 m of LW1).

The absence of a fault would reduce the probability of occurrence to 5% -10% (i.e. unlikely).

Practical experiences from other longwall operations in NSW confirm that direct hydraulic connection between the workings and surface is an issue at depths of <100 m.

Discontinuous sub-surface fracturing may interact with cracking or open joints on the surface for cover depths up to 160 m. Surface waters could drain into deeper cracks, resulting in a drop in the ground water table initially, but this would then be expected to recover either partially or fully over time, as the new voids or storage spaces became saturated or in-filled with sediment. The level of groundwater recovery would also depend on whether there were any downstream discharge points connected to the new storage areas.

12.3.2 Proposed Impact Mitigation and Management Strategies

Based on the assessment of the likely fracturing phenomena within the overburden, mitigation strategies may be identified, to minimise impacts to sub-surface aquifers. It is considered unlikely at this stage that a reduction in extraction or modification to the mine plans will be required, based on the available data. However, this may change once the impact of mining is better understood.

Changes to the hydro-geological environment can be measured using down-the-hole multi-wire borehole extensometers, as well as vibrating wire or slotted standpipe peizometers above the centre of the proposed panels. Up-stream and down-stream piezometers, mine workings water-make and in-seam pump discharge records would also provide information on sub-surface fracturing impacts.

The monitoring stations could be initially installed in less sensitive or deeper areas (i.e. where cover depth is > 150 m) to confirm the predictions prior to undermining an area considered likely to require a higher degree of impact management.

12.4 Ponding

12.4.1 Predicted Impacts

Surface slopes in the ridge-affected areas (Terrain Units R1 and R3) range between 10° and 20° and are unlikely to be affected by ponding caused by closed form depressions from subsidence trough development (i.e. the net fall across the area will still be sufficient to allow drainage to continue unimpeded).

Surface topography in the flatter parts of the study area generally falls from east to west at 2° to 3°, or about 8 to 13 m over 260 m (i.e. the panel width), representing a general crossfall of

9 m over a panel width of 260 m. Predicted subsidence magnitudes of 0.12 to 0.18 m along the edges and 1.8 to 2.4 m over the centre of each longwall panel indicate a net differential subsidence of about 1.6 to 2.4 m above each panel.

Some of the watercourses present in the lower reaches of the site (terrain units R3, A1 and A2) could be susceptible to ponding however. Several sections (A, B and C) were taken through the pre- and post mining surface topography, see **Figure 11.20**. Section A was taken along the deeply incised watercourse in the northern region (see **Figure 12.2**). Section B was taken along the access road from the Ulan-Cassilis Road to the Imrie - Mullin's property boundary (see **Figure 12.3**). Section C was taken along the gully in the southern region, from the eastern boundary to the Ulan Mine's groundwater bore field on the western boundary (see **Figure 12.4**).

Section A suggests that about 98.5 % of the 1.7 km gully section will not be susceptible to ponding with a small reach distance of 43 m above the middle of LW10 assessed to have a potential maximum ponding depth of 0.96 m, based on the predicted post-mining surface contours. Near surface cracking in this area could decrease the maximum ponding depth by increasing sub-surface storage volumes.

Section B suggests that ponding will probably not occur along the access road after mining. However, localised ponding or boggy ground could develop in the flatter A1 and A2 areas, as well as in the vicinity of the horse training area, after periods of particularly wet weather. The ponding depth is not likely to exceed 0.2 m.

Section C indicates that ponding will almost certainly not develop along this gully or impact on surface run off in the vicinity of the groundwater bore fields.

12.4.2 Proposed Impact Mitigation and Management Strategies

As it is considered unlikely that significant ponding or changes to surface drainage patterns will occur after longwall extraction, an appropriate management strategy would include the on-going review and an appraisal of changes to surface drainage paths and areas of ponding development, after each longwall is extracted.

Based on the impact assessment, some low-lying areas in the northern part of the site, near the horse training area, could become poorly drained or boggy after the extraction of LWs 12 to 13. In this case, the pattern of drainage may need to be augmented, to restore it to pre-mining conditions, through surface and sub-surface drainage works.

A small zone of ponding of up to 1 m depth could occur along a gully in the northern half of the site, above LW10. The actual ponding depth will depend upon several other factors, such as rain duration, surface cracking and effective percolation rates of the surface soils and fractured rock outcrops. The associated access road will be maintained in an all-weather trafficable condition at all times (during and after mining impacts).

The assessed sections are considered representative examples, but do not constitite an exhaustive analysis. Further work would be rquired to identify all potential ponding areas.

12.5 General Slope Stability and Erosion

12.5.1 Predicted Impacts

A broad semi-quantitative, assessment of the likelihood of *en-masse* sliding (i.e. a landslip) of massive blocks of sandstone over low strength mudstone/siltstone beds, due to subsidence effects has been undertaken. The potential for terrain adjustment due to erosion and deposition of soils due to subsidence impacts has also been broadly assessed.

These assessments on the stability of the naturally developed landform and weathering patterns are preliminary and further detailed studies may be necessary in areas identified 'high' risk, in terms of damage to property or surface features. The methodolgy applies the landslide risk assessment terminology presented in **AGS, 2000**.

The predicted subsidence troughs are expected to change existing slopes by between 1° and 3.5° (i.e. 15 and 59 mm/m tilt), which would indicate that any near surface claystone beds may have their dip increased from about 2° to 3° to a range of 3° to 6.5°, on north and east facing slopes. The net bedding dip will be decreased by a similar amount for west and south facing slopes, to a range of 0° to 1°.

Based on reference and inspection of the silty sandstone and mudstone units along the base of the cliff lines on the site, a lower bound strength of the weaker beds in the study area is assessed to be equal to a drained angle of friction (Ø') of 15° based on reference to **Fell et al, 1992**.

The assumption of saturated slope conditions with water filled joints or mining-induced cracks represents the worst possible rock-mass condition in the study area and is applied herein.

The Factors of Safety against *en-masse* sliding of a natural slope in the study area due to the predicted bedding dip increase and surface cracking effects mentioned above are estimated for the worst-case condition by the method presented in **Das, 1998** as follows:

Before mining: $FoS = (u_b/u_r)\tan(Ø')/\tan(theta) = 0.6 \tan(15°)/\tan(3°) = 3.1$.

After mining: $FoS = (u_b/u_r)\tan(Ø')/\tan(theta) = 0.6 \tan(15°)/\tan(6.5°) = 1.4$.

where:
u_b = buoyant unit weight of sandstone above the mudstone = 14 kN/m^3
u_r = dry unit weight of sandstone above the mudstone = 24 kN/m^3

Based on a recommended minimum FoS of 1.2 (**UNSW, 2004**) for the worst-case scenario, it is assessed that it is 'very unlikely' that a large scale instability or landslip will occur in the long-term due to mining effects within the study area.

The predicted impacts of the tilts are also considered 'very unlikely' to cause localised surface slope instability where existing ground slopes that are less than 20° (i.e. in Terrain Units R1, R2, R4).

It is, however, possible that localised instability could occur in Terrain Unit R3, or in cliff lines with overhangs and semi-released block wedges at slope angles <20°, if the slopes are also affected by mining-induced cracking and increased erosion rates. Further specific discussion on the stability of the cliff lines due to mine-induced cracking is presented in **Section 12.6**.

The rate of soil erosion is expected to increase significantly in areas with exposed dispersive/reactive soils and slopes > 10° (i.e. Terrain Units R2 to R4), where theses are subjected to the estimated tilt increases. Areas with slopes < 10° (Terrain Units R1 and A1 to A3) are expected to have low erosion rate increases.

12.5.2 Proposed Impact Mitigation and Management Strategies

To minimise the likelihood of significant slope instability or erosion due to cracking or changes to drainage patterns after extraction, based on the risk management principles defined in **AGS, 2000**, the management strategy should include:

(i) the on-going review and appraisal of any significant changes to surface stability, including surface cracking along ridges, increased erosion down slopes, foot slope seepages and drainage path changes after each longwall is extracted;

(ii) conducting surface slope displacement monitoring along subsidence cross lines (combined with general subsidence monitoring plans);

(iii) the infilling of surface cracking to prevent excessive ingress of runoff into the slopes or re-establishing vegetation or eroded areas likely to continue to degrade if left exposed.

Large-scale slope instability after mining may require significant stabilisation works, such as the installation of deep sub-surface drainage trenches to reduce pore pressure build up and strategic catch drains along slope crests to improve surface run-off.

An assessment of higher risk areas will be conducted during the development of the SMP.

12.6 Cliff Line Stability Assessment

12.6.1 Impact Assessment Methods

The expected mining impact on the cliffs in the study area has been assessed based on reference to the empirically based impact classification or rating system presented in **ACARP, 2002**.

The ACARP method focuses on general global stability of the cliff lines and the upper bound limit of the proportion of cliff lines that could be impacted by rock falls. The method does not allow a quantitative assessment of the potential for cracking damage; however 'moderate' to 'high' impact ratings imply that cracks are likely to occur. Estimates of cracking widths have therefore been made based on the empirical methodology presented in **ACARP, 2003.**

The above methods essentially allow an overall assessment of the impact of mining to cliff face stability and aesthetic appeal.

The contribution of the natural instability of the cliff lines due to on-going weathering processes is factored into the assessment also.

In summary, the analytical methods require the following input data:

- the geotechnical/physical characteristics of the cliffs (i.e. height, lithology, geological structure, aesthetic appeal, public accessibility);

- the predicted subsidence deformations and direction of mining in relation to the cliff lines;

- the active weathering processes that have caused cliff face instability and talus formation at the site (i.e. preferential weathering leading to overhang development, water and wind erosion, groundwater seepage etc), see **Figure 12.6.**

The assessment has used the credible worst-case values to determine the weighted scores for each cliff line. The scores in each category are then added together and divided by the maximum possible score for the category. The impact category scores are provided in **Table 12.3**.

Table 12.3 - Cliff Line Impact Classifications

Proportion of Maximum Score	Ranking	Classification
0 - 0.1	1	Insignificant (I)
0.1 - 0.2	2	Very Low (VL)
0.2 - 0.3	3	Low (L)
0.3 - 0.4	4	Moderate (M)
0.4 - 0.5	5	High (H)
0.5 - 0.6	6	Very High (VH)
>0.6	7	Extremely High (EH)

The relevant extracts from **ACARP, 2002**, which describe the assessment methodology, are presented in **Appendix C.**

12.6.2 Predicted Impacts Based on an Empirical Cliff Line Stability Assessment

Details of the cliff line stability assessment using the empirical approach in **ACARP, 2002** are presented in **Tables C1** to **C8** in **Appendix C**. Predicted values of CWC subsidence, tilt, strain and horizontal displacement are included in the tables.

The results of the stability assessment indicate that the majority of the cliff lines subject to the maximum predicted subsidence deformations are likely to be impacted by an increased proportion of rock falls and superficial cracking of the rock faces. The mining impact category ratings for the cliffs range from insignificant to extremely high, with rock falls expected to affect 0% to 65% of the subsided cliff lines.

A summary of the empirical cliff line stability assessment due to the impacts of longwall extraction is presented in **Table 12.4**.

Table 12.4 - Summary of Empirical Cliff Line Stability Assessment due to Mine Subsidence Impacts

Cliff Line #	Cliff Face Height (m)	Maximum Subsidence at Cliff (m)	Mining Impact Category		Public Exposure/ Aesthetics Category		Natural Instability Category		Total Impact Rating
			Rating	Ranking	Rating	Ranking	Rating	Ranking	
CL1 a*	3 - 15	0.1	0.28	L	0.19	VL	0.26	L	**Very Low**
CL1 b*	3 - 15	2.2	0.89	EH	0.19	VL	0.26	L	**Mod**
CL2	3 - 5	2.0	0.89	EH	0.22	L	0.21	L	**High**
CL3	10 - 30	1.9	0.89	EH	0.18	VL	0.31	M	**High**
CL4	5 - 10	2.4	0.89	EH	0.17	VL	0.23	L	**Mod**
CL5	30 - 40	0.0	0.0	I	0.48	H	0.34	L	**Low**
CL6	3 - 15	2.0	0.89	EH	0.10	VL	0.28	L	**Mod**
CL7	3 - 15	0.1	0.28	L	0.17	VL	0.29	L	**Very Low**
CL8	3 - 15	2.0	0.89	EH	0.23	VL	0.23	L	**Mod**

Notes:
Mod = Moderate impact.
* - (a) refers to the section outside the limits of the proposed longwalls;
* - (b) refers to the section above the proposed longwalls.

The results indicate that the cliffs have overall impact ratings ranging from 'Very Low' to 'High' after consideration of cliff line aesthetics and natural instability.

The 'Very Low' to 'Low' impact ratings refer to cliffs beyond the limits of workings.

According to the rock fall prediction chart (**ACARP, 2002**), an 89% or 'Extremely High' mining impact rating and a 'Low' natural instability impact rating implies that 65% of cliff lines are like to have rock falls. It should be understood that this number, as explained in the ACARP report, is likely to represent the worst-case of the cliff line database.

Impacts to the cliff lines above the longwalls are therefore expected to cracking or spalling of the cliff faces. Further detailed studies of the cliff lines will be necessary to estimated potential sizes of the blocks, based on the assumption that tensile cracking and shear failures due to compressive strains expected on the cliff faces will generate the blocks in conjunction with existing joint patterns.

Based on the above impact assessment outcomes, further analysis of the likely failure mechanisms of the cliff have been completed and presented in **Section 12.6.3**.

For The Drip, insignificant damage and no rock falls are predicted. As discussed later in **Section 12.8** the estimated horizontal displacement of the northern and southern cliff faces, due to the 'credible-worst-case' far field movements are not considered sufficient to cause cracking. However, due to the sensitive nature of the feature, it is considered that a surface monitoring program will be required to confirm that far field horizontal displacements and strains are likely to be insignificant. This is discussed further in **Section 13**.

12.6.3 Predicted Impacts based on an Analytical Cliff Line Stability Assessment

Cliff stability could be affected by both tilting and strain. Tilts can steepen or flatten the rock faces up to a few degrees, depending on their orientation to the longwalls. The differential movement of a rock face from bottom to crest is the product of the tilt and the cliff height. As shown for Cliff CL3 in **Table C3** in **Appendix C**, a tilt of 23 to 30 mm/m can cause a differential horizontal movement of 660 to 900 mm for a 30 m high cliff. This could steepen or flatten the cliff by up to 1.7^{o}.

En-masse sliding of the cliff face along bedding partings between sandstone and weaker strata along the base has been previously discussed in **Section 12.5**. The likelihood of cliffs failing due to this mechanism is assessed to be 'very unlikely', based on a worst-case analysis.

Stability is generally expressed as a Factor of Safety (FoS) and defined as the ratio of the strength over the driving force. The driving force is the gravity force which acts on the slope and the strength is the resisting force that is developed as internal friction and cohesion within the rock mass (material or defect). An FoS greater than 1 implies the rock face is in a stable condition and the greater the FoS, the more stable the rock face.

Increasing the cliff face angle will reduce its FoS since this will increase the driving force. For a 30 m high sub-vertical rock face, a 1.7 degree increase of face angle due to tilting will reduce FoS by about 2 - 5%, based on a simple two-dimensional analysis using Slide® limit equilibrium software and Phases 2® finite-element analysis.

In general, a 2 - 5% reduction of FoS is not significant. Hence, this FoS reduction should not affect the stability for most of the cliffs and overhangs. However, should the rock face or overhang be in a critical condition (i.e. with a FoS only slightly greater than 1.0) prior to, or deteriorate after mining impacts due to unfavourable cracking, a 2 - 5% FoS reduction could result in a wedge or toppling failure from the cliff face.

It is therefore very difficult to determine Factors of Safety for these cliffs and overhangs due to uncertainty in the estimates of the key stability parameters of slope geometry, rock mass strength, drainage paths and the location of planes of structure and bedding partings.

Even though a 2 - 5% reduction of FoS may not have a significant impact on most of cliff lines and overhangs, unstable conditions could still occur, and are considered to be more likely if the cliffs are subject to curvature and strain of more than 0.3 km^{-1} (i.e. a radius < 3.33 km) or 3 mm/m respectively.

The maximum predicted uniform tensile strains along the cliff lines range between 4 and 10 mm/m with concentrated values of 15 and 25 mm/m caused by cracking. Sandstone and conglomerate beds with Young's Modulii values ranging from 5 to 15 GPa and widely spaced, persistent jointing, are not likely to be able to 'absorb' strains >2 mm/m and cracking of the cliff faces is therefore expected.

It should also be appreciated that the derived FoS values from stability analysis is based on circular failure mechanism and may not be applicable to cliffs susceptible to non-circular failure mechanisms due to mid-angled structure. The evidence on site suggests that generally only widely spaced, sub vertical structure is present in the cliffs, which suggests that rupture of the rock mass material will be required before circular-slip failure would occur. However, occasional mid-angled joints are present which may contribute to a localised failure.

Regular inspection of the cliff lines is recommended before and after longwall mining impacts, to review and identify significant changes to cliff stability.

The density, width and location of the cracks will be dependent on near surface geology, topography, cover depth and relative location respective to longwall panels. In general the total width of cracks within 10 m range may vary from 40 mm to 90 mm for cover depths >130 m.

In general, cliffs subject to cracking that is sub-parallel to the face are considered more likely to become unstable. Cliff faces that strike east-west (i.e. normal to the longwall panels and transverse tensile strains) will probably suffer similar damage to those cliffs oriented on an north-south alignment, due to similar dynamic longitudinal principal strain magnitudes during longwall retreat. Again, the degree of damage for a given amount of differential subsidence will depend on the strength, geometry and joint patterns within the cliffs. For cliff lines located outside the extraction limits (i.e. part of CL1 and all of CL 5 and CL7), no significant cracking damage or low impact is expected due to mining.

Preliminary two-dimensional numerical modelling (Phases 2®) of the cliff faces indicates that the predicted tilts will not cause large-scale toppling or sliding wedge failures unless tensile cracking generates a block release mechanism that is coincident with the back of an existing overhang. Further studies will be required to determine the likelihood of this scenario.

12.6.4 Rock Fall Hazard Mitigation and Management

The predicted cliff line impacts, are considered acceptable based on the risk management principles defined in **AGS, 2000**, provided the exposure of dwellings, vehicles and people to rock falls is managed with the use of appropriate controls. Even though public access will be restricted around the cliffs, further risk analysis and management work is suggested to provide appropriate controls to minimise exposure of mine personnel and visitors to rock falls.

Appropriate controls may include rock fall face control mesh and catch ditches, barrier fencing, earth mounds and warning signs, installed at appropriate locations around the boundaries and within the vicinity of cliff lines of the No.4 Underground area. Common methods of rock fall hazard management are suggested below:

Cliff Face Stabilisation Works - Installation of rock-fall control mesh and spot bolting of potentially unstable 'blocks' and wedges prior to mining impacts.

Rock Fall Catch Ditches and/or Earth Mounds - These may be installed between private roads and areas of rock fall hazard. The private roads in the vicinity of the cliff lines CL1 and 2 on the Westwood property, as well as signage displaying 'falling rock' hazard warnings, would be considered appropriate at this stage.

Barrier Fencing - Heavy duty galvanised mesh fencing should be installed at locations with moderate overall impact, where dwellings exist within 100 m of the cliffs. The fencing should be designed to arrest a rolling boulder of an appropriate size for the specific cliff line.

At this stage, several structures have been identified on the Westwood property that will require either relocation away from the adjacent cliff, or impact barrier fencing installed to control the 'design' boulder for the given cliff line. The structures identified are:

(i) Tony's Property - This house is approximately 30 m from the toe of CL2 and has two light duty fences located between the residence and the cliff that are unlikely to arrest a rolling boulder from impacting the dwelling.

(ii) Huts B6 to B9 - These dwellings are all within 100 m of CL1 and have no fencing at all to slow or arrest the design boulder.

It should be noted that a specific study of the rock fall hazards may indicate that the above structures are not close enough to the cliffs for the design boulder to cause serious damage. Further study is therefore recommended on this issue, if the houses are to be inhabited during mining. Further work will also be necessary to derive site specific 'design' boulder sizes for the cliffs.

Any inspections of cliff lines and rock shelters by stakeholder groups during and after mining impacts, should be accompanied by mine site representatives familiar with the hazards likely to be present.

12.7 Upsidence Along Creek Beds and Valleys

12.7.1 Predicted Impacts

As discussed in **ACARP, 2002**, when creeks and river valleys are subsided, the observed subsidence in the base of the creek or river is generally less than would normally be expected in flat terrain. This reduced subsidence is due to the floor of the valley buckling upwards when subject to compressive stresses generated by surface deformation. In most cases, the observed uplift has extended outside the valley and included the immediate cliff lines and the ground beyond them.

Uplift and closure movements can be expected in cliffs and in the sides of valleys whenever longwalls are mined beneath them. Such movements, however, tend to reduce with distance outside of the goaf areas and do not usually occur outside the angle of draw.

There are two incised creek beds or gullies in the study area. The first gully is above Longwalls 10 and 11 between cross lines XL 6 and 8 in the northern domain and is about 15 to 20 m deep and 150 m wide. The second gully is above Longwalls 5 and 6 between cross lines 1 and 3 in the southern domain, and is about 20 to 30 m deep and 150 to 200 m wide.

It should be understood that these movements are strongly dependent on the level of 'locked-in' horizontal stress immediately below the floor of the gullies and more importantly the bedding thickness of the floor strata (i.e. thin to medium bedded sandstone is more likely to buckle than thicker beds). The influence of the aspect ratio (i.e. valley width/depth) is also recognised as an important factor, with deep, narrow valleys having greater upsidence than broad, rounded ones, due to higher stress concentrations.

The Drip is about 30 to 40 m high and 50 to 100 m wide, with north and south-facing cliff lines. The southern cliff is located 150 to 220 m north of LWs 13 and 14, while the northern cliff is about 250 to 450 m from these longwalls. The average distance to the Goulburn River is assessed to be about 235 m.

According to the empirical models presented in **ACARP, 2002**, the maximum closure along the creek bed gullies between cliff lines CL4 and CL6 in the study area is estimated to be 150 mm and 230 mm respectively. The associated maximum uplift range for the gullies is estimated to be 150 mm and 250 mm and are considered conservative for No.4 UG at this stage.

The predicted 'upsidence' will probably cause some localised deviation of surface flows along ephemeral creek beds into sub-surface routes above the longwall panels. Failure of the near surface rocks due to compressive strains will also contribute to the re-routing of surface flows. Surface flows would be expected to re-surface down stream of the damaged area.

At The Drip, which is located outside the angle of draw of the proposed longwalls, it is very likely that the maximum closure and uplift will be less than survey instrument accuracy of 1 to 2 mm.

12.7.2 Impact Mitigation and Management Strategies

The impact of upsidence and valley bending effects may be managed as follows:

(i) Install and monitor survey lines along ephemeral drainage gullies and along gully crests during and after longwall undermining. Combine with visual inspections to locate damage (cracking, uplift).

(ii) Review predictions of upsidence and valley crest movements after each longwall.

(iii) Assess whether repairs (i.e. cementitious grouting) to cracking, as a result of upsidence or gully slope stabilisation works (i.e. spot bolts and meshing) are required to minimise the likelihood of long-term degradation or risks to personnel and the general public.

12.8 Far-Field Horizontal Displacements

12.8.1 General

Horizontal movements have been recorded at distances outside of the angle of draw at mines in the Newcastle, Southern and Western Coalfields (**Reid, 1998, Seedsman, 2001** and **Strata Engineering, 2004**). Horizontal movements recorded beyond the angle of draw are referred to as far-field horizontal displacements. For example, at Cataract Dam in the Southern Coalfield, **Reid, 1998**, reported horizontal movements of up to 25 mm when underground coal mining was about 1.5 km away. Seedsman also reports movements of around 20 mm at distances of approximately 220 m, for a cover depth ranging from 70 to 100 m and a panel width of 193 m.

Based on a review of the above information, it is apparent that this phenomenon is strongly dependent on (i) cover depth, (ii) distance from the goaf edges, (iii) the width of the extracted area and (iv) the geology of the overburden.

The direction of the movement appears to be generally towards the extracted area, but can vary due to (i) the degree of regional horizontal stress adjustment around extracted area and (ii) the surface topography.

As shown in **Strata Engineering, 2004,** West Wallsend Colliery recorded 5 to 10 mm of horizontal movement at a distance of 250 m from a longwall face, at 160 m cover depth and a panel width of 175 m. **Figure 12.5** plots horizontal movement versus distance to the panel using data reported from several mines in the Newcastle Coalfield with similar mining geometry to the proposed Moolarben longwalls.

To better understand the likely interaction between the longwall and surrounding areas, further studies of the pre- and post-mining horizontal stress environment, as well as the extent of horizontal displacement outside the limits of extraction are recommended. At this stage however, it is considered that the prediction model adopted herein is likely to be conservative.

Predictions of far-field displacements are included in the following impact and management strategy sections for The Drip.

12.8.2 Predicted Impacts on the The Drip

The northern face of The Drip is ≥ 250 m away from the north end of the LWs 13 and 14, where the cover depth is about 155 to 160 m. Based on reference to **Figure 12.5** it is estimated that the cliff will be subjected to *en-masse* horizontal movement of 47 to 57 mm for the Upper 95% and 99% Confidence Limits (i.e. the 5% and 1% Probability of Exceedence (PoE)) values respectively. A similar outcome is estimated for the southern cliff face, although the movements are likely to be greater than for the northern cliff. At this stage, it is considered unlikely that the southern cliff faces will be damaged by the longwalls that are 150 m to 200 m away and located outside of the angle of draw. Further studies on the stability of both cliff lines should be considered during the preparation of the SMP for the No. 4 UG - North area.

The outcomes of a numerical model (Phase 2®) analysis of the overburden, for the case of full horizontal stress relief due to longwall extraction and for the given geometry, stiffness and stress values, is shown in **Figure 12.6**. The results indicate a similar magnitude of horizontal displacement of 30 to 40 mm, 250 m outside the edge of the longwall panel.

Based on a longwall width of 260 m, the FoS with regards to bending-induced cracking of the cliffs (as a consequence of horizontal displacement), has been assessed below, using the relationship proposed by **Burland and Wroth, 1974**:

For a credible worst-case horizontal curvature of p = mid-span deflection x 8/ Panel Width^2

$$= 57 \text{ mm} \times 8/260^2$$

$$= 0.0067 \text{ km}^{-1} \text{ (149 km radius or 1:5200 span:deflection ratio)}$$

The bending strain for a rock mass with a UCS of 50 MPa and Young's Modulus of 15 GPa, when subject to the above curvature, may be estimated conservatively by assuming the cliff acts as a beam with a thickness equal to its height of about 40 m:

Bending Strain = curvature x beam thickness/2

= 0.0067 x 40/2

= 0.134 mm/m

Bending Stress = strain x Youngs Modulus

= 0.134 x 15

= 2 MPa

For an estimated Ultimate Tensile Strength = UCS/10

= 5 MPa

The FoS for cracking the cliff face = UTS/Bending Stress

= 5/2

= 2.5

Due to the very low strains predicted as a consequence of far-field displacement (assuming that the model is conservative), and the absence of vertical subsidence and tilt outside a distance of 0.5 times the cover depth of 160 m (i.e. a 26.5^{o} draw angle) it is considered unlikely that The Drip will be subjected to any damage due to the cumulative effects of LWs 12 to 14. Further studies based on local monitoring data will be necessary to validate the model, however.

Reference to **Kay et al, 2006**, indicates a similar outcome to the above assessment and suggests it would be unlikely that tensile or compressive strains would be high enough to cause fracturing in deep gorges (i.e. > 50 m depth) in the Southern Coalfield further than 250 m from the end or side of a longwall panel. Theoretically, tensile strains of > 0.5 mm/m or compressive strains of > 2 mm/m would be the minimum systematic strains required to cause fracturing of massive near-surface rock exposures. This assessment is considered conservative and is based on the measurement of fracture sites above and outside of longwall blocks.

Only minor fracturing has ever been observed outside the limits of the longwalls and this has not impacted on water flows or quality of the rivers involved.

12.8.3 Impact Mitigation and Management of Impacts to The Drip

As it is difficult to determine at this stage whether the above movement estimates are acceptable or not, and based on the review of fracturing data presented in **Kay et al 2006**, the following impact management strategy is considered reasonable for The Drip:

(i) conduct cumulative start and finishing end of panel subsidence and strain monitoring (including total horizontal displacement measurements) for several southern and northern longwalls. Map the width and location of any surface cracks and their locations outside the limits of the longwalls;

(ii) review measured movements and predictions, well before the development of LWs 12 to 14 commences.

(iii) If measured strains exceed 1 mm/m or cracking occurs outside a distance of 200 m from the ends of the longwalls, a review of the proposed starting position will be required. The value of 1 mm/m is considered reasonable for standard steel tape measurement accuracy over a maximum monitoring peg spacing of 10 m or 0.5 mm/m over 20 m (i.e. the distances between the pegs must be able to be read to an accuracy of +/- 10 mm or better over the suggested peg distances).

Based on the empirical prediction methodology presented, if the above "trigger-levels" are exceeded, the start of LWs 13 and 14 could be relocated back to the proposed starting position, for LW12 (i.e. which is about 450 m from The Drip). The predicted 1% PoE value would then be reduced from 57 mm to 20 mm. The displacements of the southern cliff faces have not been specifically addressed because it is considered that the stability of the Northern cliff face will determine the final outcome during the SMP. The movements of the southern cliff line are also likely to favourable in terms of the cliff stability but should be considered in a detailed study of the cliffs.

This issue will be further discussed in regards to the recommended monitoring program presented in **Section 13**.

12.9 Ulan-Cassilis Road, Goulburn River Bridge and Road Cuttings

12.9.1 Predicted Impacts due to Subsidence

The Ulan-Cassilis Road, associated cuttings and bridge over the Goulburn River are located to the west of LWs 1 to 12. The location of the features relative to the proposed longwalls and predicted angle of draw are presented in **Table 12.5**.

Table 12.5 - Location of Ulan-Cassilis Road Relative to LWs 1-14 and the Predicted Angles of Draw.

LW #	Feature	LW Reference Point (m)	Distance from LW Side, End or Corner z (m)	Cover Depth, D (m)	z/D	Location in Terms of Draw Angle (o)	Maximum Predicted Angle of Draw* (o)
Southern LWs 1 - 7							
1	Road/Cut 1	End	360	85	4.24	76.7	26.5
2	Road	End	365	95	3.84	75.4	26.5
3	Road	End	365	135	2.70	69.7	26.5
4	Road	End	360	145	2.48	68.1	26.5
5	Road	End	360	145	2.48	68.1	26.5
6	Road	End	360	135	2.67	69.4	26.5
7	Road	End	360	130	2.77	70.1	26.5
Northern LWs 8 - 14							
8	Road/Cut 2	Side	620	145	4.28	76.8	26.5
8	Road/Cut 3	Side	140	145	0.97	44.0	26.5
8	Road/Cut 3	Corner	80	145	1.34	53.4	14
9	Road	Side	160	135	1.19	49.8	26.5
9	Road	Corner	90	140	1.46	55.5	14
10	Road	Side	230	155	1.48	56.0	26.5
10	Road	Corner	50	150	1.13	48.4	14
11	Road	Side	240	150	1.60	58.0	26.5
11	Road	Corner	40	145	1.11	48.0	14
12	Road/Bridge	Side	210	130	1.62	58.2	26.5
12	Road/Bridge	Corner	250	135	2.62	69.1	14
12	Road/Cut 4	Side	250	130	1.92	62.5	26.5
12	Road/Cut 4	Corner	300	135	2.98	71.5	14
13	Road	Side	530	155	3.42	73.7	26.5
14	Road	Side	840	155	5.42	79.5	26.5

Notes:
* - Maximum values from **Table 10.2**.

Based on the results in **Table 12.5**, the Ulan-Cassilis Road, cuttings and bridge are all located outside the maximum possible angle of draw for the proposed mining layout.

The above features could, however, be subject to far-field horizontal displacements, which are discussed further in **Section 12.9.2**.

12.9.2 Predicted Impacts due to Far-Field Horizontal Displacement

The Ulan-Cassilis Road and associated infrastructure are located outside the angle of draw for the proposed longwall panels. The infrastructure assessed in this study includes 4 cuttings and a reinforced concrete bridge that crosses the Goulburn River. The likelihood that far-field horizontal movements may affect these features has been assessed using the methodology presented in **Section 12.8.2**. As the database comprises measurements from the ends of longwall panels, predictions along a line drawn from the corners of the longwalls must be converted to equivalent end distances, using trigonometry as follows:

$z' = ((0.7071z)^2 + (0.7071z + \text{Panel Width}/2)^2)^{0.5}$

where

z' = equivalent end of LW panel distance
z = distance along a 45^{o} line drawn from the corners of the longwalls.
W = panel void width.

Estimates of expected and credible worst-case (based on the Upper 99% Confidence Limit) are presented for the road, cuttings and bridges in **Table 12.6a** and **12.6b**.

Table 12.6a - Predicted Far-Field Horizontal Displacements Along Ulan-Cassilis Road Due to the Southern LWs 1 - 7

LW #	Feature	LW Reference Point (m)	Distance from LW Side, End or Corner z (m)	Cover Depth, D (m)	z/D	Expected (mean) Horizontal Displacement (mm)	CWC (U99%) Horizontal Displacement (mm)
1	Road/Cut1	End	360	85	4.24	4	9
2	Road	End	365	95	3.84	5	12
3	Road	End	365	135	2.70	12	27
4	Road	End	360	145	2.48	14	31
5	Road	End	360	145	2.48	14	31
6	Road	End	360	135	2.67	12	28
7	Road	End	360	130	2.77	12	26

The predictions in **Table 12.6a** indicate that the road and Cutting 1, to the west of the southern longwalls (LWs 1-7) could displace 4 to 31 mm towards the mining area (i.e. east).

Table 12.6b - Predicted Far-Field Horizontal Displacements Along Ulan-Cassilis Road Due to the Northern LWs 8 - 14

LW #	Feature	LW Reference Point (m)	Distance from LW Side, End or Corner z (m)	Cover Depth, D (m)	z/D	Expected (mean) Horizontal Displacement (mm)	CWC (U99%) Horizontal Displacement (mm)
8	Road/Cut 2	Side	620	145	4.28	4	9
8	Road/Cut 3	Side	140	145	0.97	41	89
8	Road/Cut 3	Corner	80	145	*1.34*	*31*	*68*
9	Road	Side	160	135	1.19	35	76
9	Road	Corner	90	140	*1.46*	*29*	*63*
10	Road	Side	230	155	1.48	28	62
10	Road	Corner	50	150	*1.13*	*36*	*79*
11	Road	Side	240	150	1.60	26	57
11	Road	Corner	40	145	*1.11*	*37*	*80*
12	Road/Bridge	Side	210	130	1.62	26	57
12	Road/Bridge	Corner	250	135	*2.62*	*13*	*28*
12	Road/Cut 4	Side	250	130	1.92	21	46
12	Road/Cut 4	Corner	300	135	*2.98*	*10*	*22*
13	Road	Side	530	155	3.42	7	16
14	Road	Side	840	155	5.42	2	4

Notes:
Italics - corner distances converted to equivalent end or side distances.

The predictions in **Table 12.6b** indicate that the road and cuttings 2 to 4 to the west of the northern longwalls (LWs 8 -14) could displace by 2 mm to 89 mm towards the mining area (i.e. east to south-east).

The bridge over the Goulburn River could be displaced towards the east by 13 to 57 mm, although the differential displacement between the abutments is likely to be less than this range.

12.9.3 Impact Mitigation and Management of Impacts to the Ulan-Cassilis Road and Bridge

The roads in the underground mining area are flexible, granular pavements, which are amenable to repair if damaged by subsidence. Cracking, shearing and uplift of the pavement seal, concrete kerbing and drainage structures would be expected to occur in zones affected by tensile and compressive strains that exceed 2 or 3 mm/m.

Damage from subsidence (i.e. cracking and tilting) can manifest quickly after undermining. However, there is usually enough time (i.e. several hours or even days) to take corrective action and manage the impact, when it occurs.

The cracking of bitumen seals and pavement base courses could result in moisture ingress into water sensitive subgrade materials, leading to on-going deterioration and cracking due to rutting or failure of the subgrade. It is therefore recommended that repairs to surface cracks occur within a reasonable period to preserve the integrity of the pavements.

Associated drainage structures, such as kerb and guttering, concrete lined v-drains, reinforced concrete culverts or table drains, could also be damaged by tensile and compressive strains that exceed 1 to 2 mm/m along the roads. Inspection of these features and implementation of repair works, after mining impacts have occurred, should be included in the SMP with the associated council.

An appropriate management strategy for Ulan-Cassilis Road, cuttings and bridge over the Goulburn River would be as follows:

(i) Define the likely tolerable movements and impact on the road and bridge structure based on consultation with the Mid-Western Regional Council and RTA bridge engineers, during the SMP stage.

Consultation with the relevant authorities will be required to develop appropriate monitoring and trigger action response plans, to manage the potential for anomalous behaviour outside the predicted maximum angle of draw.

(ii) Review the predictions of angle of draw and horizontal displacement distances from the ends of the longwalls in non-sensitive areas to assess the appropriate subsidence impact controls.

(iii) Determine if it will be necessary to implement mitigation works to the bridge or stabilise the cuttings, prior to subsidence movements.

(iv) Develop a trigger-action response plan (TARP) in the SMP in consultation with Mid-Western Council and the DPI, to ensure the roads and associated infrastructure remain in a safe and serviceable condition during and after the impacts of mining.

The SMP will provide timely subsidence impact monitoring data and response plans to (i) repair damage (i.e. cracks) if it occurs and (ii) provide traffic control measures, such as signage to raise public/driver awareness and reduction of speed limits at appropriate times during mining.

12.10 The Ulan Groundwater Bore-Field

12.10.1 Predicted Impact due to Subsidence

The groundwater bore field dams are 200 to 300 m west of the finishing point of LW7. The cover depth at the sites ranges between 90 and 95 m, indicating the dams are well outside the angle of draw.

No direct damage or impact to the head works, dams or groundwater bores, due to subsidence is expected (the predicted movements are expected to be < 10 mm towards the east with a CWC value of 20 mm).

However, the regional drawdown effects of the water table on groundwater bore yields should be assessed by a groundwater consultant.

12.10.2 Predicted Impacts Due to Horizontal Displacement

The Ulan groundwater bore surface infrastructure is located approximately 300 m west of the proposed finishing locations of LWs 6 and 7. The likelihood that far-field horizontal movements may affect the above features has been assessed using the methodology presented in **Section 12.8.2**.

Based on reference to **Figure 12.5** it is expected that the groundwater bore could be subjected to differential horizontal shear movements ranging from 0 to 9 mm towards the east. The Upper 95% and 99% Confidence Limits (i.e. the 5% and 1% Probability of Exceedence (PoE)) values of 16 and 20 mm respectively have also been assessed, based on non-linear regression analysis techniques.

No direct damage or impact to the pump house, dams or groundwater bores, due to far-field horizontal displacement is expected (the predicted movements are expected to be < 10 mm towards the east with an Upper 99%CL value of 20 mm).

12.10.3 Impact Mitigation and Management Strategies

An appropriate management strategy for the Ulan Groundwater bore-field would be as follows:

(i) Define what the tolerable movements on the boreholes are likely to be, based on consultation with the owners/operators during the SMP stage.

Further consultation with the owners will be required, to develop appropriate monitoring and trigger action response plans to manage anomalous behaviour outside the predicted maximum angle of draw, if it occurs.

(ii) Review the predictions of angle of draw and horizontal displacement distances from the ends of the longwalls in non-sensitive areas, before LW6 and 7 is extracted, to assess the appropriate subsidence impact controls.

(iii) Determine if it will be necessary to implement mitigation works to the bore field or provide for an alternate water supply, should significant damage occur.

(iv) Develop a trigger-action response plan (TARP) in the SMP, based on consultation with the owners, to ensure the bore field and associated headworks remains in a safe and serviceable condition during and after the impacts of mining.

12.11 The Dronvisa Gravel / Clay Quarry

12.11.1 Impacts Due to Subsidence

The Dronvisa Pty Ltd quarry is located 20 to 150 m west of the proposed finishing positions of LWs 4-5. The cover depth above the proposed workings at the quarry ranges between 130 m and 140 m. The quarry will therefore be located at a distance equal to 0.77 to 1.1 times the cover depth or an equivalent longwall centreline draw angle of 37.5^{o} to 47^{o}.

Horizontal displacements are considered unlikely to be an issue for the site and have not been assessed. No damage or impact to the stability of the quarry batters is expected.

12.11.2 Impact Mitigation and Management Strategies

An appropriate management strategy for the Dronvisa Quarry would be as follows:

(i) Define the operational issues with regard to possible ground movements due to subsidence, based on consultation with the owners/operators during the SMP stage. The future expansion plans of the quarry should also be discussed.

Consultation with the owners will be required to develop appropriate monitoring and trigger action response plans, to manage anomalous behaviour outside the predicted maximum angle of draw, if it occurs.

(ii) Prepare a suitable subsidence monitoring plan to enable review of the predictions of angle of draw and horizontal displacement distances from the ends of the longwalls in non-sensitive areas, before LW5 and 6 are extracted.

(iii) Determine if it will be necessary to implement mitigation works at the quarry before mining impacts (i.e. batter slope stabilisation).

(iv) Develop a trigger-action response plan (TARP) in the SMP, mine based on consultation with the owners, to ensure conditions at the quarry remain in a safe and serviceable condition during and after the impacts of mining.

12.12 The Goulburn River National Park

12.12.1 Predicted Impacts Due to Subsidence

As discussed previously, the Goulburn River National Park is located outside an angle of draw limit of 26.5^{o} and will therefore not be impacted by subsidence.

12.12.2 Predicted Impacts Due to Horizontal Displacement

The boundary of the Goulburn River National Park is located outside the angle of draw for the proposed longwall panels. The likelihood that far-field horizontal movements may affect the boundary line has been assessed using the methodology presented in **Section 12.8.2**.

Estimates of credible worst-case horizontal displacement (based on the Upper 99% Confidence Limit) are presented for the park boundary line in **Table 12.7**.

Table 12.7 - Predicted Far-Field Horizontal Displacements Along the Goulburn River National Park Boundary Line Due to LWs 1 to 7 and 14

LW #	LW Reference Point (m)	Distance from LW Side, End or Side z (m)	Cover Depth, D (m)	z/D	CWC (U95%) Horizontal Displacement (mm)	CWC (U99%) Horizontal Displacement (mm)
1	End	500	190	2.63	23	28
2	End	500	195	2.56	24	30
3	End	550	200	2.75	21	26
4	End	550	215	2.56	24	30
5	End	300	230	1.30	58	70
6	End	280	200	1.40	54	66
7	End	250	210	1.19	63	76
14	Side	450	150	3.00	18	22
14	Side	250	175	1.43	53	65
14	Side	180	200	0.90	77	93
14	Side	150	185	0.81	82	99
14	Side	175	200	0.88	78	95
14	Side	200	180	1.11	66	80

Based on reference to **Figure 12.5**, it is estimated that the boundary line could be subjected to horizontal en-masse movement ranging from 21 to 99 mm towards the west for the Upper 95% and 99% Confidence Limits (i.e. the 5% and 1% Probability of Exceedance (PoE)) respectively.

12.12.3 Mitigation and Management Strategies

Far-field horizontal displacements are considered unlikely to cause damage to the surface within the Goulburn River National Park. However, a stability assessment and monitoring of far-field displacement movements of cliff lines on the site boundary should be included in a boundary line management plan to be developed in consultation with the DEC-NPWS.

12.13 Groundwater Dependent Eco-Systems (GDEs)

12.13.1 Predicted Impacts

As mentioned in **Section 5**, there are some minor, localised GDEs present along some of the cliff lines above the proposed longwalls. Interception of the groundwater seepages could occur due to subsidence cracking, that would probably result in the loss of these systems.

There are GDEs present on the northern cliff face of The Drip which have developed from sub-surface aquifers to the north of The Drip. It is understood that the groundwater consultant considers that the groundwater resource in this area will not be affected by the proposed longwalls to the south.

12.13.2 Impact Mitigation and Management Strategies

Appropriate monitoring and mitigation strategies for the GDEs present on the site and along the northern face of The Drip are discussed in the ecological consultant's report.

12.14 Aboriginal Heritage Sites

12.14.1 Predicted Impact Assessment Method

As discussed in **Section 5.5.5,** there are 14 aboriginal artefact sites considered by ARAS to be significant (**ARAS, 2006**) in the study area (see **Figure 5.11** for their location). The sites consist of rock shelters (some with hand paintings), scattered artefacts and axe grinding grooves. The expected impacts on the sites have been assessed, based on the following key parameters and reference to **ACARP, 2002** and **Shepherd and Sefton, 2001**:

(i) The expected magnitudes of subsidence, tilt and strain (tensile or compressive).

(ii) The length of overhang and degree of weathering impact (in the case of a rock shelter), as rated in **ACARP, 2002** for cliff line instability.

(iii) The orientation of the overhang or cliff face with respect to the principal strain direction.

(iv) The presence of favourably orientated (i.e. strain relieving) joints and bedding partings (for the case of axe grinding grooves).

(v) The degree of weathering impact prior to mining.

A damage likelihood assessment has been undertaken using the ranking system developed for this project and is summarised in **Table 12.8**.

Table 12.8 - Summary of Damage Likelihood Ranking System due to Mine Subsidence Impacts

Impact Parameter	Damage Likelihood							
	Very Low (1-5% PoD)		Low (5-10% PoD)		Moderate (10-50% PoD)		High (50-90% PoD)	
	Result	Ranking Score	Result	Ranking Score	Result	Ranking Score	Result	Ranking Score
1. Orientation of Cliff face to Principal Strains (degrees)	60-90^o	**0**	30-60^o	**1**	10-30^o	**2**	0-10^o	**3**
2. Subsidence (m)	<0.1	**0**	0.1-0.5	**1**	0.5-1	**2**	>1	**3**
3. Maximum Tilt on Face (mm/m)	<2	**0**	2-10	**1**	10-20	**2**	>20	**3**
4. Strain* (mm/m)	<0.5	**0**	0.5 -1	**1**	1-1.5	**2**	>1.5	**3**
5. Overhang length or maximum grinding grove dimension (m)	<1	**0**	1-2	**1**	2-4	**2**	>4	**3**
6. Joint Set Factor**	60-90^o	**0**	30-60^o	**0.5**	10-30^o	**1**	0-10^o	**1.5**
7. Degree of Weathering***	Extreme (soil)	**0**	High (UCS< 15 MPa)	**0.5**	Moderate (UCS< 30 MPa)	**1**	Low (UCS> 30 MPa)	**1.5**

Notes:
PoD = Probability of Damage.
* - Maximum of predicted uniform tensile and compressive strain.
** - Orientation of joint set to principal strain indicates the potential for joints/bedding to relieve strains before the on-set of fresh cracking.
***- Degree of alteration of fresh rock strength by weathering. The lower the rock strength the lower the likelihood of cracks developing.

The damage likelihood is based on the sum of each impact parameter for a given rock shelter or grinding groove site. The associated likelihood category is presented in **Table 12.9.**

Table 12.9 - Damage Likelihood Probabilities

Item	**Total Damage Likelihood Outcomes**			
Damage Likelihood	Very Low	Low	Moderate	High
Total Score*	0 - 4	5 - 9	10 - 14	15 - 18
Probability of Damage	1-5%	5-10%	10-50%	50-90%

Notes:
* - Sum of the seven scores for the impact parameters presented in **Table 12.8**.

12.14.2 Impact Assessment Outcomes for Significant Archaeological Sites

The sites are expected to be subject to various ranges of subsidence, tilt and strain due to both dynamic and static subsidence development.

The predicted credible worst-case "smooth profile" subsidence, tilt, strain and curvature values for each significant artefact site are summarised in **Table 12.10** and used as input into the damage likelihood ranking system. Damage likelihood has been summarised in **Table 12.11**.

Table 12.10 - Predicted CWC Subsidence, Tilt, Strain and Curvature for the Significant Archaeological Sites

AS #	S1MC #	Final Transverse				Final Longitudinal*		
		Subsidence (m)	Tilts (mm/m)	Strains (mm/m)	Curvature (km^{-1})	Tilt (mm/m)	Strain (mm/m)	Curvature (km^{-1})
1	254	2.019	**8E**	**-4.0**	-0.408	0.4N (15N)	-0.01 (2)	-0.001 (0.25)
2	256	0.000	0.0	0.0	0.000	0.0	0.0 (0.0)	0.00 (-)
3	261	0.002	0.4E	0.3	0.031	0.2N (0.2N)	0.1 (0.1)	-0.01 (-)
4	264	0.032	2E	**0.7**	0.067	0.5S (0.5S)	-0.01 (0.3)	0.001 (-)
5	267	0.590	**13W**	**2**	0.215	6.3S (6S)	-0.20 (1.0)	0.02 (0.2)
6	271	0.000	0.0	0.1	0.005	0.1W (0.1W)	0.2 (0.08)	0.02 (-)
7	280	0.995	**20N**	**3**	0.3	3.2W (10W)	0.1 (2)	-0.01 (0.1)
8	281	0.000	0.0	0.0	0.000	0.0	0.0 (0.0)	0.00 (-)
9	282	0.000	0.0	0.0	0.000	0.0	0.0 (0.0)	0.00 (-)
10	283	0.000	0.0	0.0	0.000	0.0	0.0 (0.0)	0.00 (-)
11	284	0.000	0.0	0.0	0.000	0.0	0.0 (0.0)	0.00 (-)
12	285	0.027	1.5E	**0.5**	0.049	0.4S	-0.02 (0.1)	0.001 (-)
13	286	0.002	0.3E	0.2	0.019	0.2S	0.03 (0.01)	-0.003 (-)
14	PAD 11	0.000	0.0	0.0	0.000	0.0	0.0 (0.0)	0.00 (-)

Note:
AS = Strata Engineering numbering system as shown in figures.
S1MC# = Heritage Consultant numbering system.
- subsidence impact parameter predictions based on U95% CL smooth profile contours.
E = tilting downwards towards the east, N = north, S =South, W = West;
- Negative strain denotes compressive strain.
* - Dynamic longitudinal deformation expected in brackets ( ).
- Strains may increase by up to 2 times the 'smooth' profile strains presented in the table if cracking occurs.
Bold - Potentially damaging tilt and strains.

Table 12.11 – Damage Likelihood Outcomes for the Significant Archaeological Sites

S1MC #	Damage Likelihood Parameter Scores															
	IP1	Score	**IP2**	Score	**IP3**	Score	**IP4**	Score	**IP5**	Score	**IP6**	Score	**IP7**	Score	Total	
254 (AS1)	0-10°	**3**	2.0	**3**	8E	**1**	-4	**3**	NA	**0**	30-60	**0.5**	Soil	**0**	10.5	**Mod**
256 (AS2)	10-30°	**2**	0.0	**0**	0	**0**	0	**0**	3-4	**2**	30-60	**0.5**	Low	**1.5**	6	**Low**
261 (AS3)	10-30°	**2**	0.02	**0**	<2	**0**	0.5	**1**	3-4	**2**	30-60	**0.5**	Low	**1.5**	7	**Low**
264 (AS4)	10-30°	**2**	0.03	**0**	2E	**0**	0.7	**1**	NA	**0**	0-10	**1.5**	Low	**1.5**	6	**Low**
267 (AS5)	0-10°	**3**	0.59	**2**	13 W	**2**	2	**3**	2-3	**2**	0-10	**1.5**	Low	**1.5**	15	**High**
271 (AS6)	10-30°	**2**	0.0	**0**	1W	**0**	0.1	**0**	2-3	**2**	30-60	**0.5**	Low	**1.5**	6	**Low**
280 (AS7)	0-10°	**3**	1.0	**3**	20N	**3**	1.4	**2**	5-6	**3**	0-10	**1.5**	Low	**1.5**	16	**High**
281 (AS8)	60-90°	**0**	0.0	**0**	NA	**0**	0.0	**0**	NA	**0**	30-60	**0.5**	Soil	**0**	05	**Very Low**
282 (AS9)	60-90°	**0**	0.0	**0**	NA	**0**	0.0	**0**	NA	**0**	30-60	**0.5**	Soil	**0**	0.5	**Very Low**
283 (AS10)	10-30°	**2**	0.0	**0**	0	**0**	0.0	**0**	2-3	**2**	30-60	**0.5**	Low	**1.5**	6	**Low**
284 (AS11)	10-30°	**2**	0.0	**0**	<2	**0**	0.0	**0**	4-7	**3**	0-10	**1.5**	Low	**1.5**	5	**Low**
285 (AS12)	0-10°	**3**	0.03	**0**	<2	**0**	0.5	**1**	4-5	**3**	30-60	**0.5**	Low	**1.5**	10	**Mod**
286 (AS13)	0-10°	**3**	0.0	**0**	<2	**0**	0.2	**0**	2-3	**2**	30-60	**0.5**	Low	**1.5**	7	**Low**
PAD 11 (AS14)	60-90°	**0**	0.0	**0**	<2	**0**	0.0	**0**	5-7	**3**	30-60	**0.5**	Low	**1.5**	5	**Low**

Note:
IP - impact parameter (see **Table 12.3** for definitions).
* - where a parameter is considered to be non-applicable (i.e. NA) a score of 0 is assumed.
Mod = Moderate.

Based on the outcomes shown in **Table 12.11** it is considered that the scattered artefact site S1MC 254 (AS1), the axe grinding groove site, S1MC 264 (AS4) and the rock shelter S1MC 285 (AS 12), will have a 'moderate' likelihood (i.e. 10 to 50% probability) of potentially damaging tensile strains of > 0.5 mm/m or compressive strains > 2mm/m.

The rock shelter with artefact sites, S1MC 267 (AS5) and 280 (AS7), have a 'high' likelihood (i.e. 50 to 90% probability) that they will be subject to potentially damaging tensile strains.

Maximum crack widths will be dependent on the predicted strains presented in **Table 12.10** and are estimated to range between 5 and 40 mm in the absence of strain relieving joints, or saw cuts at the site locations. Back wall spalling, due to bedding shear, could also occur due to the predicted strain levels in the rock shelters. Collapse of the rock shelters is not expected, although the possibility of collapse cannot be ruled out, particularly if the shelter is already in a fragile state.

Tilts can cause differential movements of rock faces and steepen or flatten them by up to 2 degrees, depending on their orientation to the developing subsidence trough. However, a 20 mm/m tilting of a rock shelter with limited height would only be expected to have a very low impact on stability, since the rock face would only be steepened by about 1 degree.

The remaining archaeological sites are located outside of the longwall extraction limits and very minimal to zero subsidence (i.e. < 20 mm), tilt (i.e. < 2 mm/m) and strain (i.e. <0.5 mm/m) is predicted at these sites.

The likelihood of damage at sites 256 (AS2), 261 (AS3), 271 (AS6), 281 (AS8), 282 (AS9), 284 (AS11), 286 (AS13) and PAD11 (AS14) is assessed to be 'low' to 'very low'.

12.14.3 Impacts to Rock Shelters

Predicted credible worst-case subsidence, strain, tilt and curvature for the 177 rock shelters are presented in **Appendix B**. General impacts on the rock shelters are discussed in the previous sections on the cliff line sites, since the rock shelters are produced by the active weathering and natural cliff line instability mechanisms.

Based on the outcomes of the assessment of the cliffs in **Section 12.8**, it is assessed that the rock shelters within the limits of extraction have a moderate to high likelihood of damage. Any shelters outside of the extraction limits will have low to very low damage likelihood.

12.14.4 Impact Mitigation and Management Strategies

Based on the impact assessment method, scores of 9 or less (i.e. low to very low likelihood of damage) will probably not be impacted visibly by mining. However it will be necessary to conduct regular visual inspections (say monthly) during and at least 6 months after mining is completed.

If visible deterioration of the shelters occurs, such as back wall spalling, crack development and rock falls, then mitigation works may be necessary, to maintain the stability of the shelter (see below for discussion on appropriate mitigation options).

Scores of 10 or more, (i.e. moderate to high likelihood of damage) suggest the shelters will probably require support during mining and repairs to cracks, to control accelerated weathering effects.

Other options, such as shallow saw cuts to form ‘strain relief’ breaks at a shelter or grinding groove site may also be appropriate to protect a significant feature from cracking. However the effectiveness of this technique is difficult to quantify.

Overall, each of the significant sites should have a minimum of two survey pegs installed parallel and normal to the rock shelters, for subsidence and strain measurements using either 2-D or 3-D techniques.

12.15 Residential Development

12.15.1 Tolerable Subsidence Limits and Predicted Impacts

Subsidence, tilt and strain have been calculated at corner locations around properties, based on the CWC subsidence contours in **Figure 11.19. Table 12.11** summarises the maximum dimensions of the buildings in the east-west (approximately cross the panels) and north - south (approximately parallel to the panels) directions.

Table 12.11 - A Summary of the Maximum Dimensions of the Buildings

Building Number	Building Name	East-West Dimension (m)	North-South Dimension (m)	Building Height (m)	Type
1	Tony's house	10.6	16	3	Fibro Clad
2	Tony's shed	10.6	11	3	CB Clad
3	Jim's house	20.2	23	3	Brick Veneer
4	Jim's shed	8	8	3	CGI Clad
5	Stable	10	20	3	CGI Clad
6	Hut	10	11	3	Timber Clad
7	Hut	6	14	3	Fibro Clad
8	Hut	10	11	3	Fibro Clad
9	Hut	8	8	3	CB Clad

Note:
CGI - Corrugated Galvanised Iron
CB - Colour Bond Sheet Metal

The impact of longwall mining upon the residential development at the individual sites has been assessed based on subsidence, tilt and strain at the perimeter of each unit. **Table 12.12** summaries the outcomes.

The assumed tolerable subsidence limits for the residences are based on the MSB Graduated Index Guidelines presented in **Appleyard, 2001** and **AS2870, 1996**, as follows:

- Subsidence (no limit)
- Tilt < 5 mm/m
- Curvature < 0.3 km^{-1} (i.e. Radius of Curvature > 3.3 km)
- Span: Deflection Ratio > 1:800
- Maximum differential displacement < 15 mm
- Strain < 2 mm/m

Should the predicted subsidence parameters exceed the above limits, it is expected that significant damage will occur to the structure, rendering it unsafe and uninhabitable.

Table 12.12 - A Summary of CWC Subsidence, Tilt and Strain for the Residential Development in No.4 UG - North

Building #	Corner #	Final Transverse (perpendicular to panels)				Final Longitudinal (parallel to panels)		
		Subs (m)	Tilt (mm/m)	Strain (mm/m)	Curvature (km^{-1})	Tilt (mm/m)	Strain (mm/m)	Curvature (km^{-1})
B1 (Tony's house)	1.1	0.56	11	2	0.18	6	-0.2	-0.02
	1.2	0.48	9	2	0.16	5	-0.2	-0.01
	1.3	0.53	10	2	0.16	5	-0.2	-0.02
	1.4	0.65	12	2	0.19	6	-0.2	-0.02
B2 (Tony's shed)	2.1	0.74	13	2	0.19	6	-0.3	-0.03
	2.2	0.63	11	2	0.19	5	-0.3	-0.03
	2.3	0.60	11	2	0.17	5	-0.3	-0.03
	2.4	0.71	12	2	0.19	5	-0.3	-0.03
B3 (Jim's House)	3.1	0.04	-1	0.3	0.03	-0.1	0.0	0.00
	3.2	0.06	-1	1	0.08	-0.1	0.0	0.00
	3.3	0.06	-1	1	0.08	-0.1	0.0	0.00
	3.4	0.06	-1	1	0.07	-0.1	0.0	0.00
	3.5	0.05	-1	1	0.07	-0.1	0.01	0.00
	3.6	0.05	-1	0.4	0.04	-0.1	0.01	0.00
	3.7	0.05	-1	0.5	0.05	-0.1	0.01	0.00
	3.8	0.03	-1	0.1	0.01	-0.0	0.01	0.00
	3.9	0.03	-1	0.1	0.01	-0.1	0.01	0.00
	3.10	0.04	-1	0.2	0.02	-0.1	0.01	0.00
	3.11	0.04	-1	0.2	0.02	-0.1	0.01	0.00
	3.12	0.04	-1	0.2	0.02	-0.1	0.01	0.00
	3.13	0.04	-1	0.2	0.02	-0.1	0.01	0.00
	3.14	0.04	-1	0.3	0.03	-0.1	0.00	0.00
B4 (Jim's shed)	4.1	0.04	-1	0.4	0.04	-0.1	-0.01	0.00
	4.2	0.06	-1	0.7	0.07	-0.1	-0.01	0.00
	4.3	0.06	-1	0.8	0.08	-0.1	0.00	0.00
	4.4	0.05	-1	0.4	0.04	-0.1	0.00	0.00
B5 (stable)	5.1	2.18	-16	-6	-0.60	-1.6	-0.02	0.00
	5.2	2.24	-13	-6	-0.59	-1.6	-0.02	0.00
	5.3	2.24	-12	-6	-0.58	-1.4	0.01	0.00
	5.4	2.29	-10	-6	-0.56	-1.3	0.01	0.00
	5.5	2.31	-9	-6	-0.55	-1.2	0.02	0.00
	5.6	2.25	-12	-6	-0.57	-1.4	0.02	0.00
	5.7	2.26	-12	-6	-0.56	-1.3	0.03	0.01
	5.8	2.22	-14	-6	-0.58	-1.4	0.03	0.01
B6 (Hut)	6.1	1.21	22	0.3	0.03	8	-0.5	-0.05
	6.2	1.08	20	1	0.11	7	-0.5	-0.05
	6.3	1.01	20	2	0.18	6	-0.5	-0.05
	6.4	1.15	22	1	0.12	7	-0.6	-0.06
B7 (Hut)	7.1	0.96	19	2	0.15	7	-0.4	-0.04
	7.2	0.87	18	2	0.18	6	-0.3	-0.03
	7.3	0.89	18	2	0.19	6	-0.4	-0.04
	7.4	0.99	20	2	0.16	7	-0.4	-0.04

Table 12.12 (Continued) - A Summary of CWC Subsidence, Tilt and Strain for the Residential Development in No.4 UG - North

Building #	Corner #	Final Transverse (perpendicular to panels)				Final Longitudinal (parallel to panels)		
		Subs (m)	Tilt (mm/m)	Strain (mm/m)	Curvature (km^{-1})	Tilt (mm/m)	Strain (mm/m)	Curvature (km^{-1})
B8 (Hut)	8.1	0.23	2	2.2	0.22	3	-0.0	-0.01
	8.2	0.20	0	2.2	0.21	3	-0.0	-0.01
	8.3	0.21	-2	2.2	0.22	2	-0.1	-0.01
	8.4	0.23	0	2.3	0.23	2	-0.1	-0.01
B9 (Hut)	9.1	2.37	4	-4.7	-0.47	1	-0.3	-0.03
	9.2	2.36	6	-4.7	-0.47	2	-0.3	-0.03
	9.3	2.33	7	-4.3	-0.43	2	-0.3	-0.03
	9.4	2.36	5	-4.5	-0.45	2	-0.3	-0.03

Note:
- Subsidence impact parameter predictions based on CWC smooth profile contours.
- Negative tilt denotes tilting down to east or north, negative strain denotes compressive strain.
- Strains shown are CWC uniform values and may increase by a factor of 2 if cracking occurs.

12.15.2 Impacts to Tony's House and Shed (B1/B2)

Tony's house is near the north-east corner of LW11. Subsidence impact has been studied at the corner locations of the property. Predicted subsidence after LWs 11 and 12, ranges from 0.48 to 0.56 m, with tilts from 9 to 12 mm/m and uniform tensile strains from 1 to 2 mm/m. Curvatures will range from 0.16 to 0.18 km^{-1} (5.5 to 6.3 km).

Based on the building length of 10.6 m, a maximum differential horizontal displacement or potential maximum crack width of 10 to 20 mm is assessed, indicating Category 2 (Slight) to 3 (Moderate) level of damage in accordance with **AS2870, 1996**. Damage is likely to range from cracking to internal wall linings and cornices, with mild jamming of windows and door frames.

The magnitude of predicted tilt, however, is greater than 7 mm/m, which is the maximum tilt at which the Mine Subsidence Board would consider the residence to be inhabitable. Damage mitigation works are therefore probably not warranted, as the building may not be able to be re-levelled after mining.

12.15.3 Impacts to Jim's House (B3)

Jim's house is located 60 m from the western rib side of LW12. CWC subsidence impact has been studied at 14 points around the property. As indicated in **Table 12.12**, all 14 locations around the house will be subject to 3 - 6 mm subsidence, a 1 mm/m tilt towards the east and a maximum east-west uniform tensile strain of 0.8 mm/m. Tilting and strain along the panel direction are negligible. Since the magnitudes for subsidence, tilts and strain are very low, no damage is expected to the residence.

12.15.4 Impacts to the Remaining Huts and Sheds (B5-B9)

Based on the predicted CWC results shown in **Table 12.12**, Huts B5 and B9 will be subject to 2.2 to 2.4 m of subsidence, tilts of 4 to 16 mm/m, curvatures of 0.4 to 0.6 km^{-1} and uniform strains of 2 to 3 mm/m.

Huts B6 and B7 will be subject to subsidence of 0.9 to 1.2 m, tilts of 18 to 22 mm/m and uniform tensile and compressive strains of about up to 1 mm/m.

Hut B8 will be subsided 0.2 to 0.3 m after the extraction of LW13. Tilts of 1 to 2 mm/m will probably not require re-levelling of the hut. Some repairs of cracks, due to 2-3 mm/m strains and curvatures of 0.2 to 0.3 km^{-1}, may be necessary.

Damage to Huts 5 - 7 and 9 will be similar to that described for Tony's house, with significant tiltand possibly cracking of internal wall linings, chimneys and floor slabs.

An assessment of the condition of the huts is recommended, before and after mining impacts. It may also be prudent to re-locate them beyond the mine subsidence area, rather than attempt to re-level and repair them after mining is completed.

12.15.5 Impact Mitigation and Management Strategies for Existing Residences

Apart from Jim's house and shed, the predicted impacts to the existing houses are not likely to be repairable. Therefore, impact management will involve one of the following options:

(i) compensation and re-construction of a new residence after mining impacts;

(ii) relocation of the existing structures outside the angle of draw to the longwalls;

(iii) acquisition of the property by the mine.

12.16 Old Farm House (circa 1920's)

The old farmhouse in the southern area of UG 4 is likely to be impacted by the proposed longwall mining. Further study of possible mitigation and repair works will be investigated for the SMP and will involve consultation with the stakeholder.

12.17 Water Storage Dams D1 to D13

12.17.1 Predicted Impacts

The predicted CWC subsidence deformations at the 13 dams on the site (as defined in **Section 5.6.7**) are summarised in **Table 12.13**.

Table 12.13 - Summary of CWC Subsidence, Tilt and Strain for the Dams in No.4 UG - North

Dam #	Final Transverse (perpendicular to LW panels)				Final Longitudinal (parallel to LW panels)		
	Subsidence (m)	Tilt (mm/m)	Strain (mm/m)	Curvature (km^{-1})	Tilt (mm/m)	Strain (mm/m)	Curvature (km^{-1})
1	0.00	0	0.1	0.006	0	0.0	0.001
2	0.00	0	0.0	0.000	0	0.0	0.000
3	0.03	-1	0.3	0.033	0	0.0	0.002
4	0.22	-9	4	0.412	0	0.1	0.010
5	0.02	-1	-0.2	-0.016	0	0.1	0.008
6	0.05	1	2	0.169	-3	4	0.376
7	0.06	1	0.0	0.006	-4	0.1	0.025
8	0.00	0	0.0	0.000	0	0.0	0.000
9	0.00	0	0.0	0.000	0	0.0	0.000
10A	0.00	0	0.0	0.000	0	0.0	0.000
10B	0.00	0	0.0	0.000	0	0.0	0.000
11	1.56	-18	-4	-0.365	0	-0.2	-0.018
12	0.65	13	2	0.200	1	0.3	0.034
13	1.63	21	-3	-0.342	0	-0.2	-0.023

Note:
- subsidence impact parameter predictions based on CWC 'smooth profile' contours.
- Negative tilt denotes tilting down to east or north, negative strain denotes compressive strain.
- Strains are uniform CWC and may increase by a factor of 2 if cracking occurs.

Stock watering dams **D4, D6** and **D12** are expected to be subject to tensile cracks of 20 to 40 mm width, due to uniform tensile strains of 2 to 4 mm/m. This may result in subsequent loss of storage, with repair works required to seal the cracks.

The dams are also expected to be subject to temporary longitudinal deformations of similar magnitude to the transverse movements. Dams **D11** and **D13** may be impacted to a similar degree by tensile strains associated with the transient longitudial deformations.

The remaining water bore dams are unlikely to be damaged, with negligible tilt and strain predicted after longwall extraction.

12.17.2 Impact Mitigation and Management Strategies

Non-engineered farm dams and water storages are susceptible to surface cracking and tilting from mine subsidence. The tolerable tilt and strain values for the dams would depend upon the materials used, construction techniques, foundation type and likely repair costs to re-establish the dam's function and pre-mining storage capacity.

It should be noted that dams like the ones in the underground mining area have been undermined by longwalls elsewhere in NSW and any damage effectively managed. The dams have then been reinstated in a timely manner by the MSB and an alternative supply of water has been provided by the mine during the interim period.

Appropriate impact management strategies and relevant SMP issues would be:

(i) The development of a suitable monitoring and response plan based on consultation with the owners of the dams and regulatory authorities, to ensure the impacts on the dams do not result in unsafe conditions or loss of access to water during and after the effects of mining.

(ii) Management would include maintaining the integrity of the dams and preventing potential downstream flooding (involving flora and fauna and public safety) and/or providing an alternate supply of water to the affected stakeholder, until the dams can be reinstated to pre-mining conditions (including re-filling the dams).

(iii) Damage from subsidence (i.e. cracking and tilting) can manifest quickly after mining (i.e. within hours). The appropriate management plan will therefore need to consider the time required to respond to the impact in a controlled manner, when it occurs. It will also be possible to identify the dams likely to be impacted significantly, based on their location above the mine panels and predicted subsidence profile, during the preparation of the SMP.

(iv) Suitable responses to subsidence impacts would be to either i) drain the dam storage area before subsidence occurs and repair the dam with an impermeable clay liner after mining, or ii) monitor the dam wall during mining and place high capacity pumps on 24 hour stand-by during mining to draw down the storage area, if the walls are significantly weakened by subsidence development.

12.18 Gulgong to Sandy Hollow Railway

The cover depth ranges between 85 m and 145 m at the railway line, indicating a distance equal to about 3.4 to 5.9 times the cover depth (or an equivalent angle of draw of 74^{o} to 80^{o}).

No damage or impacts are expected to the Gulgong to Sandy Hollow railway, which is located some 250 to 500 m south of the study area.

12.19 Moolarben Mine Site and Other Infrastructure

No damage or impacts are expected to the proposed mine site infrastructure, including the water treatment ponds and entry drifts. Likewise, the proposed 330 kV Transgrid easement and the Ulan-Wollar road, to the south of the study area, are too far from the underground workings to be affected by mine subsidence-related movements.

12.20 Property Fences and Livestock

The impact of mining on the grazing of livestock would primarily require the management and repair of surface cracking and fences. Ponding is not expected to affect grazing or pasture areas.

12.21 Memorial Garden and Grave Site

Based on a cover depth of 140 m, the memorial garden and grave site are located well outside the angle of draw to the proposed starting position of LW12. No impact to the site is expected.

13.0 SUGGESTED SURFACE AND SUB-SURFACE MONITORING PROGRAM

13.1 Surface Monitoring Program

Based on the surface topography, aboriginal heritage sites and surface infrastructure present above the proposed longwalls, the following subsidence and strain monitoring program is suggested. This will facilitate review of the predictions and provide adequate information to monitor and implement appropriate subsidence impact management plans in the study area:

- Install a cross line, that can be extended as required, across both the northern and southern area longwalls, to monitor transverse panel subsidence (levels) and strain (using standard steel tape).

- Install centre lines at the start and end points of LWs 1 and 12 to 14, to monitor subsidence, far-field displacements and strain development from the ends of the panels and out as far as 250 m, to provide "early warning" data for impacts to the Drip. Establish reflectors on the crest of the northern cliff face of The Drip, for confirmation of predicted movements.

- Visual inspection and surveying of surface cracking (width and depth), any cliff line instability and significant erosion during longwall extraction. Repair works to cracks should be completed at the earliest practicable stage, to prevent injury or vehicle damage.

- 3-D (i.e. total station level and horizontal displacement) monitoring of Cliff Line CL3 using reflectors down the cliff face, to check stability during the extraction of LWs13 and 14.

- Survey base line data for all buildings and dams for follow up surveys if required to confirm subsequent subsidence and strains where necessary.

- Low frequency subsidence monitoring of the Ulan-Cassilis Road by running survey corner lines out from the NW corners of LWs 8, 10 and 11. Visual inspections of the road cuttings and pavement, with reviews after the completion of each longwall panel.

- 2-D and/or 3-D monitoring of subsidence and strain between pairs of survey pegs adjacent to the significant aboriginal archaeological sites. Pegs should be installed parallel to and normal to the cliff faces, or aligned with the longwall blocks and 10 m apart.

Survey pegs should be spaced approximately spaced 10 m apart along the cross line and over the longwall panel ends, and a maximum of 20 m apart along centre line sections located outside of end-affected areas.

13.2 Surface Survey Accuracy

Subsidence and strains may be determined using total station techniques to determine 3-D coordinates, provided that the accuracy is suitable. Survey accuracy using EDM and traverse techniques from a terrestrial base line is normally expected to be +/- 2mm for level and +/- 7 mm for horizontal displacement (i.e. a strain measurement accuracy of +/- 0.7 mm/m over a 10 m bay-length).

Strain measurement using the steel tape method generally improves accuracy to +/- 3mm (or 0.3 mm/m strain over 10 m) and would be the preferred method for measuring strain impacts on structures (i.e. dams, buildings and archaeological sites).

13.3 Sub-Surface Monitoring Program

It is expected that the mine will be required by the DPI and DoP to measure the maximum height of continuous and discontinuous fracturing above the sections of LW 1 directly below the alluvium, where the depth ranges between 80 and 100 m. The data will enable a comparison/validation of measured values with the conceptual model of expected surface and groundwater impacts, as well as empirical model predictions presented in this report. The monitoring program suggested consists of:

(i) Installation of a multi-wire borehole extensometer above the centre of LW 1, at Chainage between 260 and 500 m from the proposed finishing point of the panel.

The borehole should be fully cored (preferably HQ wire line) from the surface and terminated 10 m above the mine roof horizon. The core should be geotechnically logged, including fracture logging. (Double packer testing could be conducted at 10 m intervals to measure rock mass permeability, with Lugeon or constant head/injection tests and a down-the-hole vibrating wire piezometer tool to measure ground water levels. However, the base-line permeabilty and groundwater level data provided by the hydro-geologist consultant may be adequate at this stage.

A minimum of 5 spring-loaded anchors set at 10, 30, 50, 70 and 90 m above the seam and with an allowance for vertical displacements of up to 5 m are recommended. Readings would be taken using a real time data-logger.

Reaming the borehole out to 125 mm or 150 mm diameter, prior to the installation of the extensometer may reduce the risk of losing the hole through shear movements. It is estimated that the hole may shear, if dynamic longitudinal tilts exceed 20 to 30 mm/m. The empirical model predicts static longitudinal tilts of 25 mm/m +/- 12.5 mm/m which suggests dynamic tilts of 12.5mm/m +/- 7.5mm/m based on an assumed ratio of dynamic/static tilts of 0.5). Reaming the borehole out to 150 mm therefore appears prudent. The possibility of borehole shearing during LW retreat is still significant, although more data would be obtained prior to failure. A second borehole would be required after LW1 is extracted, if the first hole is lost pre-maturely.

(ii) Changes to the hydro-geological environment due to mining will be initially assessed using measured strata movements, changes to surface and groundwater levels and in-seam water makes / pump discharge (volume) records.

(iii) In the event that the results from the borehole extensometer are inconclusive, or the extensometer is sheared before full subsidence development occurs, a further borehole may be drilled to measure partial and complete drilling fluid loss locations in the overburden. This would provide a direct measure of the A and B Zone horizons. This potential second borehole should be drilled closer to the rib, in the tensile strain zone, to ensure intersection with overlying fracture sets (drilling near the centre of the LW, in the compression zone, may prove inconclusive as fractures may close after subsidence has fully developed).

Fully coring the second borehole would also allow a comparison of fracture logs before and after mining. Repeating the packer testing could also be useful, although sealing of the packer may be difficult in fractured zones.

It is considered that the proposed sub-surface drilling and testing program will probably only be required for the first LW block, should measurements confirm the predicted values. Other management tools, such as groundwater monitoring wells and underground pumping records, would then be regarded as sufficient for assessing the impacts of subsequent longwalls.

13.4 Subsidence Development Rates

Subsidence development at a given point above a longwall is generally dependent on the relative distance from the retreating longwall face. The rate of subsidence development is also influenced by the mining geometry, as is shown in the measurements for the Newcastle Coalfield in **Figure 13.2**.

Development rates are normally greatest when the longwall face has retreated between 0.2 and 0.8 times the cover depth past a given point. The maximum rate of subsidence development is expected to range between 200 and 300 mm per day for Moolarben and will probably reach 95 to 97% of final subsidence after the face has retreated a distance equivalent to 1.2 to 1.5 times the cover depth past the point.

Small subsidence increases due to goaf consolidation are likely to be ongoing for 6 to 12 months after extraction of a longwall block, or until further subsidence occurs when subsequent longwalls retreat past the site. Further increases will also occur due to compression of the chain pillars and adjacent strata between extracted longwalls.

The subsidence increases above a given panel generally decrease exponentially after successive each longwall is extracted and will probably not be measureable after 4 or 5 panels are extracted, see **Figure 13.3**. These incremental movements are included in the subsidence predictions presented in **Section 7**.

14.0 CONCLUSIONS

A preliminary mine subsidence prediction and impact assessment has been completed for the proposed LWs 1 to 14 in the Ulan Seam at the proposed Moolarben Coal Mine. Appropriate impact mitigation and management strategies have also been assessed to provide guidance for the preparation of Subsidence Management Plans at a later stage of the project.

The report has assessed the surface and sub-surface conditions, including the influence of massive sandstone units within the overburden on the predicted subsidence.

The surface within the study area is largely undeveloped bush land with several intermittent watercourses and 5 to 30 m high sheer to rounded cliff faces. Surface development consists of several access tracks, fire trails, small stock watering dams and residential dwellings.

The Goulburn River National Park and The Drip are located outside a 26.5^{o} angle of draw from the proposed longwalls. The Gulgong to Sandy Hollow Railway, existing Ulan groundwater bore field, Dronvisa's gravel and clay quarry, Ulan-Cassilis Road, cuttings and bridge are also located outside the angle of draw limits of the proposed longwall blocks.

Fourteen significant aboriginal archaeological sites have been identified within the study area by a heritage consultant. The impact of the proposed longwalls is assessed to range from 'low' to 'very low' for eight sites, with 'moderate' to 'high' impact (due to cracking) expected for five sites.

The Drip is considered an environmentally significant site with high tourism value and will be required to have on-going public access. The Drip is located outside the angle of draw limits to the proposed longwalls and is not expected to be impacted by the proposed mining layout. Further studies of far-field horizontal displacement through surface movement monitoring outside the limits of longwalls (further to the south) will be required to determine whether the starting positions of longwalls 12 to 14 are likely to impact the cliff lines. Based on published data from the Southern Coalfields, it is considered very unlikely that cracking will occur outside a distance of 250 m from the ends of the longwall starting positions.

The credible worst-case magnitudes of surface movement at the above mentioned surface features due to the extraction of the proposed longwalls have been predicted with Strata Engineering's empirically based subsidence prediction model.

The study outcomes include the final surface deformation predictions within 95% Confidence Limits. Validation of the model using cross line and centre line data over Ulan Mine’s LWs A , B and 1 to 19 indicates good agreement between the predicted and measured values. The predictions of differential subsidence (i.e. tilt and strains) for the proposed Moolarben Panels are of the same order of magnitude as the measured Ulan data.

Based on the outcomes of the study, it is considered that subsidence for the Moolarben No. 4 UG longwalls is likely to be higher than the measured subsidence above the Ulan LWs 12 to 19, primarily due to the increased longwall face extraction height.

It is also apparent that the predicted subsidence values presented in this report are likely to be conservative, because the Ulan subsidence profile data plotted well below the Upper 95% Confidence Limits used in this study to assess the impacts on the features in the study area.

There is, however, greater uncertainty with the prediction of maximum tilts and strains above the Moolarben longwalls, due to skewed subsidence profile development around ridges, secondary curvatures, strain concentrations due to cracking and variation of near surface lithology characteristics.

Nevertheless, previous success with the model over the past three years in all of the NSW Coalfields has provided enough confidence to make predictions of subsidence, tilt and strain profiles with an allowance for discontinuous behaviour issues. Any further increase in tilt or strain due to the increases extraction height of the Moolarben longwalls (compared to the Ulan longwalls) are not likely to significantly change the overall impacts assessed in this report.

Based on reference to crossline subsidence and strain data from Ulan Mine's LWs 12 to 19, it is considered that the prediction outcomes for Moolarben are still likely to be conservative if a multiplying factor of 10 is applied to the curvatures to predict uniform strains for 'smooth' subsidence profiles. The development of cracking is expected to occur above all of the proposed longwalls and is likely to concentrate the uniform strains by up to a factor of two.

The specific findings of this study include:

(i) The cover depth over the study area ranges from 85 to 215 m.

(ii) Several massive sandstone units are present above the Ulan Seam. These range between 5 m and 75 m in thickness above the proposed longwalls and are located between 5 m and 125 m or so above the longwalls. The thicker units are associated with the plateau forming Triassic Wollar sandstone member, which overlies the generally thinner Permian sandstone units located within the Illawarra Coal measures.

(iii) The Subsidence Reduction Potential (SRP) of the sandstone units is assessed as ranging from Low to High for the proposed 260 m wide panels (total void width between the ribs), with maximum subsidence likely to range from 0.4 to 0.6 times the extraction height after mining is complete.

(iv) Predicted subsidence and associated parameters have been provided using statistical regression analysis techniques to derive Upper 95% Confidence Limits (credible worst-case) values in the context of the empirical data base from which they were derived. For sensitive features, such as The Drip, the Upper 99% Confidence Limits has been assessed, to predict maximum far-field displacements and their potential impact.

(v) Subsidence parameter values have been determined for each longwall when first extracted, with final predictions made after mining activities have been completed.

(vi) Credible worst-case (CWC) subsidence over the longwalls is predicted to range between 1.81 m and 2.44 m for cover depths of 215 m and 85 m.

(vii) The predicted CWC subsidence values above the proposed chain pillars between LWs 1 to 14 range between 0.19 m and 0.49 m after the pillars are subject to double abutment loading conditions.

(viii) Predicted final transverse and longitudinal tilts are estimated to range between 23 and 86 mm/m. These values compare well to the measured tilts above the Ulan longwalls, which ranged between 5 and 54 mm/m for similar mining geometries to the Moolarben panels.

(ix) Predicted maximum tensile and compressive uniform strains range between 8 and 35 mm/m, with concentrated strains of between 14 mm/m and 41 mm/m predicted.

The strains include the effects of cracking and near surface beam thickness. These values compare well to the measured strains above the Ulan longwalls (with a lower extraction height of 3.2 m) which ranged between 5 and 25 mm/m.

(x) Predicted final transverse and longitudinal curvatures are estimated to range between 0.78 and 3.49 km^{-1} (i.e. minimum curvature radii of 0.28 to 1.2 km).

(xi) The predicted range of surface crack widths range between 40 mm and 180 mm. These are likely to occur within the limits of extraction (i.e. goaf) after mining is completed. In particular, significant cracks are most likely to occur above areas where surface rock exposures with widely spaced, adversely orientated (or absent jointing), coincide with the peak strains (i.e. Terrain Units R1, R2 and R3).

(xii) Crack widths are expected to range between 40 mm and 90 mm above the deeper longwalls with cover depths > 130 m. Crack widths ranging between 90 mm and 180 mm are estimated above the shallower areas, where the cover depths are <130 m.

(xiii) The crack widths have been estimated by multiplying the mean uniform strains by a distance of 10 m (based on the typical bay-length and crack widths observed in the field for the corresponding strains) and assuming that a single crack will occur in the given bay-length. In reality, several smaller cracks may develop or existing joints open.

The cracks will probably be tapered and extend to depths ranging from 3 to 10 m and possibly deeper, where massive near surface strata units exist. Repairs to cracks will probably be needed in the areas of the site where people and livestock are active.

(xiv) Several geotechnically distinct terrain units exist above LWs 1 to 14 and consist of residual (R1 to R3) and alluvial (A1 to A2) soil profiles. Ground slopes typically range between 1^o and 20^o on crests, mid-slopes and gullies with several sandstone cliff lines with slopes ranging from 65^o to 85^o. Numerous exposures of Triassic Wollar Sandstone also exist on the ridges or plateaus on the site. Deeply incised erosion gullies exist in the low lying areas of the site with downstream alluvial or slope wash deposits up to 3 m deep.

(xv) It is assessed that the likelihood of general slope failure (i.e. landslip) due to subsidence will be highly unlikely in the terrain units presented.

(xvi) The cliffs on the site have been given 'very low' to 'low' impact ratings outside of the longwall extraction limits, with a 'moderate' to 'high' impact rating assessed for cliff lines above the longwalls. The overall impact of mine subsidence has been assessed based on the methodology provided in **ACARP, 2002**. The impact on the cliffs has been assessed based on (i) mining subsidence deformation, (ii) public exposure to instability and aesthetics and (iii) instability due to natural weathering conditions.

None of the cliffs directly above the proposed longwalls in the No.4 UG area can be viewed from Ulan - Cassilis Road, Ulan - Wollar Road or the public access vantage points to the north of the site (i.e. The Drip carpark). Appropriate barriers, fences and/or signage will be installed around the cliff lines to warn bushwalkers of subsidence hazards during mining.

Whilst it expected that localised cracking damage to the cliff lines above the longwalls will develop down the full height of the cliff faces, it is considered unlikely that large scale collapse will result. Preliminary two-dimensional numerical modelling (Phase 2®) and limit-state equilibrium analysis (Slide®) of the cliff faces indicates that the predicted tilts will not cause large scale toppling or sliding wedge failures, unless deep tensile cracking develops directly above existing overhangs. Based on a review of the expected tensile strain locations and the position of the cliffs, this scenario is considered very unlikely to not credible.

(xvii) A rock fall hazard along the cliff lines has been identified based on the impact assessment of mine subsidence deformation on the cliff faces. Further risk analysis and management work is suggested to provide appropriate controls to minimise exposure of the public and private property to rock falls that may be initiated or accelerated by mine subsidence damage.

(xviii) The impact of the proposed longwalls on the stability of the cliffs in the Goulburn River Gorge (known as "The Drip") will be negligible due to the following study outcomes:

- It is assessed that both sides of The Drip are located outside the angle of draw to the ends of the longwalls and are therefore unlikely to be subject to uplift and closure mechanisms caused by vertical or horizontal subsidence deformation. Predicted credible worst-case bending curvatures of < 0.0067 km^{-1} or 149 km radius have been assessed in the horizontal plane, with zero curvature estimated in the vertical plane.

- Based on predictions of potential bending strains of <0.3 mm/m due to far-field horizontal displacements, it is assessed to be a very unlikely scenario that cracking will develop in the southern cliff faces (and practically impossible in the northern cliffs, where the 'Drip' from groundwater seepages exist).

  The far-field horizontal displacements have been predicted using an empirical database of measured movements outside the ends of longwalls in the Newcastle Coalfields, with similar geometry as the Moolarben panels. Preliminary two-dimensional numerical modelling (Phase 2®) of full horizontal stress relief effects indicates a similar pattern of behaviour as seen in the measured movement database.

  Further field monitoring studies of the far-field displacement and pre-mining horizontal stress will be required for the earlier longwalls to validate the models used.

(xix) The Ulan groundwater bore-field infrastructure is located approximately 300 m west of the proposed finishing locations of LWs 6 and 7. It is expected that the groundwater bores could be subjected to differential horizontal shear movement ranging from 0 to 9 mm towards the east. Upper 95% and 99% Confidence Limits (i.e. the 5% and 1% Probability of Exceedence (PoE)) values of 16 and 20 mm respectively has also been assessed based on non-linear regression analysis techniques.

(xx) The boundary of the Goulburn River National Park is located outside the angle of draw for the proposed longwall panels. Estimates of expected and credible worst-case (based on the Upper 99% Confidence Limit) horizontal displacements towards the west range between 10 and 100 mm.

(xxi) In general, the surface drainage patterns are likely to function with minimal changes after subsidence trough development. Some localised deviation of surface flows along ephemeral creek beds into sub-surface routes is expected above the longwall panels, due to uplift or buckling movements and compressive strain failures of the near surface rocks.

Some low lying areas in the northern area of the site near the horse training area however, could become poorly drained or boggy after the extraction of LWs 12 to 13. In this case, the pattern of drainage may need to be augmented to restore it to pre-mining conditions through surface and sub-surface drainage works.

(xxii) A small zone of ponding of up to 1 m depth could occur along a gully in the northern half of the site above LW10. The actual ponding depth will depend upon several other factors such as rain duration, surface cracking and effective percolation rates of the surface soils and fractured rock outcrops.

(xxiii) Five of the 14 significant aboriginal heritage sites are assessed to have a 'moderate' to 'high' likelihood of being damaged by mine subsidence movements. The five sites consist of an artefact site, an axe grinding groove site and three rock shelters that are likely to be subject to tensile strains > 0.5 mm/m or compressive strain > 3 mm/m and cracking 5 to 40 mm wide due to subsidence. The rest of the sites are located outside the limits of extraction and are assessed to have a 'low' to 'very low' likelihood of being damaged by mine subsidence.

(xxiv) It is predicted that continuous fracturing or direct hydraulic connection will occur to all of the coal seams above the proposed workings, but will not extend into the Wollar Sandstone member.

A sub-surface monitoring program to assess the heights of fracturing developed above LW 1 will be required prior to the longwall reaching its finishing point, or where cover depths are < 100 m. The data will also be used to validate the predicted heights of fracturing to assess the impact of subsidence on the sub-surface aquifers and deep alluvium at the surface.

Any cracking at the surface should be sealed off to limit the ingress of surface water and air (i.e. oxygen) into the goaf, to minimise the potential for a self-heating event.

(xxv) The Ulan Mines groundwater bore-field, dams and surface infrastructure are located outside the angle of draw of LW6 and 7. No damage is expected to occur to the surface works, however far-field horizontal displacements of between 0 and 20 mm may occur along the groundwater bore.

(xxvi) The memorial garden and grave site are located well outside the angle of draw to the proposed starting position of LW12. No impact to the site is expected.

(xxvii) The location of the old farmhouse is unknown, but this will probably be damaged, if located above a longwall panel.

(xxviii) Three of the stock watering dams (D4, D6 and D12) are expected to be subject to tensile cracking of 20 to 40 mm width due to uniform tensile strains of 2 to 4 mm/m. This may result in subsequent loss off storage with repair works required to seal the cracks. The dams are also expected to be subject to temporary longitudinal deformations of similar magnitude to the transverse movements.

(xxix) Dams (D11 and D13) may also be impacted to a similar degree by tensile strains associated with the transient longitudial deformations. The remaining dams are unlikely to be damaged, with negligible tilt and strain predicted after longwall extraction.

(xxx) The Dronvisa Quarry is currently located outside the angle of draw to LWs 4 and 5 and is considered unlikely to be impacted significantly by longwall extraction to the east.

Further consultation with the quarry owners (and subsidence impact assessment) will be required, however, before the quarry is extended further to the east and over the proposed longwalls.

(xxxi) The Ulan-Cassilis Road, associated cuttings and bridge over the Goulburn River, are located outside the angle of draw to LWs 1 to 12 and not expected to be impacted by mine subsidence. The bridge and Cutting No 3 are however located between 200 and 250 m from the NW corners of LWs 8 and 12 respectively and could be subject to far-field CWC horizontal displacements ranging between 42 mm and 57 mm. Cutting No.s 1 and 2 are 350 m and 600 m west of LWs 1 and 8 respectively and are not expected to be affected by far-field horizontal displacements of more than 9 mm and 4 mm respectively.

Consultation with the Mid-Western Regional Council and RTA bridge engineers will be required to develop appropriate monitoring and trigger action response plans to manage anomalous behaviour outside the angle of draw, if it occurs.

(xxxii) Subsidence and strain monitoring along several cross lines and ends of panel centre lines (i.e. panel start and finish locations) is suggested for subsidence parameter prediction and SMP review purposes.

The details of monitoring programs around the surface features mentioned should be assessed based on the prediction provided in this report and mutually agreeable SMP's developed between individual stakeholders and DPI.

Overall, it is considered that each of the long-term impacts due to the proposed Moolarben longwalls can be addressed with the proposed mitigation and management strategies presented.

15.0 REFERENCES

ACARP (1993). **Improved Methods of Subsidence Engineering**. Project No. C1311. Willey, P., Hornby, P., Ditton, S. and Puckett, G. (ACIRL) and McNally, G. (Department of Applied Geology, UNSW).

ACARP (1998). **Establishing the Strength of Rectangular and Irregular Pillars**. Project No. C5024. Galvin, J.M., Hebblewhite, B.K., Salamon, M.D.G., Lin, B.B.

ACARP (2002). **Subsidence Impacts on River Valleys, Cliffs, Gorges and River Systems**. Project No. C9067,Waddington Kay & Associates, Report WKA110.

ACARP (2003). **Review of Industry Subsidence Data in Relation to the Impact of Significant Variations in Overburden Lithology and Initial Assessment of Sub-Surface Fracturing on Groundwater**. Project No. C10023. Ditton, S. and Frith, R. Strata Engineering Report No. 00-181-ACR/1 (September).

Aitchison and Grant (1967). **The PUCE Programme of Terrain Description**. In 4th Regional Conference on Soil Mechanics and Foundation Engineering, Cape Town, South Africa.

Appleyard, L.D. (2001). **A Review of the Formulation and Implementation of Graduated Design Guidelines for Residential Construction in Mine Subsidence Areas of NSW**. Published in Mine Subsidence Technical Society (MSTS) 5th Triennial Conference Proceedings, Coal Mine Subsidence 2001 - Current Practice and Issues (August).

ARRAS (2006). Moolarben **Coal Project Aboriginal Cultural Heritage Assessment Report**. Archaelogical Risk Assessment Services Report, March.

ARRB Special Report No. 41(1992). **Pavement Design Guidelines**, Australian Road and Research Board.

AS2870 (1996). **Australian Standard for the Design of Residential Slabs and Footings**.

AGS (2000). **Landslide Risk Management Guidelines**. Australian Geomechanics Society Journal No. 35 No. 1 (March).

Burland, J.B. and Wroth, C.P. (1974). **Settlement of Buildings and Associated Damage**. Conference on Settlement of Structures, British Geotechnical Society.

Brady, B.H.G and Brown, E.T. (1985). **Rock Mechanics for Underground Mining**. 2nd Edition, Chapman & Hall, London.

Das, B.M. (1998). **Principles of Geotechnical Engineering** (4th Edition), PWS Publishing Company Inc.

DEC (Date unknown) **Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation**. NSW Department of Environment and Conservation.

DIPNR (2005). **Management of Stream/Aquifer Systems in Coal Mining Developments - Hunter Region - Version 1** (April). NSW Department of Infrastructure Planning and Natural Resources.

DMR (2003). **New Approval Process For Management of Coal Mining Subsidence**. NSW Department of Minerals Resources.

DMR (1998). **The Western Coalfield (Northern Part)**. Geological Sheet Series.NSW Department of Minerals Resources

Fell, R., MacGregor, P., Stapledon, D. (1992). **Geotechnical Engineering of Embankment Dams**. A.A. Balkema.
Harrison, S.R. and Tamaschke, H.U. (1984). **Applied Statistical Analysis**. Prentice-Hall of Australia.

Hebblewhite, B.K. (2001). **Regional Horizontal Movements Associated with Longwall Mining**. Mine Subsidence Technological Society 4th Triennial Conference Proceedings. Newcastle, July 1998.

Holla, L. (1987). **Mining Subsidence in the NSW, 2. Surface Subsidence Prediction in the Newcastle Coalfield**. NSW Department of Minerals and Resources, Sydney.

Holla, L. (1991). **Mining Subsidence in the NSW, 3. Surface Subsidence Prediction in the Western Coalfield, NSW**. NSW Department of Minerals and Energy (January).

Holla, L. and Barclay, E. (2000). **Mine Subsidence in the Southern Coalfield, NSW, Australia**. NSW Department of Minerals and Resources (June).

International Society for Rock Mechanics (1981), **Basic Geotechnical Description of Rock Masses**. Commission on Classification of Rocks and Rock Masses. ISRM Journal, Vol 18 pp 85 to 110.

Johnstone, M (2005). **The No. 4 Underground Area Report on Geological Investigations**. Internal White Mining Report (July).

Kay, D., Barbato, J., Brassington, G. and deSomer, B.(2006). **Impacts of Longwall Mining to Rivers and Cliffs in the Southern Coalfield**. 7th Underground Coal Operators' Conference, University of Wollongong, 5 - 7 July.

Reid, P. (1998). **Horizontal Movements around Cataract Dam, Southern Coalfields**. Mine Subsidence Technological Society 4th Triennial Conference Proceedings. Newcastle, July 1998.

Seedsman, W. W. and Watson, G. (2001). **Sensitive Infrastructure and Horizontal Ground Movement at Newstan Colliery**. Mine Subsidence Technological Society 5th Triennial Conference Proceedings, Maitland, August 2001.

Shepherd, J. and Sefton, C.E. (2001). **Subsidence Impacts on Sandstone Cliff Rock Shelters in the Southern Coalfield, NSW**. Mine Subsidence Technological Society 5th Triennial Conference Proceedings, Maitland, August 2001.

SCT (2004). **Subsidence Monitoring for Longwalls 11-20 at Ulan Coal Mine**. Strata Control Technology Report No. ULA2806 (August).

SCT (2005). **Subsidence Assessment for Longwalls 23-26 and Longwall W1 at Ulan Coal Mine**. Strata Control Technology Report No. ULA2824 (August).

Strata Engineering (2004). **Review of LW29 Subsidence Monitoring Data and Subsidence Predictions of F3 Fill Embankment due to LW30**. Report No. 03-005-WWD/4 (August).

Strata Engineering (2005). **Pre-Feasibility Geotechnical Study of the Proposed Moolarben Underground Mine**. Report No. 03-001-MIN/1 (August).

UNSW (2004). **Mine Slope Stability Short Course Notes - UNSW Mining Research Centre**. University of NSW School of Mining, September.

Vick, S.G. (2002). **Degrees of Belief: Subjective Probability and Engineering Judgement**. ASCE Press.

APPENDIX A

Strata Engineering's Empirical Geological Subsidence Prediction Model Summary - GEOSUB

A1 INTRODUCTION

Strata Engineering has developed an empirical subsidence prediction model for the Newcastle Coalfield. The model enables the influence of massive strata units such as conglomerate and sandstone channels to be included in the prediction of subsidence over single and multiple longwall panels. It has been recognised for some time that the presence of massive strata units above longwall panels has resulted in reduced subsidence compared to that measured over longwall panels with similar geometry and thinner strata units.

A database of maximum single and multi longwall panel subsidence and associated massive strata units has been compiled for the Newcastle Coalfield. The database draws on subsidence data from over fifty longwall panels and covers a panel width to cover depth (W/H) ratio from 0.2 to 2.0 (cover depth ranges between 70m and 351m) as shown in **Figure A1**.

The project database has included single seam mining data from eleven collieries in the Lake Macquarie area of the Newcastle Coalfield as presented in **Table A1**.

Table A1 - Empirical Database Sources

Colliery	Colliery
Cooranbong	New Wallsend No. 2 (Gretley)
Moonee	Stockton Borehole
Newstan	Lambton
Teralba	Burwood
West Wallsend	John Darling
Wyee	

The wide range of W/H in the database for single extraction panels is unique compared to the other Australian coalfields and has therefore been the focus of the study. Pillar extraction or multiple panel data has not been used for producing the subsidence prediction curves, as it invariably makes the assessment of geological influences difficult, if not impossible.

Apart from the above stated issues, current empirical design curves are also now out of date and unable to adequately predict subsidence for cover depths > 250 m in the Newcastle Coalfield. It has also been realised that it is necessary to divide the database into various cover depth categories before the influence of geology can be reliably assessed as shown in **Figure A1** and **A2**. The main reason for this approach is that the minimum thickness of the strata units required to span or bridge across an extracted longwall panel is a function of the cover depth (i.e. the load acing on the beam) and the width of the panel (the span of the beam).

Details of the database and prediction methodology are presented in the following sections.

A2 MODEL DEVELOPMENT

The first stage of the development of the subsidence prediction model addressed the influence of significant overburden lithology over single longwall/miniwall panels only. **Figure A3** illustrates a physical model showing the subsidence reducing effects of a massive strata unit. The subsidence prediction model has been developed with the goal of providing the industry with a robust and reliable technique to utilise the vast amount of geological and testing information already gathered by mining companies. It was considered that once the prediction of S_{max} could be made with a confidence level of 90 to 95%, other parameters such as tilt, curvature, horizontal strain and the angle of draw could then be derived from the S_{max} and associated key geometrical parameters with improved, if not similar, confidence levels. The impact of multi-panel subsidence effects and the role of the chain pillars on final subsidence have also been subsequently addressed.

The development of the new empirical prediction methodology has used borehole data to derive the thickness and location of massive strata units that have been considered to be critically important for surface subsidence prediction for a given panel width and depth. The methodology takes into account the maximum massive strata unit thickness (t) at each location and the height to the base of the unit above the longwall panel (y).

It has been found that the subsidence above a panel of a given cover depth (H) and a panel width (W) decreases significantly when a massive strata unit is thicker than a certain threshold value. The threshold thickness is also reduced when the unit is located closer to the surface. In this case, the strata unit is considered to have a 'high' subsidence reduction potential (SRP) as shown in **Figure A4**.

Obviously, for a thin strata unit located relatively close to a panel, the subsidence reduction potential will be 'low'. However, there also appears to be an intermediate zone where a single strata unit (or several thinner units) below the 'high' subsidence reduction threshold thickness can result in a 'moderate' reduction in subsidence. A second threshold line can therefore be drawn which represents the threshold between 'moderate' and 'low' subsidence reduction potential as shown in **Figure A4**. Similar threshold lines have been determined for strata units located at various heights (y) above the workings as shown in **Figure A4**.

Based on the above analysis, the subsidence reduction potential for a strata unit can now be defined as being 'high', 'moderate' or 'low'.

Overall, the massive unit thickness, panel width, depth of cover and height of unit above the workings are considered to be key parameters for assessing the overburden stiffness and spanning capability over a given panel width which control surface subsidence. A concept model for overburden behaviour is illustrated in **Figure A5**.

A3 MODEL OUTCOMES

The major finding of the project is that the historically used relationship between subsidence and panel width to cover depth ratio (W/H) is not a constant for the range of cover depths (H) involved. Surface subsidence increases with increasing cover depth (H) for the same W/H ratio, and is primarily a function of the increasing panel width (W). For constant single panel width (W), subsidence will decrease with increasing cover depth (H).

Therefore it has been necessary to separate the data into various depth ranges. Three depth categories of H = 100, 200 and 300 m have been identified which divide the database up into H = 70m to 150m, 151m to 250m and 251m to 351m.

The influence of overburden lithology was found to be readily apparent once the database was filtered using the above cover depth ranges.

Other outcomes of this new methodology are the introduction of several new parameters to improve the definition of various types of overburden behaviour and the associated mechanics.

The 'Subsidence Reduction Potential' (SRP) of massive or thickly bedded geological units above single longwall panels for the Newcastle Coalfield has been introduced to describe the influence that a geological unit may have on subsidence magnitudes. The massive geological units are defined in terms of 'high', 'moderate' or 'low' SRP.

Variation in subsidence along the length of a panel may be due, partial, to the SRP variation of geological units within the overburden.

The database for the Newcastle Coalfield also indicates the presence of a 'Geometrical Transition Zone' whereby subsidence increases significantly regardless of the SRP of the geological units as shown in **Figure A6**. This behaviour occurs when panel width to cover height ratio (W/H) is in the range from 0.6 to 0.8. This phenomenon can be simply explained as a point of significant shift in structural behaviour of the overburden.

This model allows the user to determine a range of subsidence magnitudes that may be expected and the location of geology related SRP and/or 'geometrical transition zones' along a panel. The identification of the transition zones is an important factor when assessing potential damage risks of differential subsidence to important infrastructure, buildings and natural surface features such as rivers, lakes and cliff lines etc.

For W/H ratios <0.7, the overburden appears to behave as a 'deep' beam or linear arch whereby the mechanics of load transfer to the abutments is predominantly by axial compression along an approximately parabolic shaped line of thrust. This is depicted by the load vectors as shown in **Figure A7(a)**.

For W/H ratios >0.7 the geometry of the overburden will no longer allow axially compressive structural behaviour to dominate, as the natural line of thrust now lies outside of the overburden and bending action due to subsequent block rotation occurs as depicted in **Figure A7(b)**.

Provided that the abutments are able to resist this rotation, flatter lines of thrust will still develop within the overburden units, but the structural action is now dominated by bending action. This type of overburden behaviour has been defined as 'shallow' beam behaviour in the context of this project. ‘Shallow’ beam behaviour in structural terms is fundamentally less stiff than ‘deep’ beam behaviour, resulting in a significant increase in subsidence or sag across an extracted longwall panel (all other factors being equal) as shown **Figure A7(b)**.

“Voussoir beam” or “fractured linear arch” theory can be used to explain both types of overburden behaviour, as deep seated and flatter arches develop in the strata in an attempt to balance the disturbing forces in a jointed sedimentary rock mass with essentially zero-tensile strength.

The ‘strata unit location factor’ (y/H) has been developed to assess the behaviour of massive strata units above the workings. The y/H factor is a simple way to include the influence of the unit location above the workings in terms of the effective span of the unit and the horizontal stress acting upon it.

The key elements of this factor and their influence on the behaviour of the strata unit are:

- y, the height of the beam above the workings, which determines the effective span of the beam, and
- H, cover depth over the workings, which exerts a strong influence on the horizontal stress environment and, hence, the propensity for buckling or compressive failure of the beam.

Essentially beam failure due to the action of increasing horizontal stress (i.e. material crushing or buckling) appears more likely as y decreases and H increases. The ratio of y/H may therefore be used to differentiate between the SRP of a beam of similar thickness but at varying heights above the workings. The model also demonstrates that as the depth of cover increases, a thicker beam is required for the same SRP above a given panel width as shown in **Figure A8**.

Subsequent stages of the project expanded the single panel model to predict:

- panel goaf edge or rib subsidence
- angle of draw
- maximum final subsidence after multi-panel effects, which includes subsidence over chain pillars
- maximum transverse and longitudinal tilt, curvature strain
- the locations of the above parameters over the longwall panel for the purposes of subsidence profile development, and
- heights of continuous and discontinuous fracturing above the longwall based on measured surface tensile strains and fracture limit horizons over extracted panels.

All of the above subsidence parameters have been statistically linked to key geometrical parameters such as the cover depth (H), panel width (W), working height (T) and chain pillar width (w_{cp}).

After the completion of the project the majority of the above project outcomes have been successfully incorporated into a spreadsheet-based subsidence analysis tool.

The conceptual models of overburden behaviour have been developed and tested such that it is now possible to address subsidence behaviour in other coalfields including the prediction of multiple seam mining effects by pseudo-superposition techniques as shown in **Figures A9** to **A11**.

To date, the model has been used to make successful subsidence profile predictions for Mandalong, Newstan and West Wallsend collieries, an example is provided in **Figure A12**. The model has also made credible 'blind' predictions of subsidence for Springvale Colliery in the Western Coalfield based on the geometry and geology information provided by the mine.

The key input parameters required to make subsidence predictions using the model include the following:

- Panel Width (W)
- Cover Depth (H)
- Seam Working Height (T)
- Overburden lithology, specifically the thickness and location of massive strata units (t, y)
- Chain Pillar Width (w_{cp})
- Number of panels extracted

The statistical inferences and estimates of the model uncertainty of the prediction methodology are presented in **Sections A4** to **A6** with examples of the prediction method presented in **Section A7**.

A4 Subsidence Impact Parameter Predictions above Longwall Panels

The database allows an assessment of variance and standard error such that the required subsidence parameter's mean and upper 95% confidence limit (credible worst case) values can be determined for a given mining geometry and geology.

Predicted 'smooth' subsidence profiles have been determined based on cubic spline curve interpolation through a number of key points along the subsidence trough (i.e. maximum in-panel subsidence, inflexion point, goaf edge or rib-side subsidence, subsidence over chain pillars and 20 mm subsidence or angle of draw limit) that have been empirically derived from regression relationships between the variables and the geometry of the panels. Both transverse and longitudinal profiles have been derived in this manner.

The first and second derivatives of the fitted spline curves provide the 'smooth' or continuous subsidence profiles and values for tilt and curvature. Horizontal displacement and strain profiles were derived by multiplying the tilt and curvature profiles by an empirically derived constant associated with the bending surface beam thickness (and based on the linear regression relationship between the variables as discussed in **ACARP, 2003**).

An allowance for the possible horizontal shift in the location of the inflexion point (within the 95% confidence limits of the database) has also been considered for the predictions of subsidence at surface features that are located over the goaf or extracted area.

Subsidence contours have been created based on the empirically derived subsidence profiles along cross lines, centre lines and corner lines around the ends of the longwall panels. The contours were derived using geostatistical kriging techniques and the data processing software Surfer 8®. Vertical 'slices' were then taken through the contours where required to (i) determine the final CWC subsidence profiles, and (ii) assess the likely impacts on the relevant surface features.

A5 Prediction of Subsidence Impact Parameters Using Regression Analysis Techniques

The prediction of key impact parameters inside or outside the limits of extraction have been estimated using normalised longwall subsidence data from the Newcastle Coalfield. This approach allows a reasonable assessment of the uncertainty of the predictions to be considered using statistical regression techniques. A linear or non-linear regression line has been fitted to the database for each impact parameter, which has been normalised to easily measured parameters such as maximum subsidence, panel width and cover depth. The quality or significance of the regression line is significantly influenced by the following parameters:

(i) the size of the database,

(ii) the presence of outliers, and

(iii) the physical relationship between the key parameters.

The regression curves have been reviewed carefully because they can be (i) affected by outliers, and (ii) misleading in that by adopting a mathematical relationship which gives the best fit (i.e. R^2) the curves are strongly biased by the database and may not reflect the true physical dependencies or mechanisms that the data represents.

These issues are inherent in all prediction modelling techniques because, for example, all models must be calibrated to field observations to validate their use for prediction or back analysis purposes. SEA has developed the regression techniques presented in the **ACARP, 2003** report by firstly assessing conceptual models of the mechanics and key parameter dependencies (based on established solid mechanics and structural analysis theories) before generating the regression equations.

Several outliers in the model databases were excluded in the final regression equations, and were removed only when a reasonable explanation could be given for each anomaly (i.e. multiple seam subsidence, geological faults and surface cracking effects).

The regression equations developed by SEA in the **ACARP, 2003** study have R^2 (i.e. Coefficients of Determination) values that are mostly greater than 50%; which indicates that the relationships between the variables are significant.

A6 Prediction Model Uncertainty

Provided there are (i) more than 10 data points in the data sets which cover the range of the prediction cases, and (ii) the impact parameter and independent variables have an established physical relationship based on solid or structural mechanics theories, then it is considered unlikely that the regression lines will be significantly biased away from the underlying physical relationship between the variables by the data set.

On-going review of each of the regression equations used in this report over the past three years have not required significant adjustment of the equations in order to include new measured data points.

A7 WORKED EXAMPLE OF MAXIMUM SUBSIDENCE FOR A SINGLE PANEL

An example is presented below to demonstrate how to use of the model to predict the maximum subsidence for a single longwall panel. The overburden is first characterised by contouring the key input parameters over the proposed mining area and selecting the average values for a given panel.

Input Parameters:

The average mining geometry for this case is assumed to be:

Panel Width, W = 200 m,

Cover Depth, H = 200 m,

Working Height, T = 4 m,

Surface ground slopes < 20 °.

Geology:

A review of several borehole logs above the panel from the surface to below the seam floor indicates that a massive sandstone channel ranging in thickness between 30 and 35 m exists over half of the area of the panel. The base of the unit is situated at about 160 m depth. The remaining strata in the overburden generally consists of a typical inter-bedded coal measures sequence of shale, sandstone, siltstone and coal with strata unit thicknesses ranging between 0.1 and 5 m.

A7.1 Analysis of Subsidence Reduction Potential

The first step of the analysis is to assess the geometry of the panel and select the appropriate cover depth range.

For a cover depth of 200 m, the appropriate subsidence prediction and SRP curves for cover depths between 150 and 250 m are presented in **Figures A13** and **A14**.

Based on these two figures, the Subsidence Reduction Potential (SRP) of the overburden lithology above the panel may be considered for two areas as follows:

Area 1 – Affected by Massive Strata:

Maximum Unit Thickness, t = 30 m,

Height above Workings, y = 40 m,

Panel Width, W = 200 m,

Cover Depth, H = 200 m,

Massive Unit Location Factor, y/H = 40/200 = 0.2.

As shown in **Figure A13**, for a unit location factor of 0.2, the massive unit has a 'Moderate' to 'High' SRP.

Note : The SRP lines are used to determine the range of subsidence reduction that has been observed over longwall panels. It is therefore possible that a particular unit impact will range between moderate to high or moderate to low. For cases that plot between the High and Moderate SRP threshold limits, the closest SRP line will be selected by the model to infer the most likely SRP range. For cases which plot above the High SRP line, the SRP range is assumed to be High only, but a range of S_{max} will still be defined by the subsidence prediction boundary limit lines shown in ***Figure A14****.*

Area 2 – Not Affected by Massive Strata:

Maximum Unit Thickness, t = 5 m

Height above Workings, y = 200 m

Note: it is considered that where there is no obvious massive strata unit with a thickness greater than say 5m, it is appropriate to adopt a value of y = H or y/H =1 for the SRP analysis.

Panel Width, W = 200 m

Cover Depth, H = 200 m

Massive Unit Location Factor, y/H = 200/200 = 1

Note: in the case where a specific y/H line is not shown on the SRP charts it is intended that the next lowest y/H line be adopted when assessing the SRP of a geological unit (i.e. for a y/H of 1.0, the y/H = 0.5 line should be used on ***Figure A13****).*

Several massive units that exist in the overburden may also be assessed using the same methodology.

In this case, the strata unit plots below the 'Moderate' SRP line on **Figure A13** and is assessed to have a Low to Moderate SRP.

A7.2 Analysis of Maximum Subsidence for a Single Panel

The maximum subsidence range above the Area 1 and Area 2 may now be assessed as follows:

Area 1 – Affected by Massive Unit:

By reference to the 'Moderate' to 'High' SRP subsidence prediction curves shown in **Figure A14**, for a W/H = 1 and an extraction height T = 4 m:

High SRP Limit S_{max} /T = 0.342 so that S_{max} = 0.342 x 4.0 = 1.37 m, and

Moderate SRP Limit S_{max} /T = 0.425 so that S_{max} = 0.425 x 4.0 = 1.70 m.

Therefore, the predicted single panel S_{max} = 1.37 to 1.70 m, or in average terms

Area 1 S_{max} = 1.54 m +/- 0.17m (the mean value with 95% Confidence Limits).

Area 2 – Not affected by Massive Unit:

By reference to the 'Low' to 'Moderate' SRP subsidence prediction curves shown on **Figure A14**, for a W/H = 1 and an extraction height H = 4 m:

Low SRP Limit S_{max} /T = 0.545 so that S_{max} = 0.545 x 4.0 = 2.18 m, and

Moderate SRP Limit S_{max} /T = 0.425 so that S_{max} = 0.425 x 4.0 = 1.70 m.

Therefore, the predicted single panel S_{max} = 1.70 to 2.18 m, or in average terms.

Area 2 S_{max} = 1.94m +/- 0.24 m (the mean value with 95% Confidence Limits).

A8 MULTI-PANEL SUBSIDENCE PREDICTION MODEL

The effect of extracting several longwall panels adjacent to one another is dependent on the stiffness of the overburden and the chain pillar(s) left between the panels. Invariably, 'extra' subsidence above a previously extracted panel, and is considered to be caused primarily by the compression of the chain pillars left between the extracted panels.

A chain pillar will undergo the majority of its life cycle compression after it has been subject to double abutment loading (i.e. the formation of goaf on either side after two adjacent panels have been extracted). Surface survey data indicates that an extracted panel can effect up to three or four gate road chain pillars that have been formed between previously extracted panels. The stiffness of the overburden and chain pillar system will determine the extent of load transfer to the preceding chain pillars.

Multiple-panel effects have therefore been included in the subsidence prediction model by adding empirical estimates of surface subsidence over chain pillars to the maximum subsidence predictions for single panels.

The empirical model presented in **ACARP, 2003** for estimating the subsidence above a chain pillar, has been based on the regression equation presented in **Figure A15**. The model compares the ratio of chain pillar subsidence (S_p) over the extraction height (T), to the width of the chain pillar divided by the cover depth multiplied by the total extracted width ($1000w_{cp}/W'H$).

A regression analysis on the data indicates a strong exponential relationship for $1000w_{cp}/W'H$ values up to 0.543. For values > 0.543, the relationship becomes constant.

$S_p/T = 7.4044e^{-10.329F}$ ($R^2 = 0.92$) for F< 0.543, and

$S_p/T = 0.023$ for F > 0.543

where

F = $1000w_{cp}/W'H$

W' = The total extracted width which includes the width of the panels extracted on both sides of the subject chain pillar, and the width of the chain pillar itself (i.e. $W' = W_i + w_{cp(i)} + W_{i+1}$). Note that this approach does not include a caving angle.

A reasonable, but generally conservative estimate of the final subsidence for a panel with several subsequent extracted panels of similar geometry, can then be determined by adding 50% of the predicted chain pillar subsidence (S_p) to the single panel S_{max} estimate.

However, the above chain pillar model has now been superseded as more data from other coalfields has shown that subsidence above chain pillars is strongly influenced by the Factor of Safety (FoS) of the pillars and the caving angle of the overburden above them. The maximum subsidence generally occurs when the pillars are subject to double abutment loading conditions (i.e. goaf on both sides).

In the new approach, the measured subsidence above chain pillars is considered to be strongly influenced by the following key parameters:

- The volume of the rock prism (i.e. the load) acting on the pillar and immediate roof and floor strata (W'D). *Note: this has been conservatively estimated for an assumed caving angle of 21 degrees.*

- The longwall face extraction height (T).

- The pillar width and development height (w and h).

The coal pillar and column of rock above and below the seam will behave either elastically or plastically (depending on their strength and stiffness properties) under double abutment loads.

The subsidence above the pillars is a function of the following combination of these key parameters:

S_p = f (T, W'H/w_{cp}, h/w_{cp}) or

S_p/T = f(W'Hh/w_{cp}^2) = the "Chain Pillar Subsidence Index" (CPSI)

where:

T = the extraction height (or sometimes the seam height) is applied instead of the pillar development height as this approximates to the column of coal that is subject to maximum pillar stresses.

W'H/w_{cp} = a pillar stress index

w_{cp}/h = a pillar strength index.

Prediction curves for the mean and U95%CL subsidence magnitudes above the chain pillars have been included in the updated model as shown in **Figure A16**.

Multiple panel subsidence predictions can then be made using the models presented to predict first and final subsidence above a given longwall panel.

The definition of first and final S_{max} is as follows:

First S_{max} = the total subsidence after the extraction of a longwall panel including the effects of previously extracted longwall panels adjacent to the subject panel.

Final S_{max} = the total subsidence over an extracted longwall panel after at least three more production panels have been extracted, or when mining is completed.

The prediction of the first and final S_{max} for a panel are predicted by adding 50% and 100% of the predicted subsidence over the respective chain pillars (i.e. between the previous and current panel) less the goaf edge subsidence and is further explained below.

A8.1 Methodology for Calculating First and Final Subsidence for Multiple Longwall Panels

For i = 1 to n longwalls with known panel width (W), cover depth (H), extraction height (T), massive unit thickness (t), massive unit height above extraction (y) and pillar width (w_{cp}), the mean first and final S_{max} and S_p values are determined as follows:

Step 1 - Calculation of pillar subsidence (First S_p), and final pillar subsidence (Final S_p), for the chain pillar under double abutment loading conditions for a given chain pillar FoS:

For the subject panel under consideration, first pillar subsidence S_p refers to the first subsidence which develops over a chain pillar when subject to double abutment loading conditions and may be estimated as follows:

Final $S_{p(i)}$ = First $S_{p(i)}$ +b $S_{p(i+1)}$ + c $S_{p(i+2)}$

U95% Final $S_{p(i)}$ = $S_{p(i)}$ + U95% S_p error,

where:

Single $S_{p(i)}$ - is the pillar subsidence under double abutment load and can be derived from **Figure A16**; "i" denotes the subject panel and the pillar under consideration; $S_{p(i+1)}$ and $S_{p(i+2)}$) are the pillars subsidence for the subsequent pillars after the second and third panels are extracted.

Note : If the panels and pillars have the same geometry, then $S_{p(i)} = S_{p(i+1)} = S_{p(i+2)}$.

c and b - multiple longwall panel effects constants presented in **Table A2**,

It is assumed that after three more longwall panels are extracted subsequently, any panel extracted afterwards will have negligible impact on pillar subsidence for the pillar under consideration.

Table A2 – Coefficient Constants b and c for Various w_{cp}/H

w_{cp}/H	b *	c*
< 0.15	0.2	0.035
> 0.15 and <0.3	0.15	0
> 0.3	0.005	0

Note:
* - The overburden load coefficients coefficients b and c are used to calculate the increase in chain pillar compression or subsidence due the extraction of subsequent longwalls; b represents the relative increase in pillar compression from the next extracted panel and c indicates the influence of subsequent longwalls to that. Their magnitude has been linked to the relative stiffness index or the pillar width to cover depth ratio (w_{cp}/H) as shown in **Table A3**.

Table A3 - Proportional Coefficients for Adjacent Panel Chain Pillar Subsidence Effects on the Subject Chain Pillar

Coefficient Name	Value for $w_{cp}/H < 0.15$	Value for $0.15 < w_{cp}/H < 0.3$	Value for $w_{cp}/H > 0.31$
a	0.07	0.035	0.0
b	0.20	0.15	0.005
c	0.035	0.0	0.0

Step 2 - Calculation of single mid-panel subsidence (Single S_{max}), first subsidence (First S_{max}), and final subsidence (Final S_{max}) for the subject panel:

Single S_{max} can be derived using either of **Figures A17** to **A23**, depending on the cover depth.

First S_{max} is calculated by adding 50% of the predicted pillar subsidence of the chain pillar positioned between the previous and current panel, $S_{p(i-1)}$, less the goaf edge subsidence, S_{ge}, to the single subsidence, S_{max}. Where S_{ge} is the goaf edge subsidence of the subject panel respecting to Single S_{max} and can be derived using **Figure A24.**

Final S_{max} is calculated by adding 100% of the predicted Final $S_{p(i)}$ less the goaf edge subsidence due to first S_{ge}, where first S_{ge} is the goaf edge subsidence due to first S_{max} and can also be derived using **Figure A24**.

In summary, the mean values of the First S_{max} and Final S_{max} are calculated as:

First S_{max} = Single S_{max} + 0.5 ($S_{p(i-1)}$ - S_{ge}),

Final S_{max} = First S_{max} + (Final $S_{p(i)}$ - First S_{ge}).

The U95% Confidence Limits or Credible Worst Case Values are then,

U95% First S_{max} = mean First S_{max} + 1.64 (U95% S_{max} error + U95% S_p error)$^{1/2}$,

U95% Final S_{max} = mean Final S_{max} + 1.64 (U95% S_{max} error + U95% S_p error)$^{1/2}$,

A8.2 Example of Predicting Subsidence above a Panel Due to Multiple Longwalls

Input parameters:

Panel width, W = 150 m,

Pillar height, h = 2.4 m,

Pillar FoS = 3.46,

Pillar width, w_{cp} = 25 m, and

Cover depth, H = 145 m.

It is assumed that all the panels and pillars have the same geometry.

Step 1 - Calculation of chain pillar subsidence:

According to **Figure A16**, the first and final subsidence above the chain pillars (S_p) between two extracted areas are determined as follows:

$S_p/h = 0.2934\ (FoS)^{-0.14901}$ when FoS < 2;

$S_p/h = 0.0465\ (FoS)^{-0.3314}$ when FoS > 2.

For FoS = 3.46 >2,

$S_{p(i)}/h = 0.0465\ (FoS)^{-0.3314}$

$= 0.0465\ (3.46)^{-0.3314}$

= 0.0308, and

<u>$S_{p(i)}$ = 0.074 m (the mean value).</u>

U95% S_p error = 0.07 h when FoS < 2;

= 0.03 h when FoS > 2;

For FoS = 3.46, S_p error = 0.03 h and

U95% $S_{p(i)}$ = $S_{p(i)}$ + S_p error,

= 0.074 + 0.03 x h,

= 0.074 + 0.03 x 2.4

<u>= 0.146 m (the credible worst case value).</u>

According to **Table A2** and **A3**, for w_{cp}/H =25/145 = 0.172 , then b= 0.15 and c = 0.

Final $S_{p(i)}$ = First $S_{p(i)}$ +b $S_{p(i)}$ + c $S_{p(i)}$,

= (1 + b + c) $S_{p(i)}$,

= (1 + 0.15) x 0.074,

<u>= 0.085 m (the mean value)..</u>

Final U95% $S_{p(i)}$ = Final $S_{p(i)}$ + S_p error

= 0.085 + 0.072

<u>= 0.157 m (the credible worst case value).</u>

Step 2 - Calculation of maximum mid-panel subsidence:

According to **Figures A17** to **A24**, the maximum mid-panel subsidence (S_{max}) and goaf edge subsidence (S_{ge}) may be estimated as follows:

Single S_{max} = 0.818 m, U95% error = 0.12 m and S_{ge} = 0.054 m,

hence,

First S_{max} = Single S_{max} + 0.5 ($S_{p(i-1)}$ - S_{ge}),

= 0.818 + 0.5 (0.078 - 0.054),

= 0.83 m (the mean value).

It follows then that,

First S_{ge} = 0.055 m, and

U95% S_{max} error= 0.12 m.

U95% First S_{max} = First $S_{max(i)}$ + U95% S_{max} error

= 0.83 + 0.12

= 0.95 m (the credible worst case value)

The final mid-panel subsidence may then be calculated as follows:

Final S_{max} = First S_{max} + (Final $S_{p(i)}$ - First S_{ge}),

= 0.83 + (0.085 – 0.055)

= 0.86 m (the mean value).

U95% Final S_{max} = Final S_{max} + U95% S_{max} error

= 0.86 + 0.12

= 0.98 m (the credible worst case value).

A9 SUBSIDENCE AND ASSOCIATED PARAMETER PROFILE PREDICTION

Regression analysis techniques have been used to develop subsidence and associated parameter profiles based on correlation with the measured key parameters.

Regression equations with Coefficients of Determination (R^2) ranging from 50% to 93% have been developed for each of the parameters listed in the tables below. In some cases, regressions were analysed for several parameters and the regression with the maximum R^2 value was adopted. The derived regression lines are presented in **Tables A4** to **A7**.

Table A4 - Key Subsidence Profile Parameter Predictions for Panel Crosslines

Parameter	Regression Equation (and +/- 95% Confidence Limits)	Coefficient of Determination (R^2)	Figure No.
Mean Chain Pillar Subsidence, S_p (m)	$S_p/h = 0.2934(FoS)^{-1.4901}$ +/- 0.07 for FoS < 2.0 $S_p/h = 0.0465(FoS)^{-0.3314}$ +/- 0.02 for FoS > 2.0	0.77	**A16**
TG & MG Rib Subsidence, S_{side} (m)	Mean $S_{side}/S_{max} = 0.0722(W/H)^{-2.557}$ U95%CL $S_{side}/S_{max} = 0.0719(W/H)^{-1.9465}$	0.82	**A24**
Angle of Draw, AoD (20mm limit) (º)	AoD = 7.646LN(S_{rib}) + 32.259 +/- 8.7	0.56	**A17**
Distance to T_{max} from panel rib-side, d (m)	d/W = -0.0739(W/H) + 0.3638 +/- 0.1	0.19	ACARP, 2003
Subsidence at T_{max}, S_{Tmax} (m)	$S_{Tmax}/S_{max} = 0.6$ +/- 0.24	<0.1	ACARP, 2003
Distance to S_{max} from panel centreline, x (m)	x/W = 0.0 +/- 0.18	<0.1	ACARP, 2003

Table A5 - Key Subsidence Profile Parameter Predictions for Panel Centrelines

Parameter	Regression Equation (and +/- 95% Confidence Limits)	Coefficient of Determination (R^2)	Figure No.
Panel End Subsidence, S_{end} (m)	Mean $S_{end}/S_{max} = 0.0213(W/H)^{-3.2872}$ for W/H <0.9 and S_{end}/S_{max} = 0.03 for W/H >0.9 U95%CL $S_{end}/S_{max} = 0.0213(W/H)^{-3.2872}$ 0.063	0.98	**A25**
Angle of Draw, AoD (20mm limit) (º)	AoD = 7.646LN(S_{end}) + 32.259 +/- 8.7	0.56	**A17**
Distance to T_{max} from panel end, d (m)	$d/W = 0.5569e^{-0.413(W/H)}$ and d/W >0.18 +/- 0.2	0.24	ACARP, 2003
Subsidence at T_{max} (m)	S_{Tmax}/S_{max} = 0.6 +/- 0.27	N/A	ACARP, 2003
Distance to S_{max} from panel end, a (m)	$a/W = 1.3571e^{-0.6571(W/H)}$ and a/W > 0.3 +/- 0.36	0.43	ACARP, 2003

Table A6 - Maximum Subsidence Parameter Predictions Along Panel Crosslines (i.e. Tilts, Curvatures and Strain)

Parameter	Regression Equation (and +/- 95% Confidence Limit)	Coefficient of Determination (R^2)	Figure No.
Maximum Tilt, T_{max} (mm/m)	$T_{max} = 0.9651(S_{max}/W)^{1.5054}$ +/- $0.4T_{max}$ and $W_{max} < 1.4 - 2H$	0.93	ACARP, 2003
Maximum Convex Curvature,$+C_{max}$ (km^{-1}) {Uniform}	$+C_{max} = 15.83(S_{max}/W^2)$ +/- 0.42 and $W_{max} < 1.4 - 2H$	0.74	ACARP, 2003
Maximum Concave Curvature,$-C_{max}$ (km^{-1}) {Uniform}	$-C_{max} = 19.79(S_{max}/W^2)$ +/- 0.37 and $W_{max} < 1.4 - 2H$	0.79	ACARP, 2003
Maximum Tensile Strain,$+E_{max}$ (mm/m) {Uniform}	$+E_{max} = 5.2 - 10^* (+C_{max})$ +/- 2.4mm	0.72	ACARP, 2003
Maximum Compressive Strain,$-E_{max}$ (mm/m) {Uniform}	$-E_{max} = 5.2 - 10^* (-C_{max})$ +/- 2.4mm	0.72	ACARP, 2003
Maximum Horizontal Displacement (mm) (Tension)	$+HD_{max} = 32.308Ln(+C_{max}) + 93.659$ +/- $(+HD_{max})$	0.28	ACARP, 2003
Maximum Horizontal Displacement (mm) (Compression)	$+HD_{max} = 54.306Ln(-C_{max}) + 110.94$ +/- $(+HD_{max})$	0.50	ACARP, 2003
Maximum Concentrated Strain (Surface Cracks)	Mean = HD_{max}/Bay-length U95%CL = 2HDmax/Bay-length	0.3	ACARP, 2003

Table A7 - Maximum Subsidence Parameter Predictions Along Panel Centrelines

Parameter	Regression Equation (and +/- 95% Confidence Limit)	Coefficient of Determination (R^2)	Figure No.
Maximum Tilt, T_{max} (mm/m)	$T_{max} = 0.7479(S_{max}/W)^{1.5883}$ +/- $0.5T_{max}$ and $W_{max} < 1.4\text{-}2H$	0.87	ACARP, 2003
Maximum Convex Curvature,$+C_{max}$ (km^{-1})	$+C_{max} = 1081(S_{max}/W^2)^{2.5039}$ +/- $(+0.5C_{max})$ and $W_{max} < 1.4 - 2H$	0.74	ACARP, 2003
Maximum Concave Curvature,$-C_{max}$ (km^{-1})	$-C_{max} = 479(S_{max}/W^2)^{2.1646}$ +/- $0.5(-C_{max})$ and $W_{max} < 1.4 - 2H$	0.74	ACARP, 2003
Maximum Tensile Strain,$+E_{max}$ (mm/m) {Uniform }	$+E_{max} = 5.2 - 10^* (+C_{max})$ +/- 2.4mm	0.70	ACARP, 2003
Maximum Compressive Strain,$-E_{max}$ (mm/m) (Uniform)	$-E_{max} = 5.2 - 10^* (-C_{max})$ +/- $0.5E_{max}$	0.70	ACARP, 2003
Maximum Horizontal Displacement (mm) (Tension)	$+HD_{max} = 40.193Ln(+C_{max}) + 119.7$ +/- $(+HD_{max})$	0.29	ACARP, 2003
Maximum Horizontal Displacement (mm) (Compression)	$+HD_{max} = 49.7Ln(-C_{max}) + 109.2$ +/- $(+HD_{max})$	0.39	ACARP, 2003
Maximum Concentrated Strain (Surface Cracks)	Mean = HD_{max}/Bay-length U95%CL = 2HDmax/Bay-length	0.3	ACARP, 2003

Notes:
1. S_{max}/W and S_{max}/W^2 have the same units as the dependent variables (i.e. T_{max} and C_{max}).
2. For cases where C_{max} or C_{min} are > $1km^{-1}$, the measured strains may by 2 to 4 times the predicted values due to strain concentration effects (i.e. joints or near surface rock mass failure or cracking). * - a value of 10 m has been assessed for Ulan and Moolarben lithology.
3. Maximum strains due to strain concentration effects from surface cracking may be predicted by dividing HD_{max} by the bay-length.

A10 SUB-SURFACE FRACTURING MODEL DEVELOPMENT OUTCOMES

A10.1 Whittaker and Reddish Physical Model

The most significant published work ever undertaken in the area of sub-surface fracturing over longwall panels, which gives specific guidelines (over and above such work as the Wardell Guidelines for the prevention of inundation of mine workings beneath surface and sub-surface water bodies) is that of **Whittaker and Reddish (1989)**.

The model in question was developed in response to the water ingress problems associated with early longwall extraction at the Wistow Mine in Selby, UK. The longwall panel was located at 350 m depth and experienced groundwater inflows of 121 to 136 litres/sec when sub-surface fracturing intersected a limestone aquifer that was 77 m above the seam.

The model identifies the existence of two distinct zones of fracturing above super-critical width extractions (continuous and discontinuous fracturing) and relates the height of each to "predicted maximum tensile strain at the surface". As such, its use is also based upon being able to make credible subsidence predictions. The basis of the model is summarised in **Figure A26**.

A review of the methodology that was undertaken to develop the model and its key features have been summarised below:

The model was based on laboratory controlled measurements of longwall extraction physical models.

The physical model was constructed from multiple layers of coloured sand and plaster mixtures with sawdust bond breakers placed between each successive layer.

The scale and mechanical properties of the model and prototype satisfied dimensional analysis and similtude laws.

The model was used to simulate the overburden behaviour of a panel with a W/H ratio of 1.31 and a progressively increasing working height range that commenced at 1.2 m and finished at 10.8 m. The advancing longwall face was simulated by removing timber blocks at the base of the model in 1.2 m to 2.0 m lift stages.

The extent or heights of 'continuous' and 'discontinuous' fracturing above the longwall 'face' was measured and plotted with the associated peak tensile strain predictions at the surface. *Notes:- It is not clear from the text as to how the tensile strains were predicted; it would seem likely that the SEH(1975) was used based on the comparisons that were made with the SEH subsidence predictions during the modelling work.* The fracturing path progressed up at an angle from the solid rib-side and inwardly towards the centre of the panel – see **Figures A26** and **A3**.

The definition of the extent of 'continuous' fracturing refers to the height at which a direct connection of the fractures occurs within the overburden and the workings; it represents a 'direct' hydraulic connection for groundwater inflows.

The definition of the extent of 'discontinuous' fracturing refers to the height at which the horizontal permeability increases as a result of strata de-lamination and fracturing.

However, a direct connection of the fractures within the overburden and the workings does not occur.

The fracturing in question occurred close to the rib-side only as the fracturing in the overburden above the middle portion of the panel tended to ‘close’ and did not appear to represent an area in which groundwater inflows into the workings would be generated.

Any inflow conditions were therefore considered to be “*mainly associated with the longwall rib-side fracture zone [or tensile strain zone]”*.

The maximum depth of vertical downward fracturing from the surface was 7.5 m.

Overall, the results of the model cannot be directly applied to Australian conditions as the total lift thickness and predicted strains for the W/H ratios modelled appear to be incompatible with Australian mining conditions. It was therefore considered necessary to calibrate the model based on actual drilling data before it could be applied with confidence.

A case study at Oaky Creek Colliery in the Bowen Basin was presented in **Colwell (1993)** that attempted to calibrate the Whittaker and Reddish model with actual drilling and strain measurement data. Three fully cored boreholes were drilled over already extracted longwall panels with a W/H ratio of 2.11 and strain measurement data was obtained from a nearby operating LW panel with a W/H of 1.37. The results of the study are highly encouraging and have been subsequently collated with further case histories in **Section A10.2**.

A10.2 Preliminary Sub-Surface Fracturing Prediction Model For Australian Coalfields

The database of drilling data obtained from previously published documents has been summarised below in **Table A8**.

Table A8 – Predicted Tensile Strains and Sub-Surface Fracturing Data

Mine No. (refer to Appendix D for Mine details)	**W (m)**	**H (m)**	**T (m)**	**S_{max} (m)**	**Predicted Smooth Profile Strain, E_{max} (mm/m)**	**a* (m)**	**b* (m)**	**A (a/H) (m)**	**B (b/H) (m)**	**a/T**	**S_{max}/W^2 ****
1-NSW	170	185	2.0	0.9	2.7	63	163	0.34	0.88	31.5	0.034
2-NSW	250	210	3.1	1.8	2.2	40	170	0.20	0.85	12.5	0.030
3-NSW	105	75	2.8	1.27	9.9	58	64	0.77	0.85	20.7	0.115
4- QLD	205	132	2.4	1.28	2.4	21	117	0.16	0.89	8.9	0.038
5- QLD	200	142	2.8	1.40	2.7	18	127	0.13	0.89	6.4	0.035
6- QLD	205	95	3.2	1.75	4.2	55	85	0.58	0.89	17.2	0.044
7-NSW	150	350	2.7	0.64	0.8	n/m	150	n/m	0.43	n/m	0.018

Note : *- a = Distance to total drilling fluid loss above workings.
*- b = Distance to partial drilling fluid loss above workings.
**- S_{max}/W^2 = a new robust term (i.e. Overburden Curvature Index) to plot A and B against instead of tensile strain (see below for further explanation).
n/m – not measured as drilling terminated before depth was reached.

The Australian data was initially plotted with the UK Model results as shown in **Figure A27**. It was then decided that a regression analysis would probably be useful in defining a relationship between the parameters and assess whether other parameters of significance could be identified.

The results of a regression analysis on the Australian database and UK model is presented in **Figure A28** and summarised below:

{A-Line} $A = a/H = 0.2077\ Ln(+E_{max}) + 0.150$, $R^2 = 0.44$ and S.E. = 0.164;

{B-Line} $B = b/H = 0.1582\ Ln(+E_{max}) + 0.651$, $R^2 = 0.46$ and S.E. = 0.106;

where

a, b = height above workings to A and B Horizons,

H = cover depth,

$+E_{max}$ = the maximum predicted tensile strain for a 'smooth'profile,

S.E. = Standard Error for the regression equation.

The Australian database appears to be similar to the Whittaker and Reddish model, however the predicted surface strains are much lower for a given height of 'continuous' and 'discontinuous' fracturing above the workings. It is also apparent that the model relies on the measured surface strain data which has been noted previously for its high variability.

To overcome this issue it was decided to re-plot the database using the previously derived S_{max}/W^2 term to provide a readily measurable field parameter that would not be compromised by surface strain concentration effects. The revised regression results are shown in **Figure A29** and summarised below:

{A-Line} $A = a/H = 0.2295\ Ln(S_{max}/W^2) + 1.132$, $R^2 = 0.44$ and S.E. = 0.11;

{B-Line} $B = b/H = 0.1694\ Ln(S_{max}/W^2) + 1.381$, $R^2 = 0.46$ and S.E. = 0.16;

where a, b = height above workings to A and B Horizons,

H = cover depth (m).

S_{max}/W^2 = Overburden Curvature Index,

S.E. = Standard Error for the regression equation.

The same apparent difference still remains between the Australian and UK databases, however it is of interest to note that the UK physical models B horizon coincides with the Australian field data derived A horizon.

The apparent discrepancies between the model indicate that the difference in the method of assessment for the various fracture heights may also be the reason for the differences between the models (i.e. the physical models A and B horizons were based on visual mapping of cracks, whereas the water loss data during the drilling programs was used to derive the Australian model).

The A and B horizons in the sub-surface fracturing model presented also appear to be the same as the heights to the top of the 'Fractured Zone' and 'Constrained Zone' (above an extracted longwall panel) defined in **Forster (1993)**. There is also a departure in this model from assessing heights of fracturing based on the extraction height only, although the predicted tensile strain or S_{max} is directly related to the extraction height. It is considered that sub-surface fracture heights are a function of overburden bending deformation and is therefore primarily a function of the significant geometrical parameters S_{max}, W, H and T. The influence of massive lithology is included in the S_{max} prediction.

Overall, the sub-surface fracturing model presented in this report is considered to be preliminary at this stage: more drilling data would increase our understanding and confidence in its use. The heights of fracturing derived from it however do appear to be conservative based on reference to several NSW and Queensland case studies.

It is recommended that future calibration work on the model presented herein consider both the tensile strain and S_{max}/W^2 parameters based on the results to date.

A10.3 Influence of Geology on Sub-Surface Fracture Heights

For the purposes of study completeness, an assessment was made on whether the geology effected the height of fracturing above a longwall panel.

Reference to the database presented in **Section A10.2**, indicates that two of the case studies were assessed to have High SRP and had A Horizons that coincided with the base of the massive strata units. The other data points had low SRP with no massive units present.

The massive strata unit affected data, however do not appear to plot at lower than predicted levels than those predicted for the low SRP cases, although this observation is based on a small sample of data. At this stage, the potential for a spanning strata unit to mitigate the height of continuous fracturing above the workings cannot be ignored.

A11 REFERENCES

ACARP (1998). **Chain Pillar Design (Calibration of ALPS)**. ACARP Project No. C6036, Colwell, M.

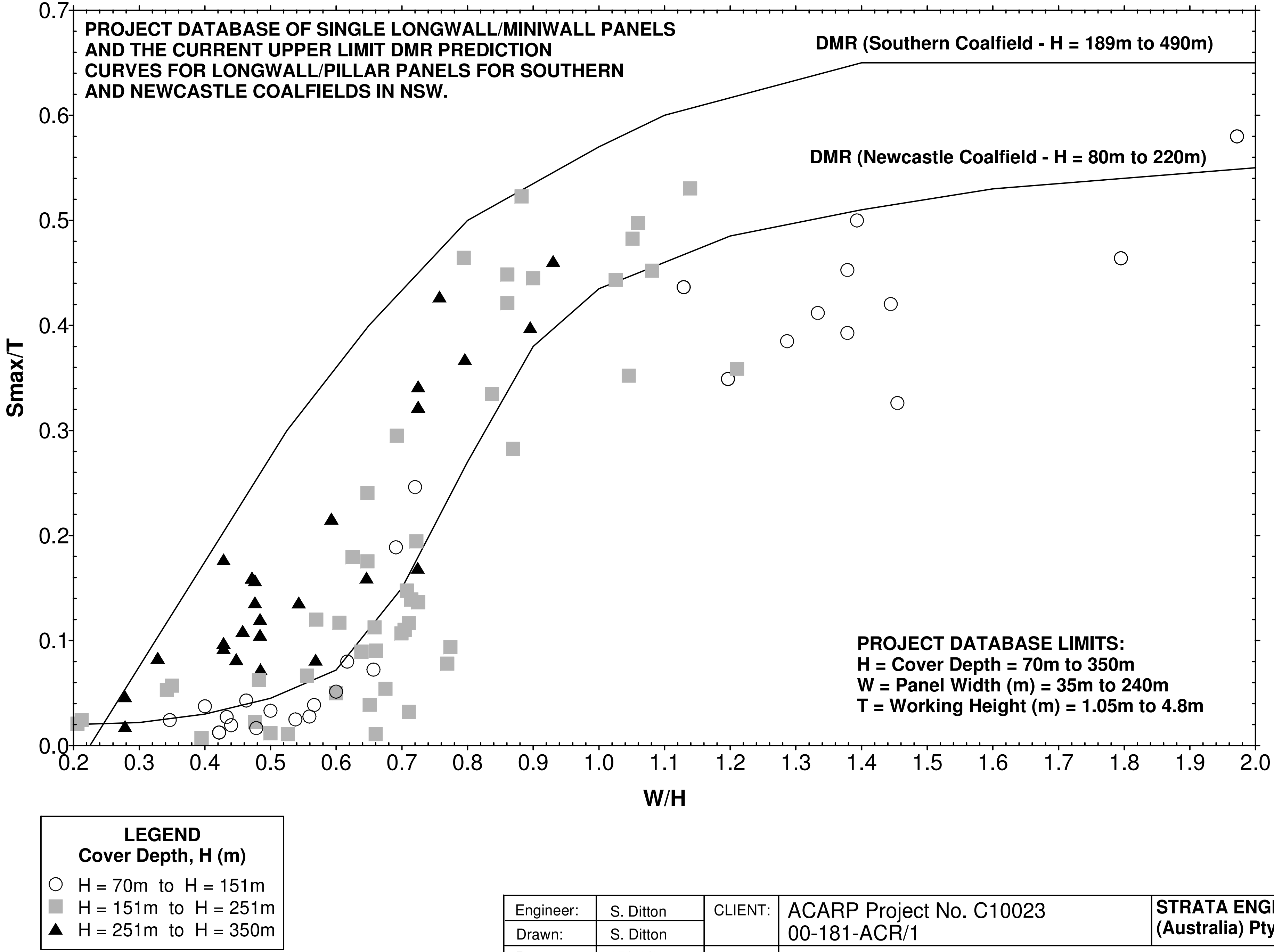
ACARP (2003). **Review of Industry Subsidence Data in Relation to the Impact of Significant Variations in Overburden Lithology and Initial Assessment of Sub-Surface Fracturing on Groundwater**. ACARP Project No. C10023, Ditton, S. and Frith, Strata Engineering Report No. 00-181-ACR/1.

Colwell, M. (1993). **Water Inflow Investigation for a Longwall Operation**. Published in Queensland Coal Geology Groups Conference Proceedings, New Developments in Coal Geology, Brisbane.

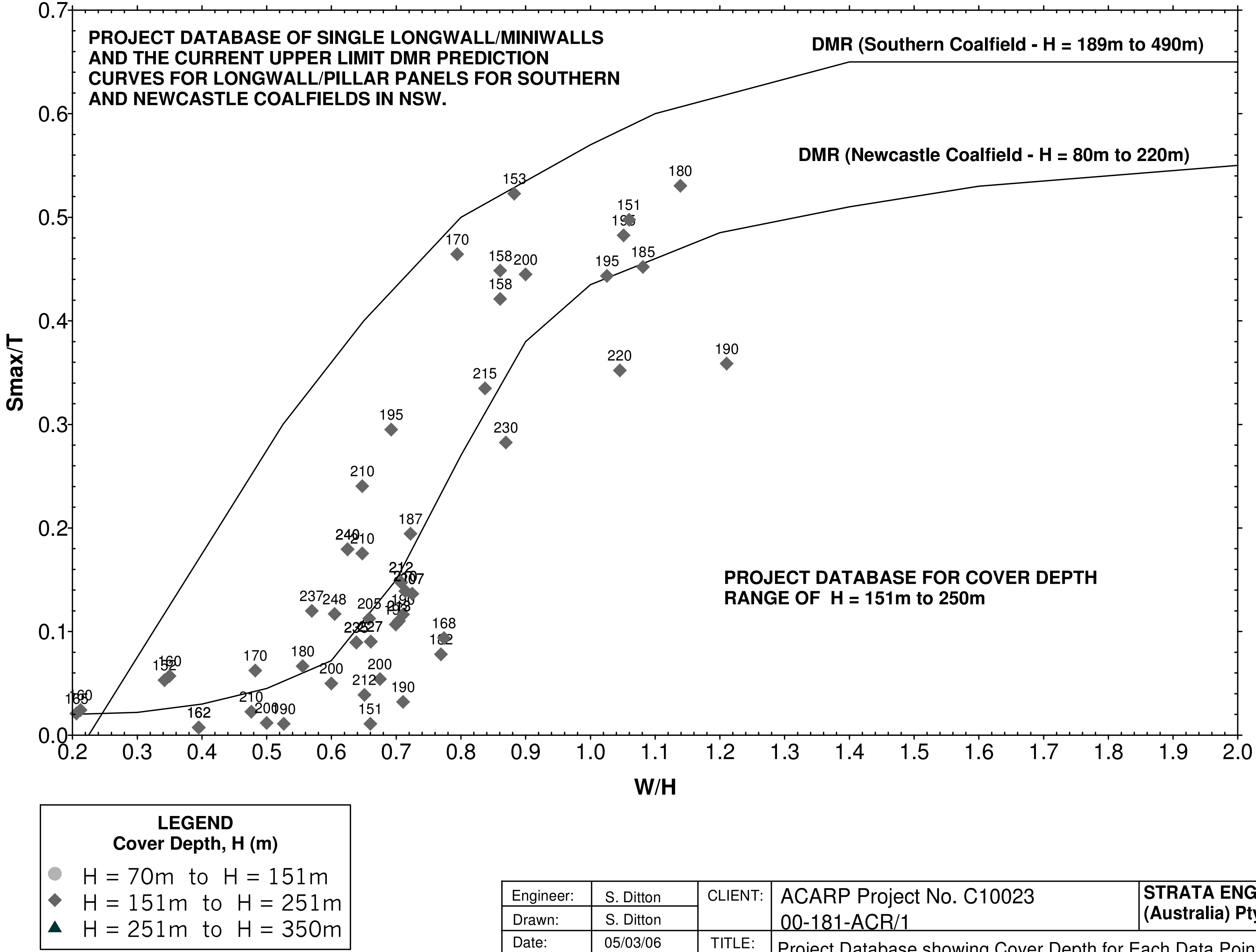
Forster, I.R. (1995). **Impact of Underground Coal Mining on the Hydrogeological Regime, Central Coast, NSW**. Published in Australian Geomechanics Society (AGS) Conference Proceedings (February), Engineering Geology of Newcastle – Gosford Region, University of Newcastle.

Harrison, S.R. and Tamaschke, H.U. (1984). **Applied Statistical Analysis**. Prentice-Hall of Australia.

Whittaker, B N & Reddish, D J. (1989). **Subsidence, Occurrence, Prediction and Control**. Department of Mining Engineering, the University of Nottingham, UK.



Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S. Ditton			
Date:	05/03/06	TITLE:	Project Database and DMR Subsidence Prediction Curves	FIGURE A1
Scale:	NTS			



Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S. Ditton			
Date:	05/03/06	TITLE:	Project Database showing Cover Depth for Each Data Point	FIGURE A2
Scale:	NTS			

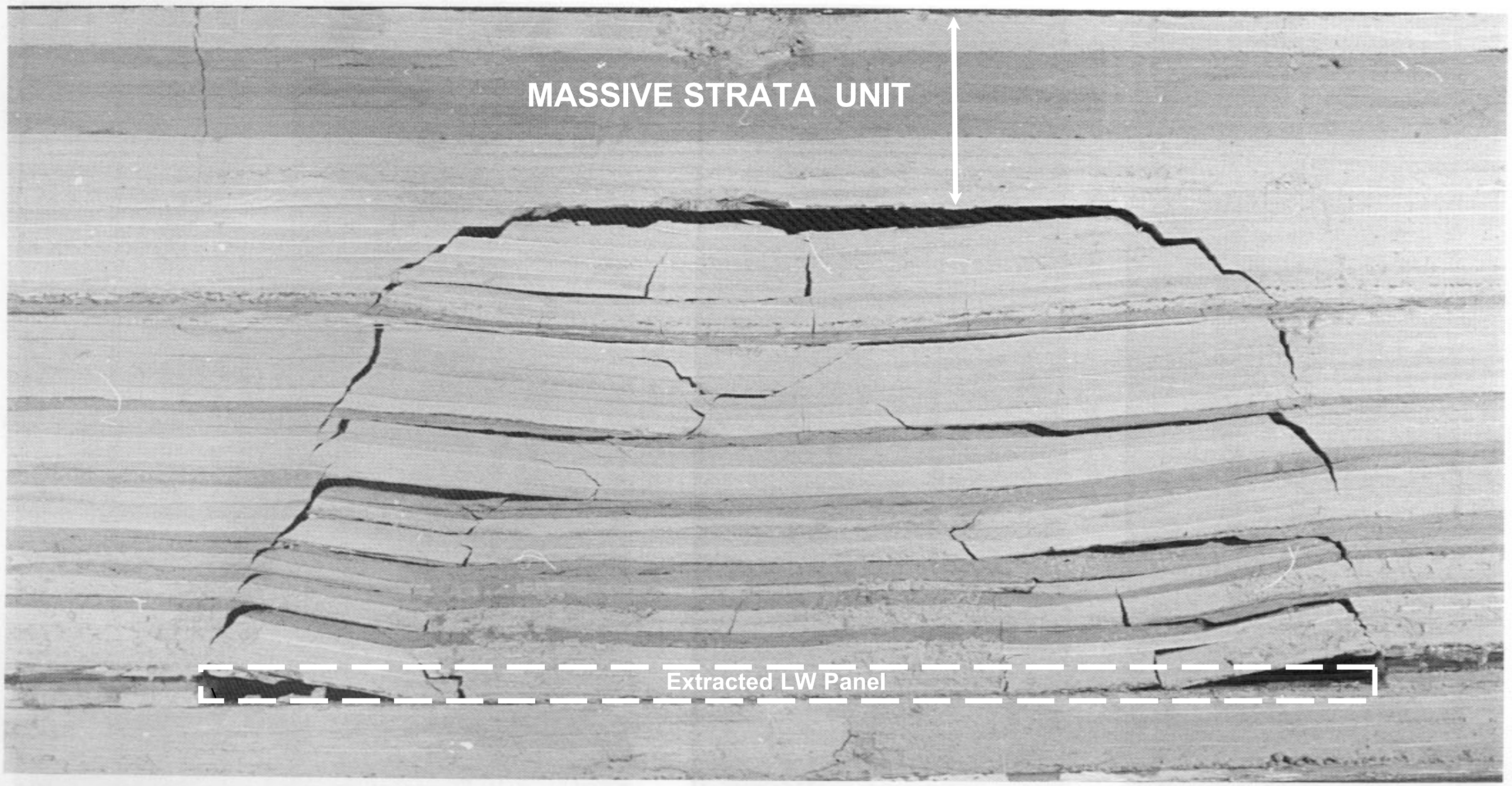
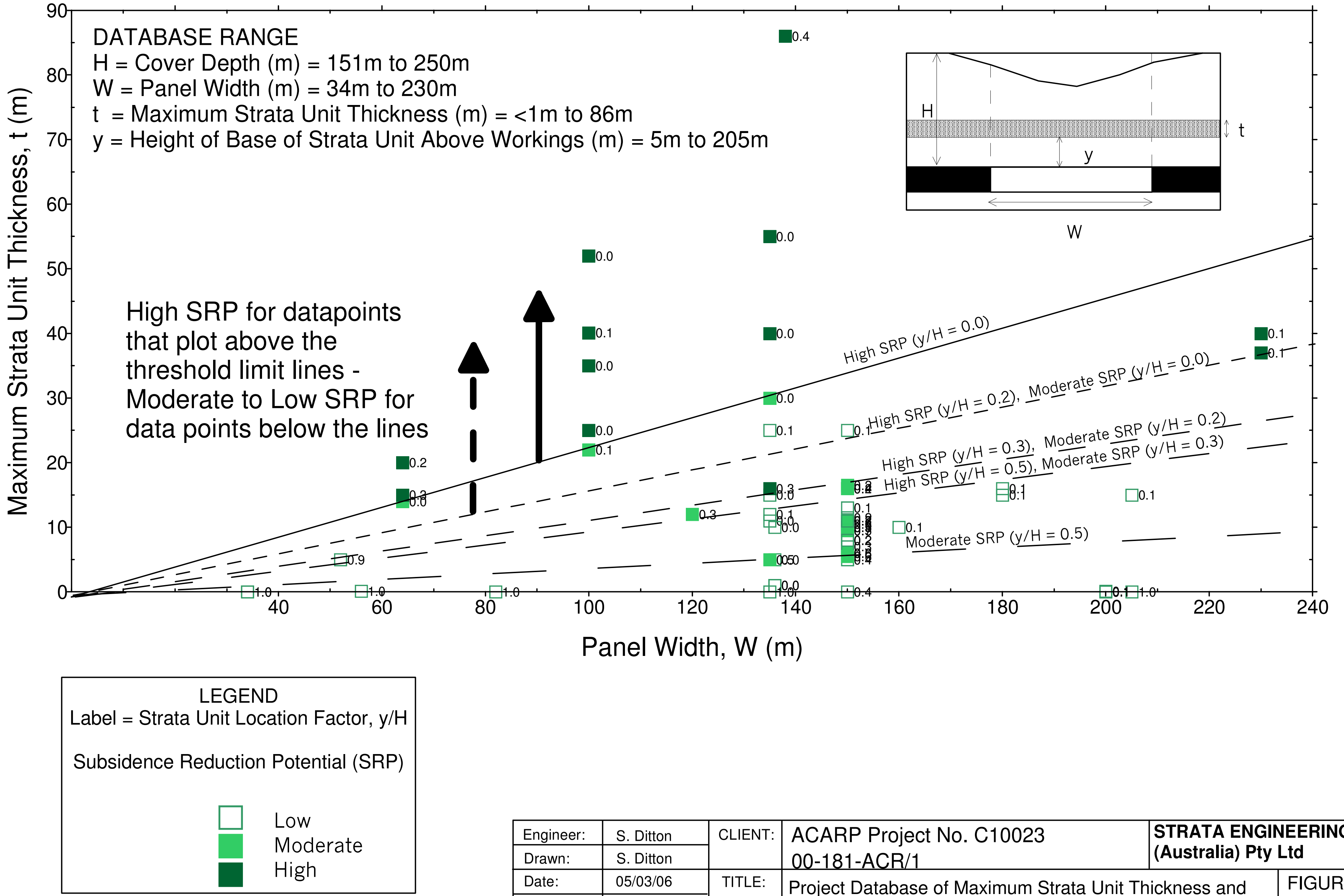


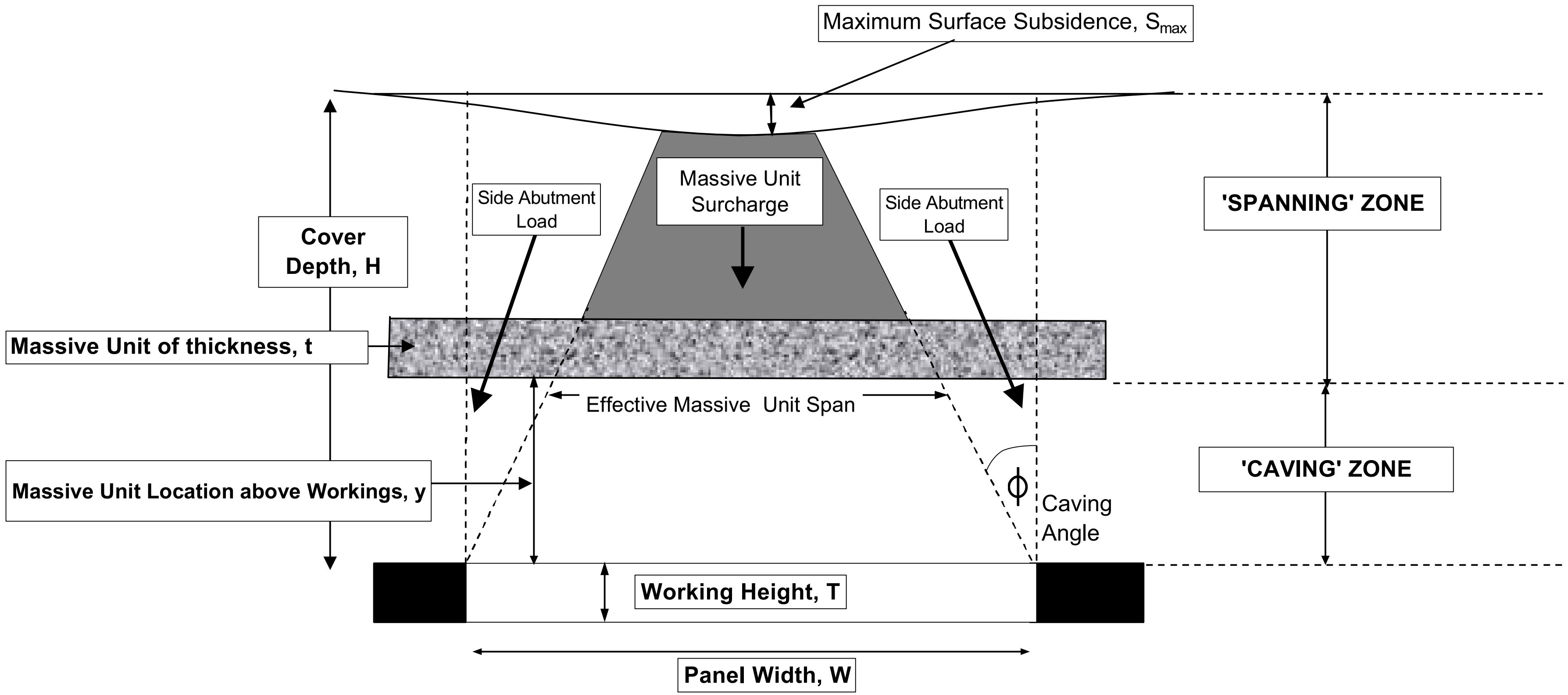
Figure 237 Physical model of caved strata above longwall extraction with strong overburden. Mining data: h = 84m; w = 118m; M = 4m.

Note :
Reference : Whittaker & Reddish (1989)

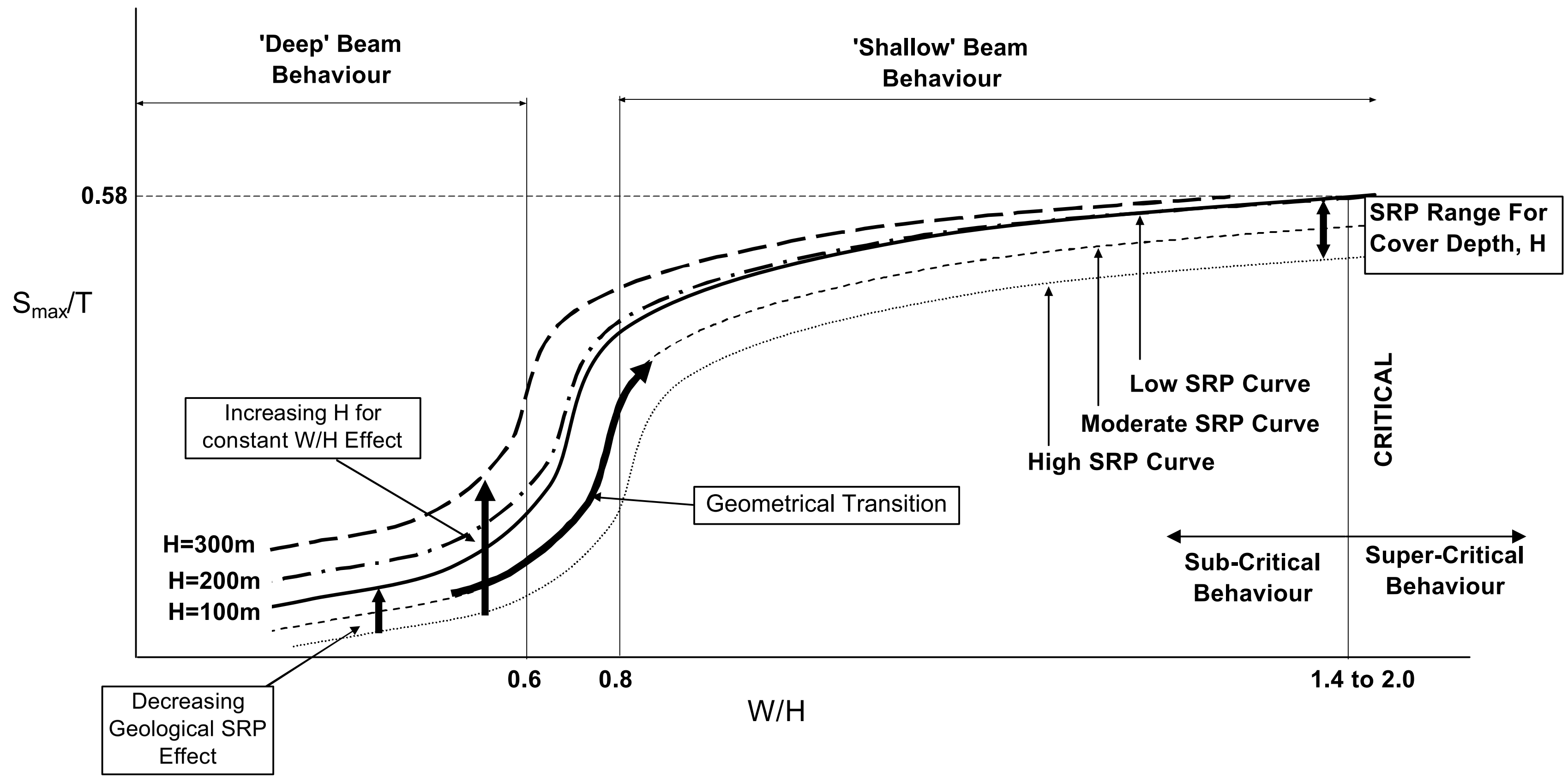
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**
DRAWN:	S.Ditton		00-181-ACR/1	**(Australia) Pty Ltd**
DATE:	22/11/2002	TITLE:	Physical Model Showing the Subsidence Reducing	FIGURE:
SCALE:	NTS		Effect of a Massive Strata Unit	A3



Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S. Ditton			
Date:	05/03/06	TITLE:	Project Database of Maximum Strata Unit Thickness and SRP Threshold Limit Lines for H = 151 to 250 m	FIGURE A4
Scale:	NTS			



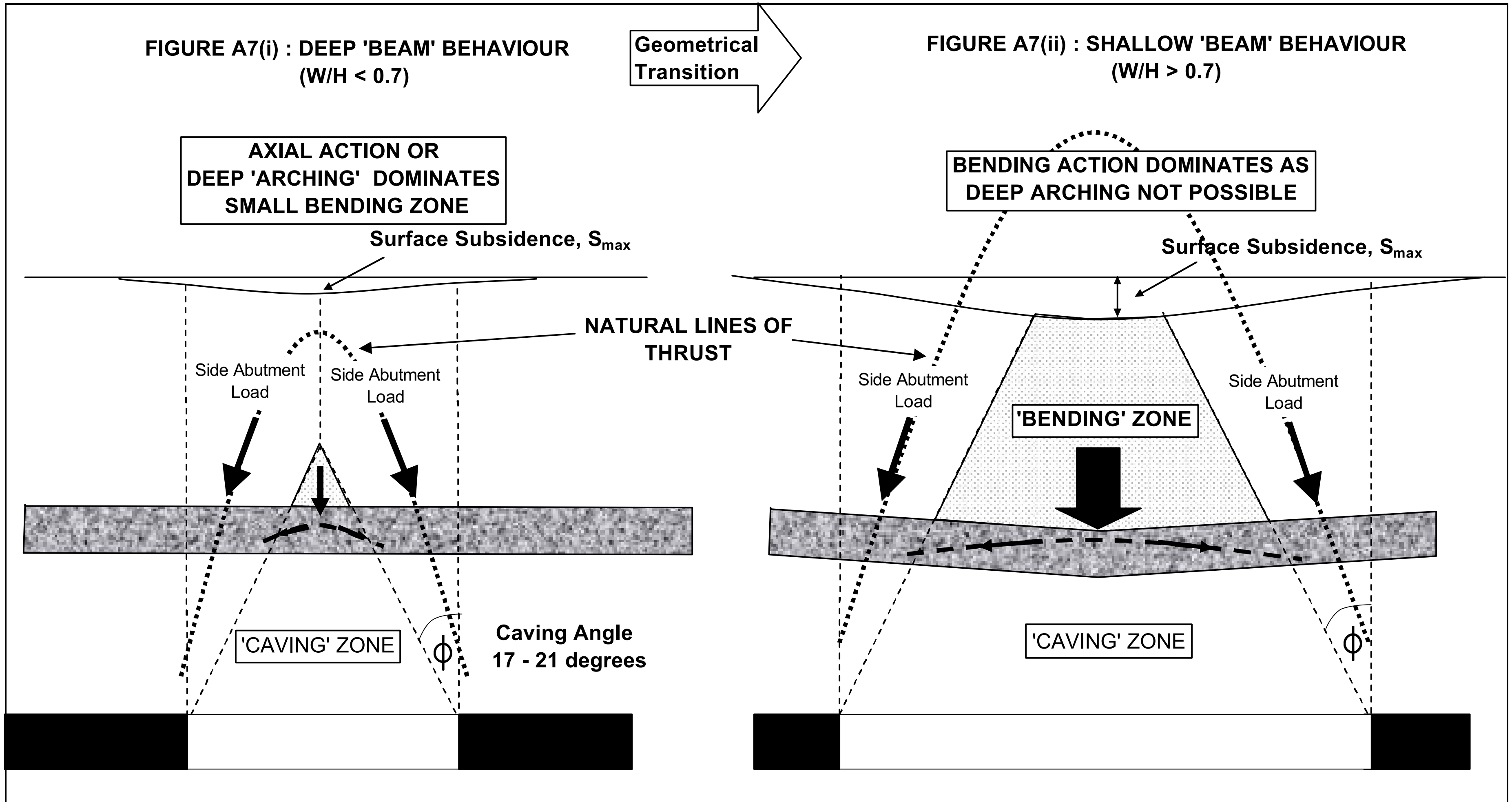
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**
DRAWN:	S.Ditton		00-181-ACR/1	**(Australia) Pty Ltd**
DATE:	1/08/2002	TITLE:	Overburden Behaviour Concept Model for the	FIGURE:
SCALE:	NTS		Newcastle Coalfield - Definitions	A5



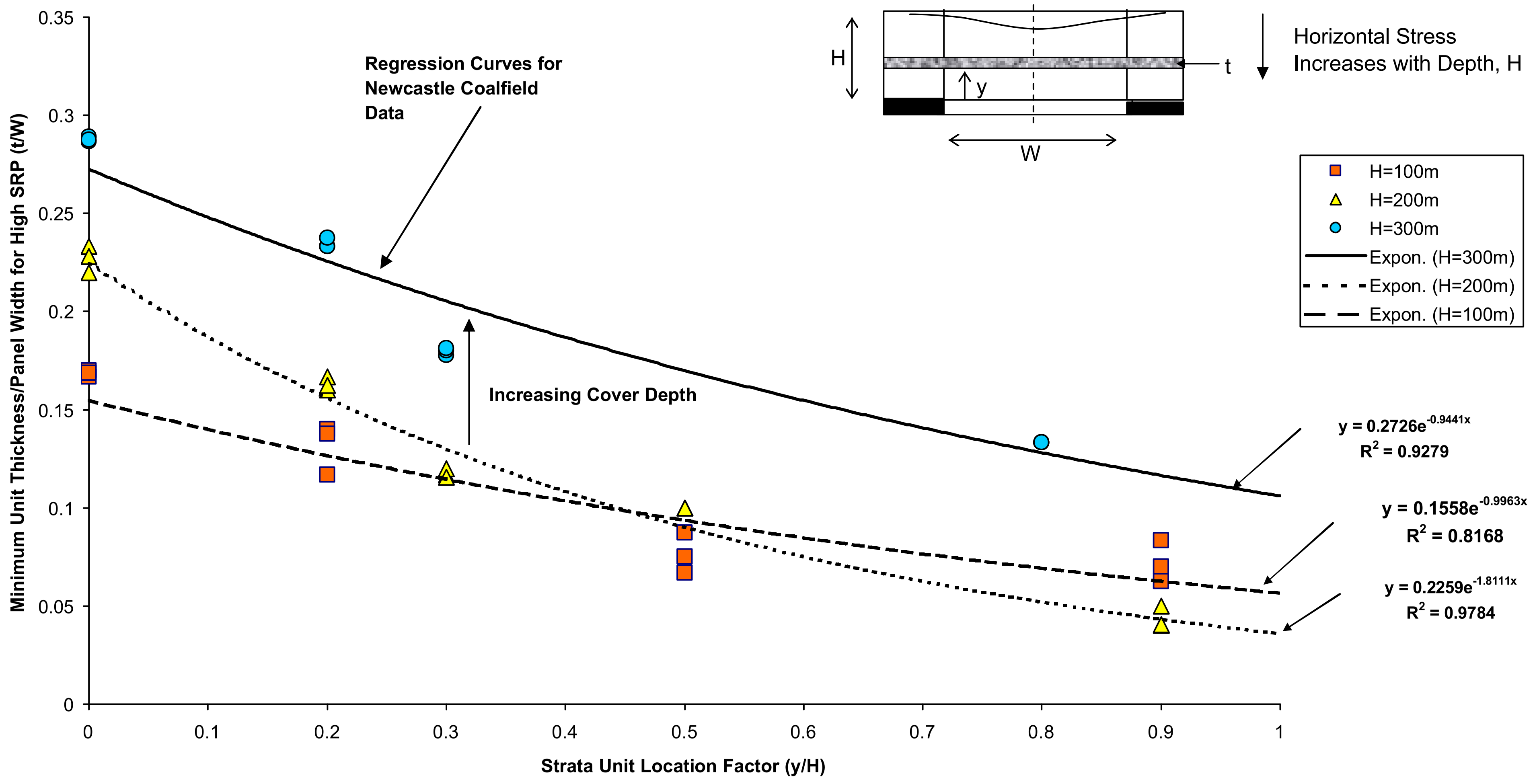
LEGEND

SRP = Subsidence Reduction Potential
W/H = Panel Width / Cover Depth Ratio
S_{max}/T = Max. Subsidence / Working Height Ratio
(For Single Longwall Panels Only)

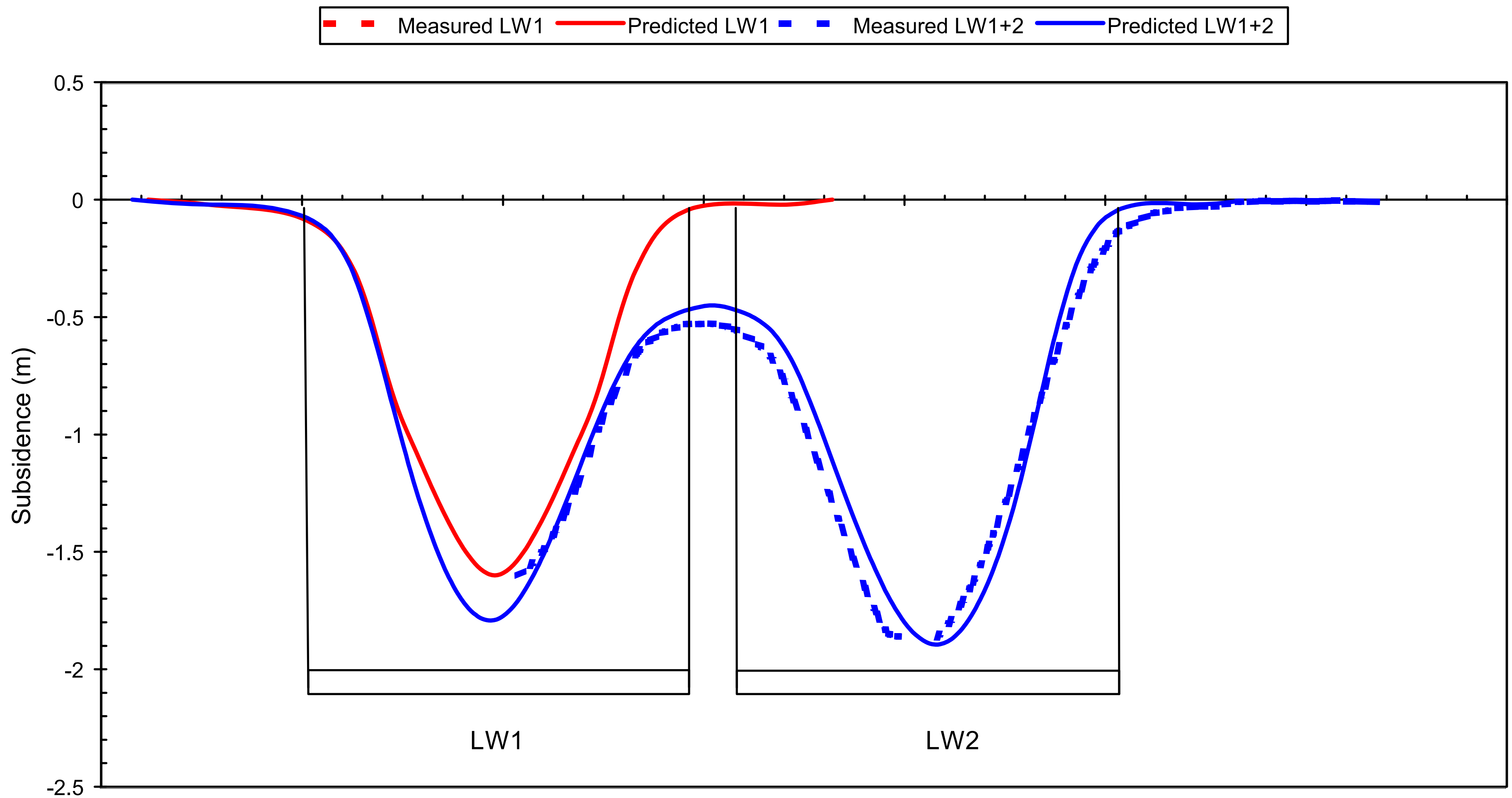
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**
DRAWN:	S.Ditton		00-181-ACR/1	**(Australia) Pty Ltd**
DATE:	17/08/2002	TITLE:	Geometrical and Geological Effects of Overburden Behaviour on Maximum Subsidence for Single Panels	FIGURE: A6
SCALE:	NTS			



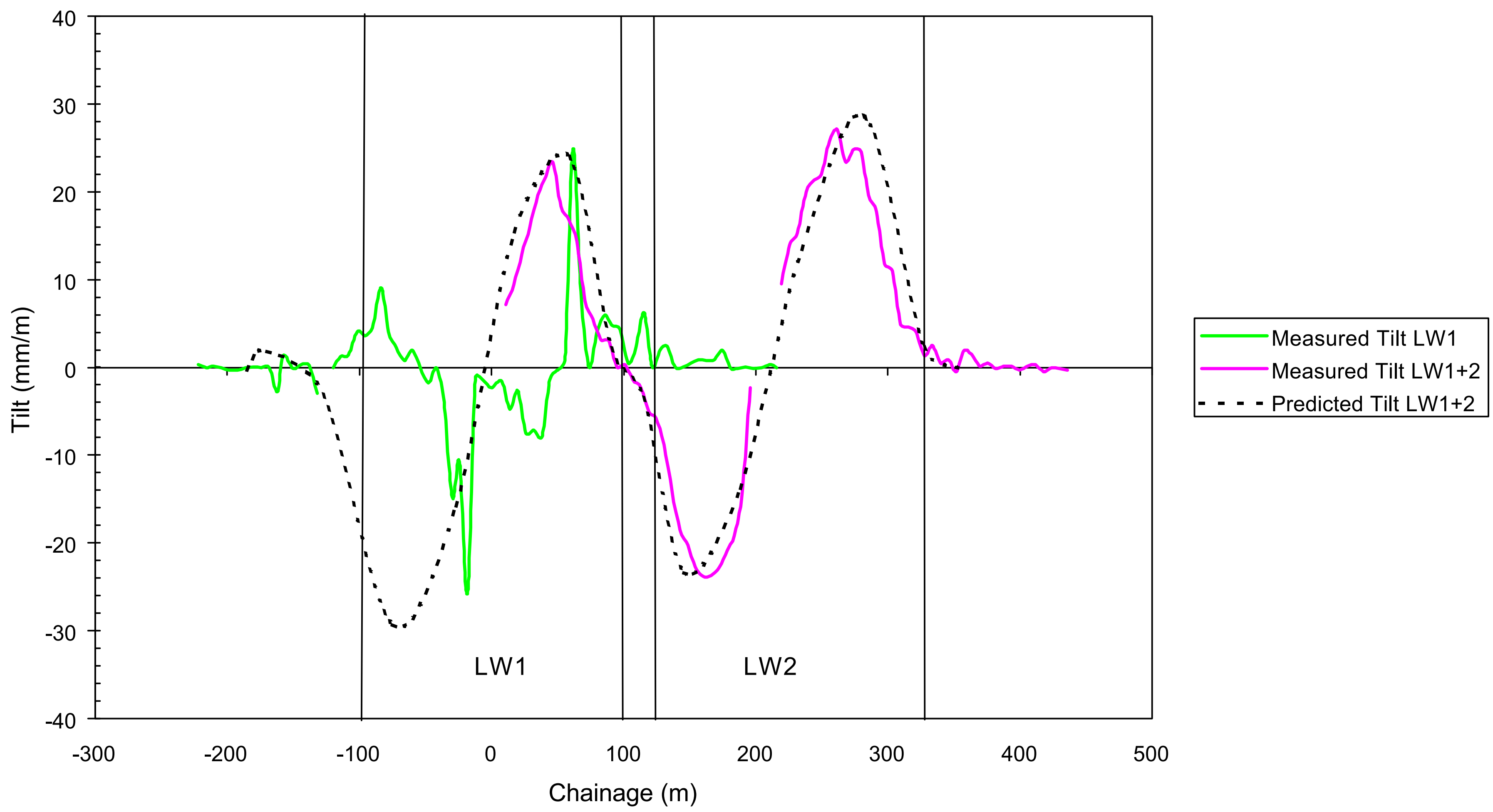
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	STRATA ENGINEERING
DRAWN:	S.Ditton		Subsidence Prediction Review	(Australia) Pty Ltd
DATE:	1/08/2002	TITLE:	Overburden Behaviour Conceptual Models	FIGURE:
SCALE:	NTS		- Beam Action Types	A7



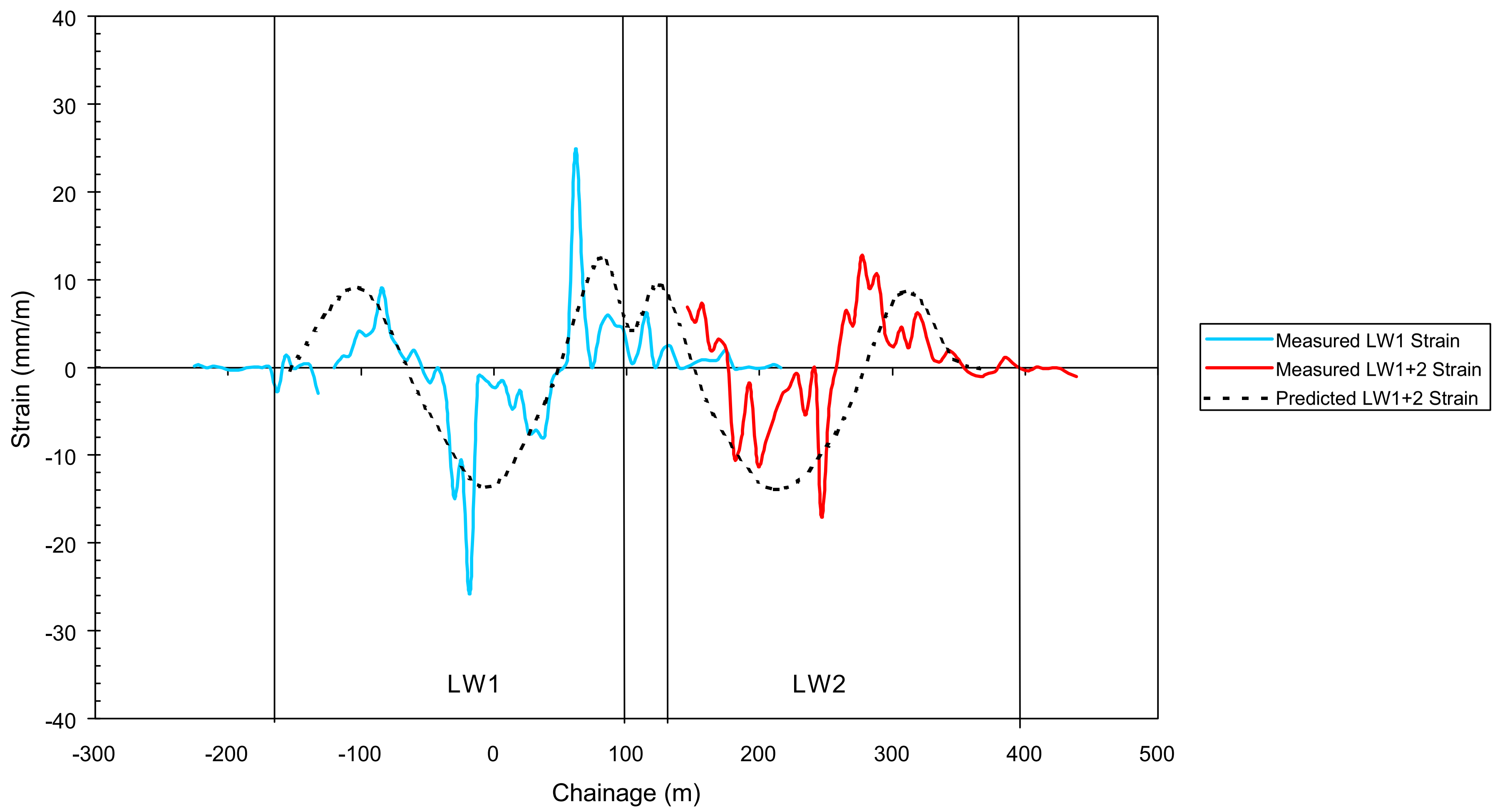
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	22/11/2002	TITLE:	Empirical Relationship Linking Minimum Massive Strata Unit Thickness Required for High SRP with Panel Width and y/H	FIGURE A8
SCALE:	NTS			



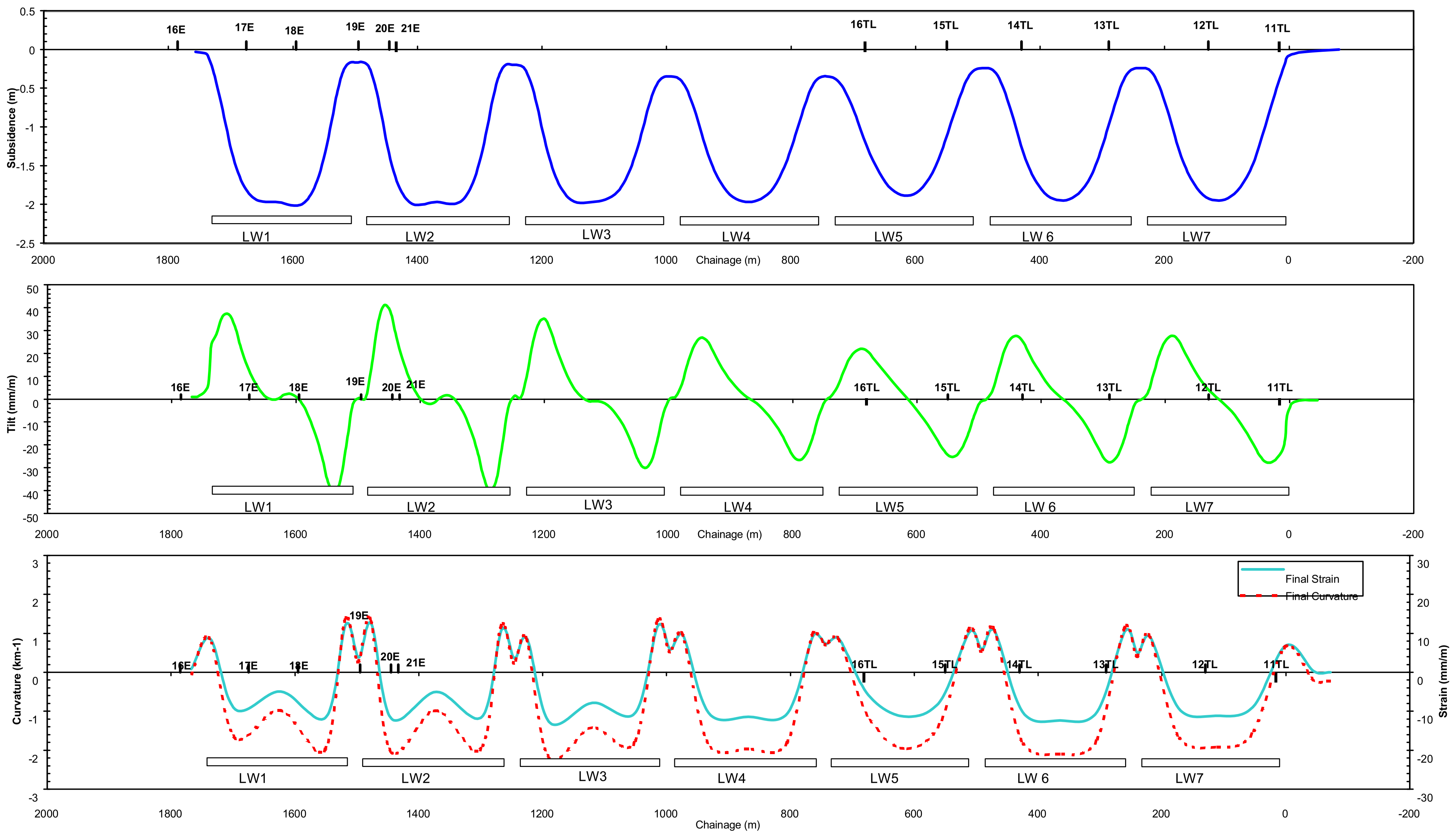
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	5/12/2002	TITLE:	Predicted v. Measured Crossline Subsidence Profiles for Mine B, LWs 15 -16	FIGURE A9
SCALE:	NTS			



ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**
DRAWN:	S.Ditton		00-181-ACR/1	**(Australia) Pty Ltd**
DATE:	5/12/2002	TITLE:	Predicted v. Measured Crossline Tilt Profiles	FIGURE:
SCALE:	NTS		for Mine B, LWs 1 - 2	A10



ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	5/12/2002	TITLE:	Predicted v. Measured Crossline Strain Profiles for MIne B, LWs 1 - 2	FIGURE: A11
SCALE:	NTS			

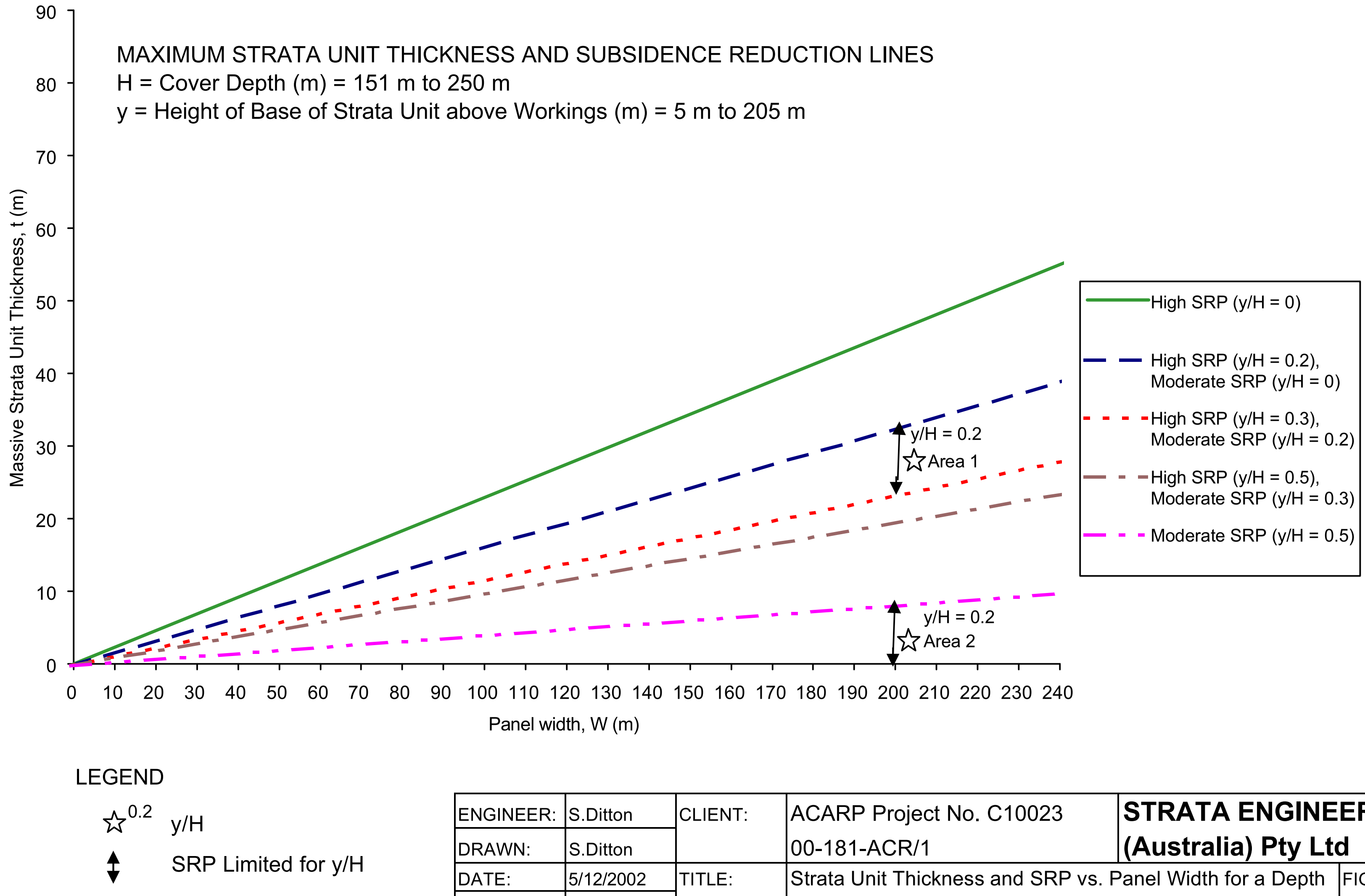


Legend

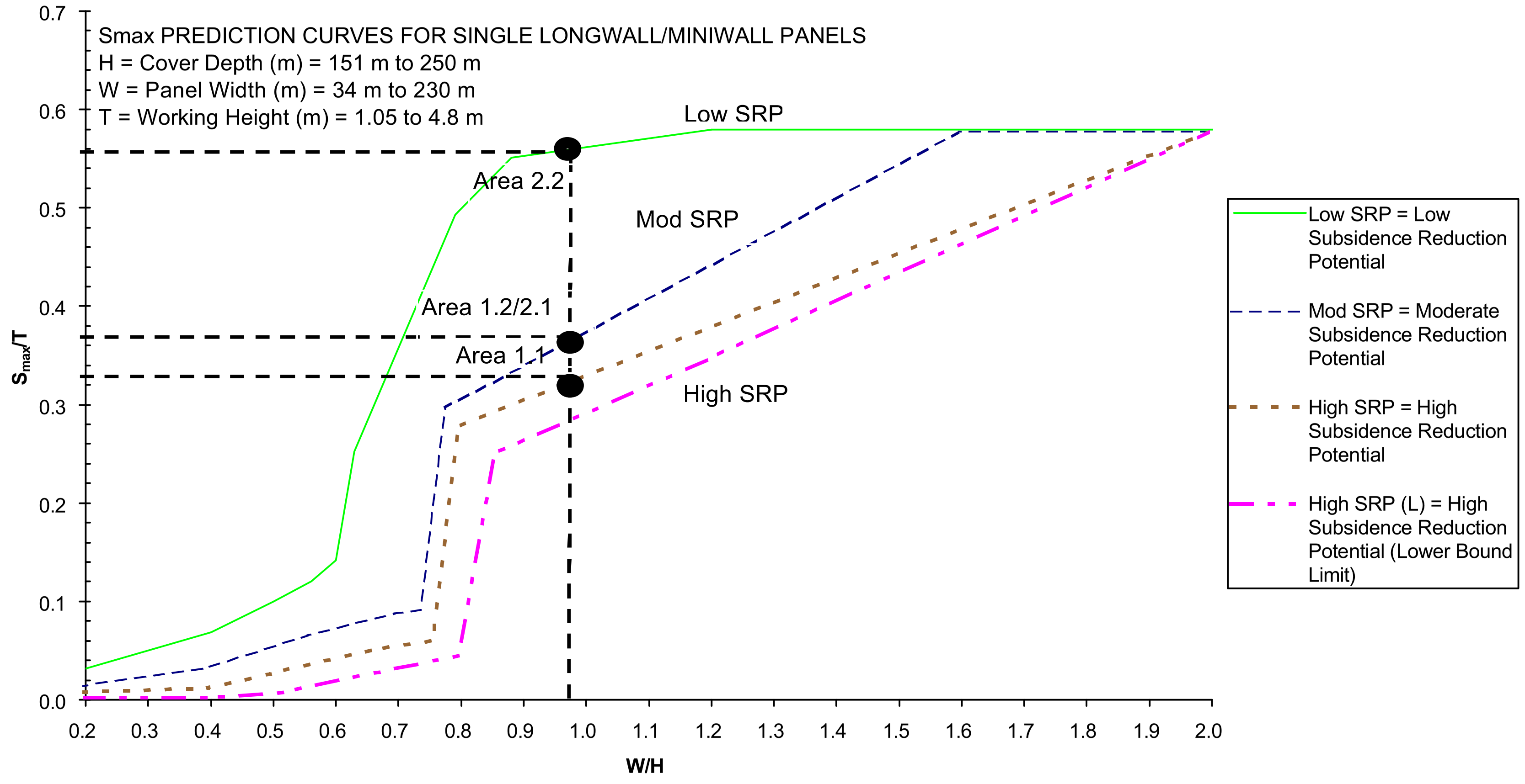
18E Transmission tower location

Note : Predictions based on a 10m baylength.

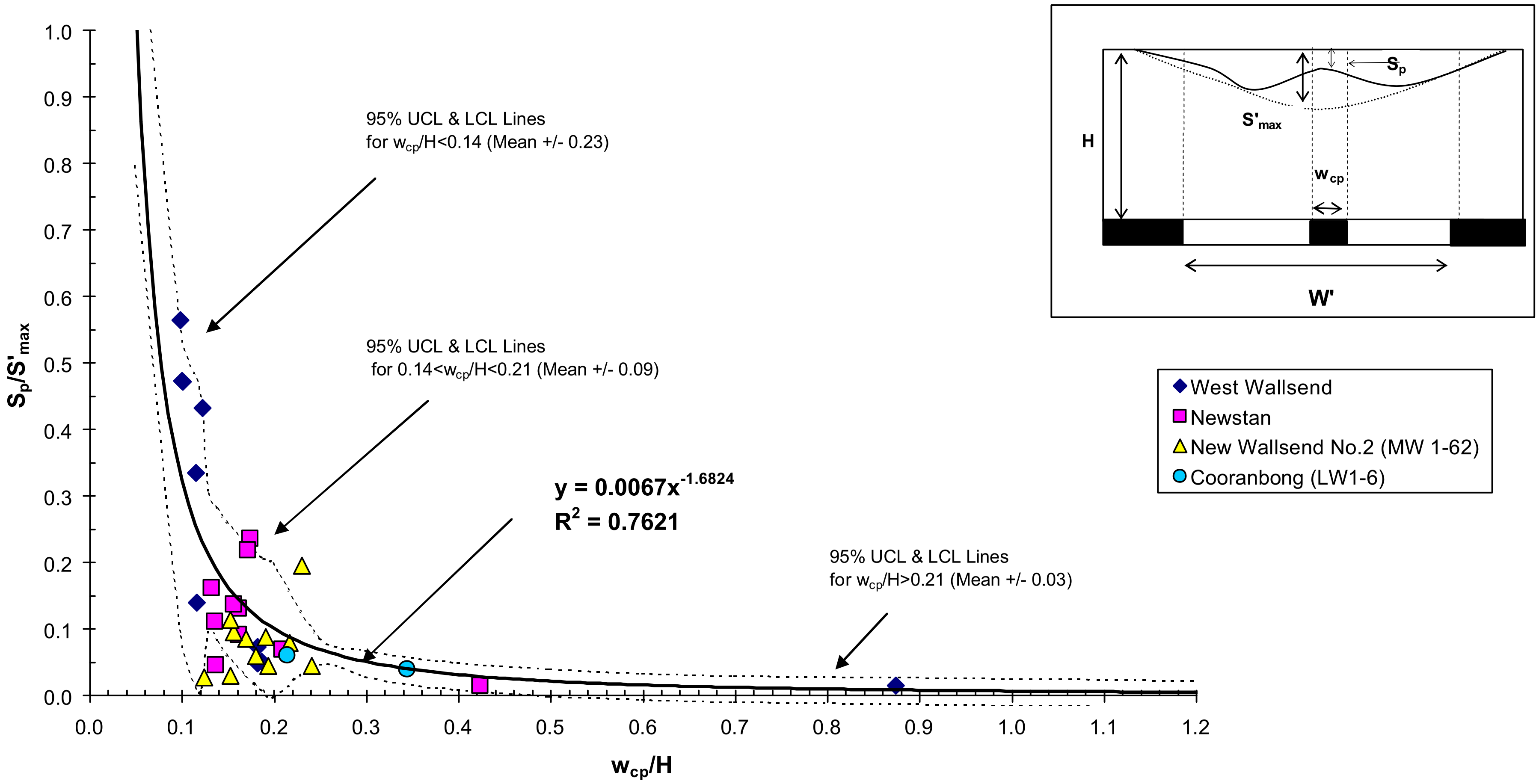
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	STRATA ENGINEERING (Australia) Pty Ltd
DRAWN:	S.Ditton			
DATE:	1/12/2002	TITLE:	Predicted Subsidence, Tilt & Strain Crossline Profiles for Multiple Longwall Panels	FIGURE: A12
SCALE:	NTS			



ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	5/12/2002	TITLE:	Strata Unit Thickness and SRP vs. Panel Width for a Depth Range of 151 to 250 m - Worked Example	FIGURE: A13
SCALE:	NTS			

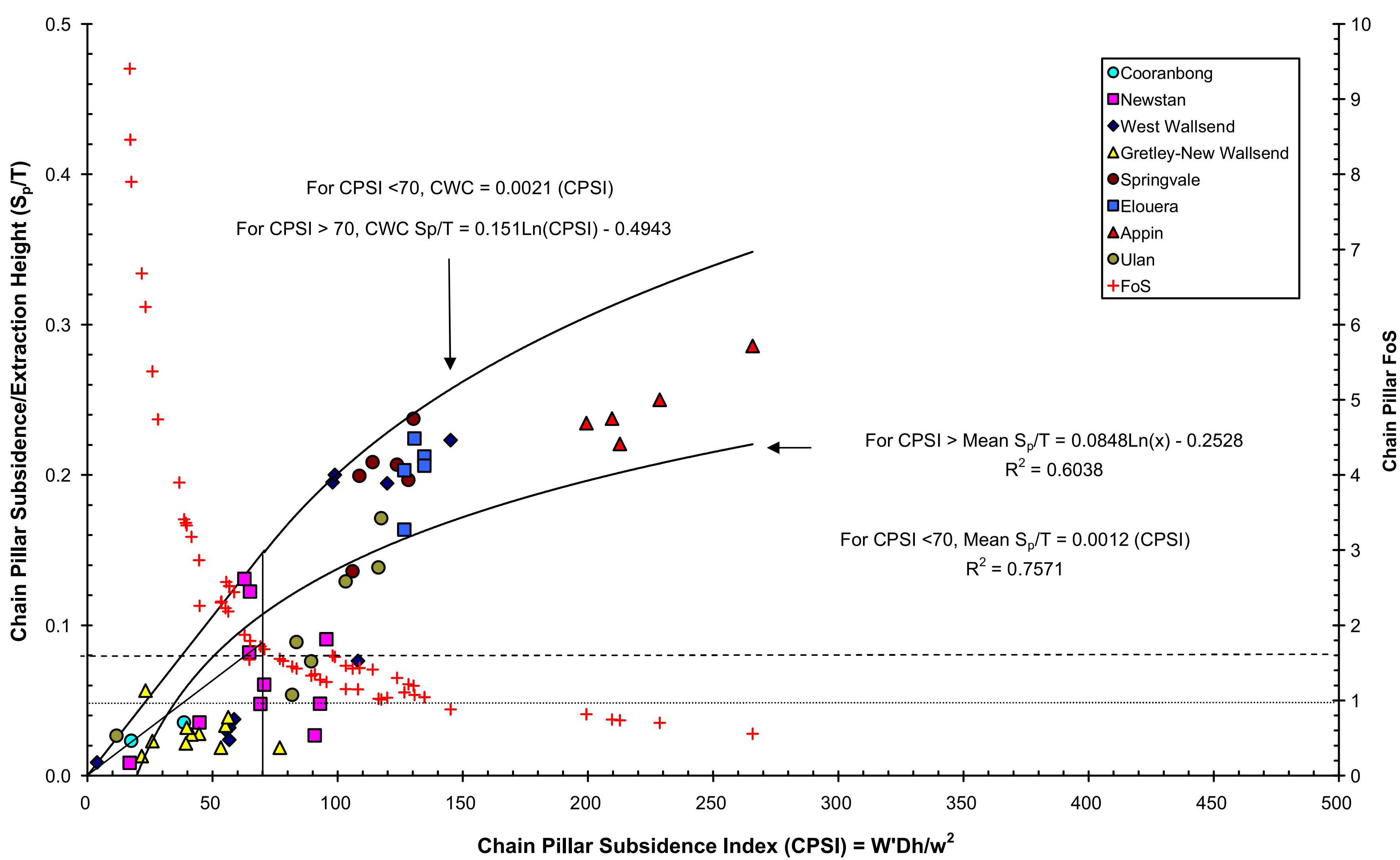


ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**
DRAWN:	S.Ditton		00-181-ACR/1	**(Australia) Pty Ltd**
DATE:	5/12/2002	TITLE:	Smax /T vs. W/H for a Depth Range of 151 to 250 m	FIGURE:
SCALE:	NTS		(Newcastle Coalfield) - Worked Example	A14

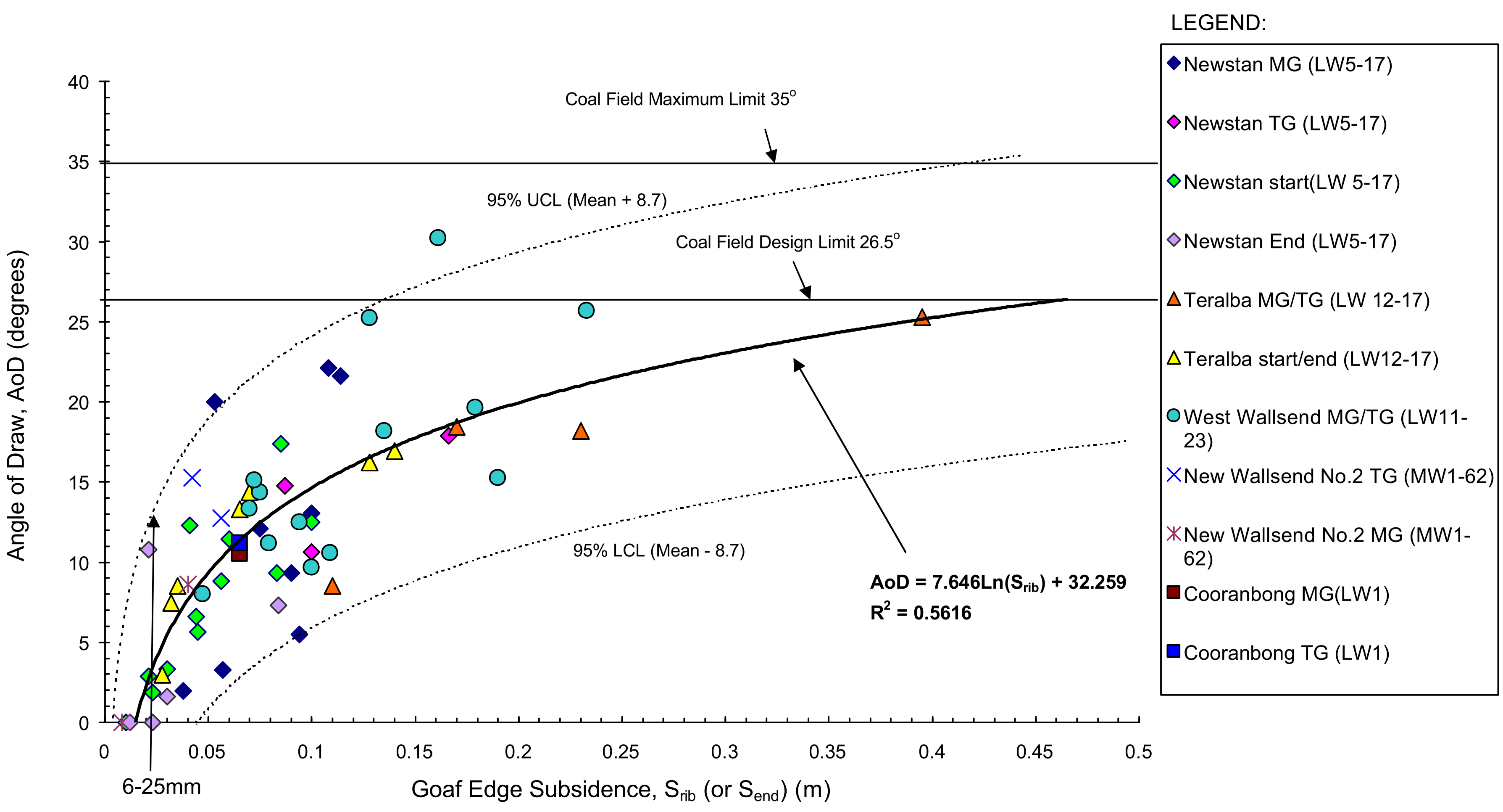


Note :
1. S'_{max} determined from Single Panel S_{max}/T using W'/H ratio for two adjacent panels.
2. UCL & LCL are upper and lower confidence limits

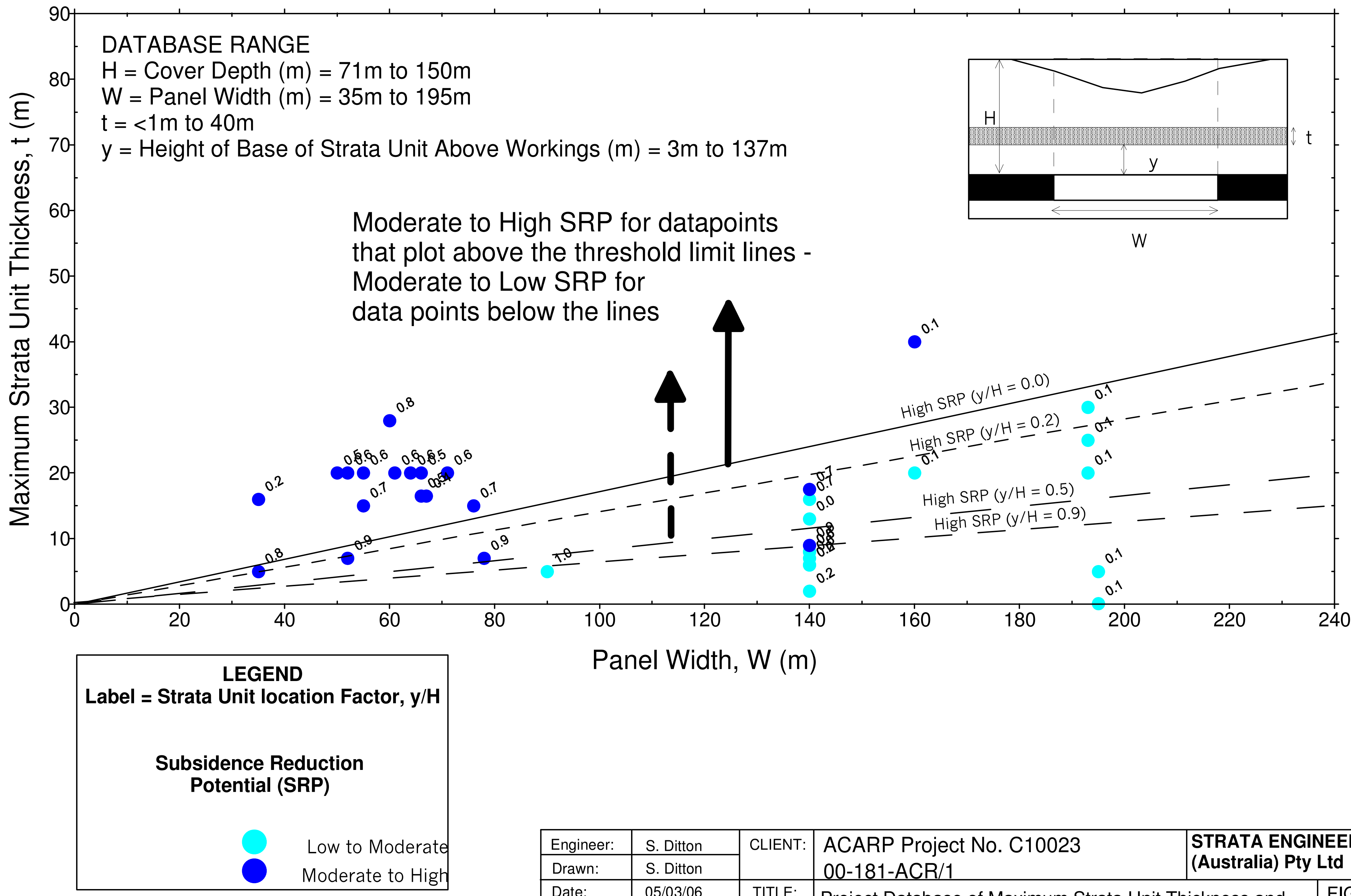
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**
DRAWN:	S.Ditton		00-181-ACR/1	**(Australia) Pty Ltd**
DATE:	30/04/03	TITLE:	2003 Empirical Model for Predicting Subsidence Above	FIGURE:
SCALE:	NTS		Chain Pillars Subject to Double Abutment Loading	A15



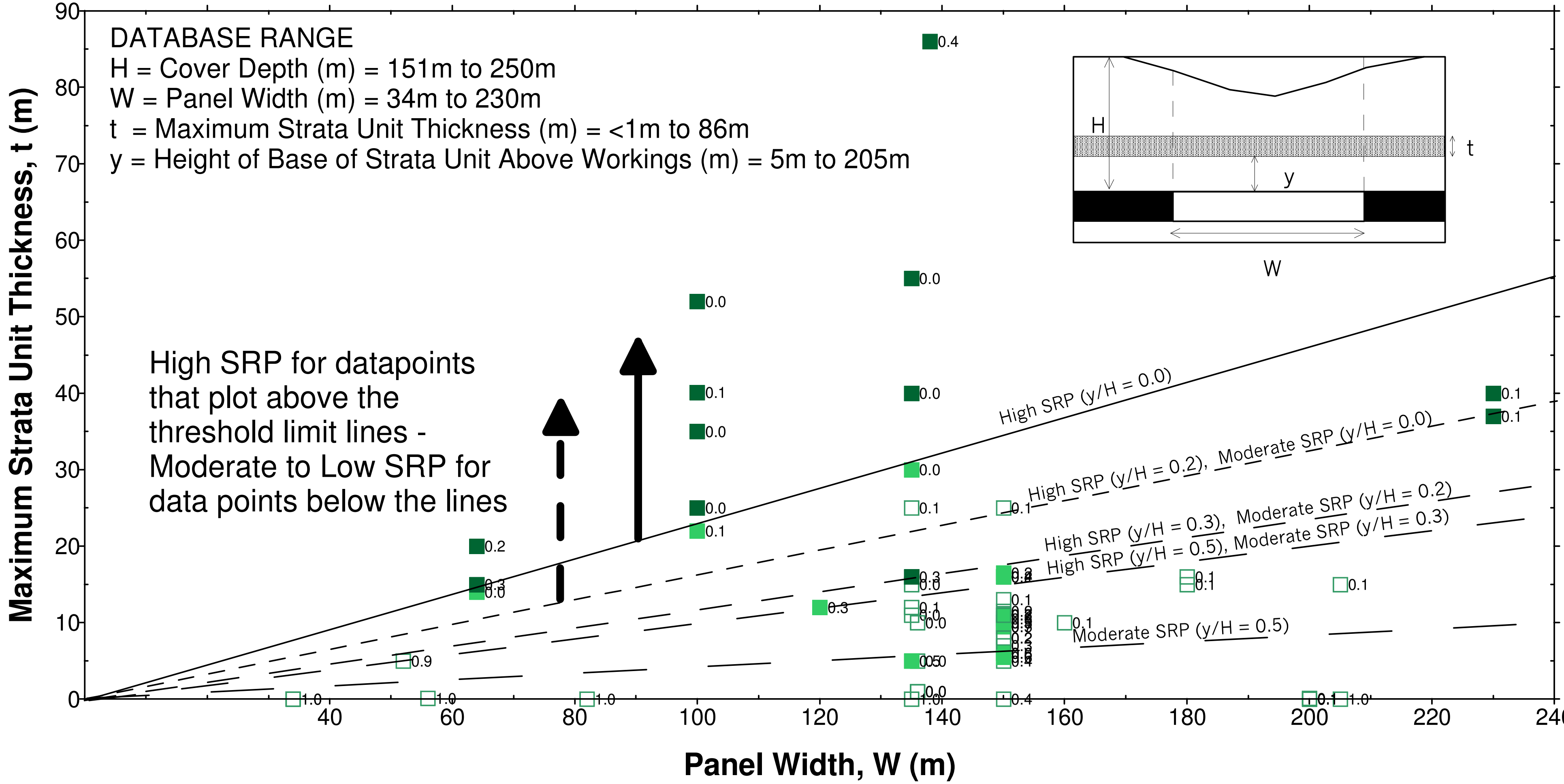
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**	
DRAWN:	S.Ditton		00-181-ACR/1	**(Australia) Pty Ltd**	
DATE:	7/09/2006	TITLE:	2006 Empirical Model for Predicting Subsidence Above		FIGURE
SCALE:	NTS		Chain Pillars Subject to Double Abutment Loading		A16



ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		00-181-ACR/1	
DATE:	22/11/2002	TITLE:	Empirical Prediction Model for LW Panel Angle of Draw for Newcastle Coalfield	FIGURE: A17
SCALE:	NTS			



Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	**STRATA ENGINEERING (Australia) Pty Ltd**
Drawn:	S. Ditton			
Date:	05/03/06	TITLE:	Project Database of Maximum Strata Unit Thickness and SRP Threshold Limit Lines for H = 70 to 150 m	FIGURE A18
Scale:	NTS			

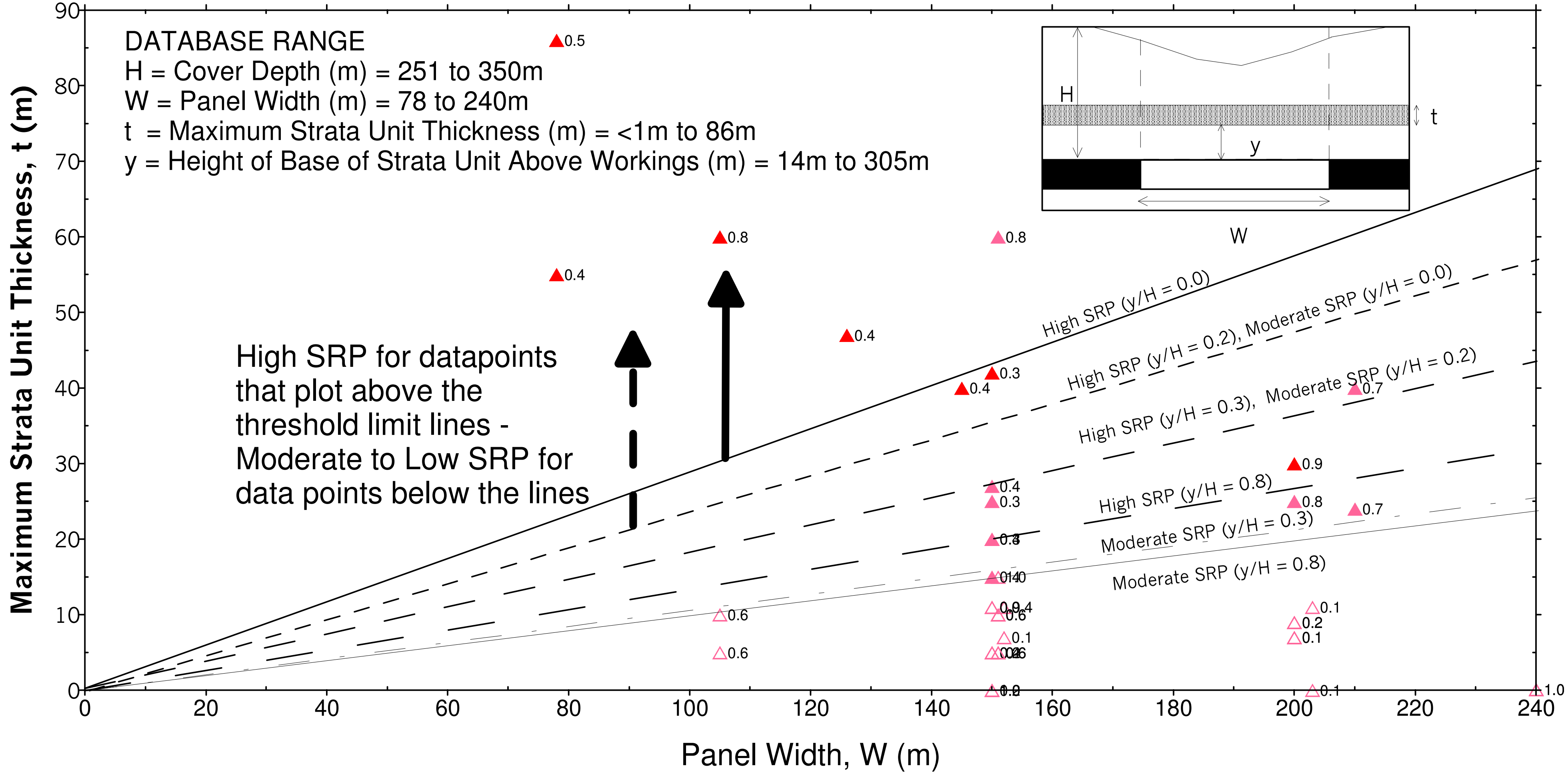


LEGEND
Label = Strata Unit Location Factor, y/H

Subsidence Reduction Potential (SRP)

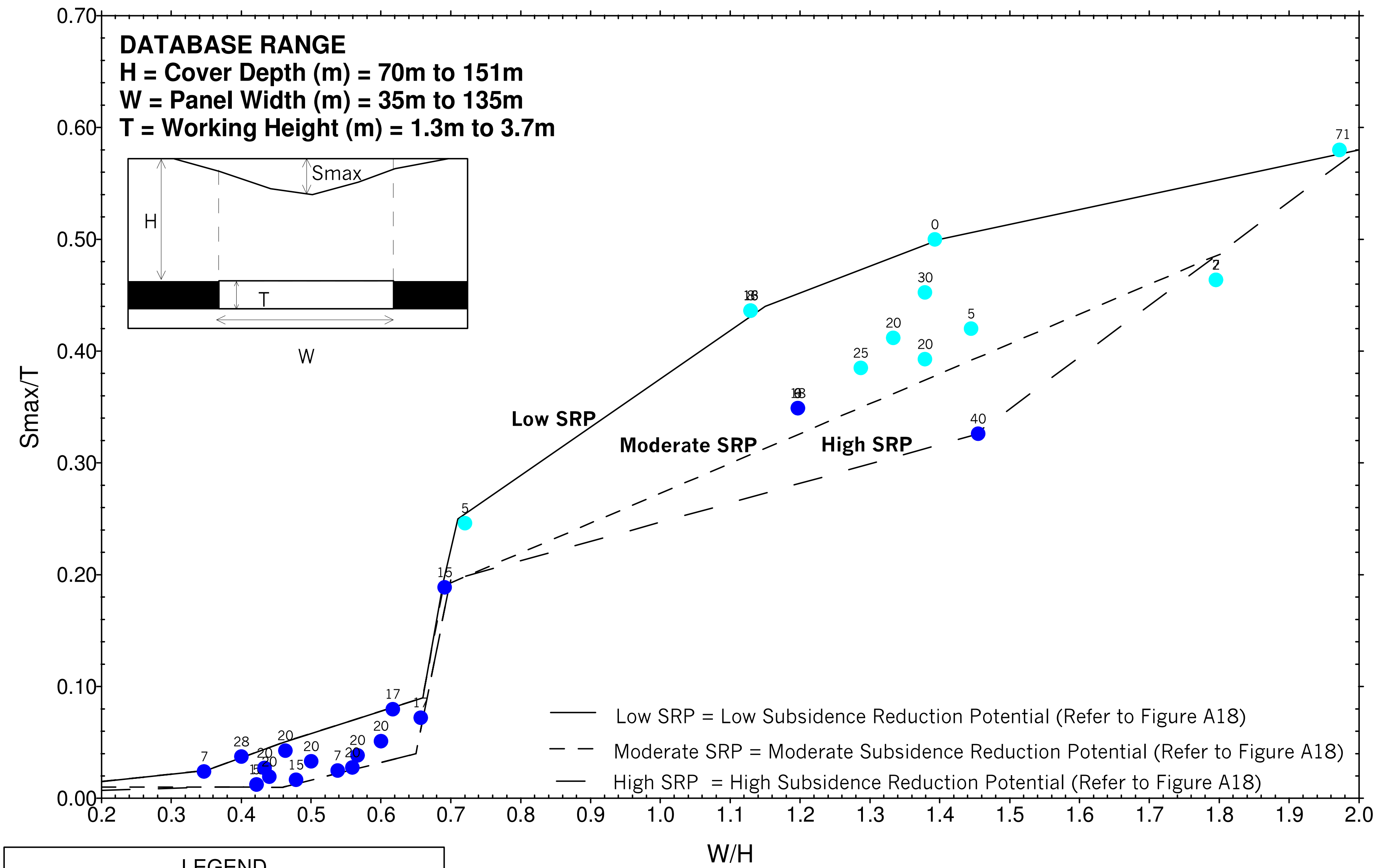
- Low
- Moderate
- High

Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1		**STRATA ENGINEERING (Australia) Pty Ltd**
Drawn:	S. Ditton				
Date:	05/03/06	TITLE:	Project Database of Maximum Strata Unit Thickness and SRP Threshold Limit Lines for H = 151 to 250 m		FIGURE A19
Scale:	NTS				



LEGEND			
Label = Strata Unit Location Factor, y/H			
Subsidence Reduction Potential (SRP)			
Low			
Moderate			
High			

Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	**STRATA ENGINEERING (Australia) Pty Ltd**
Drawn:	S. Ditton			
Date:	05/03/06	TITLE:	Project Database of Maximum Strata Unit Thickness and SRP Threshold Limit Lines for H = 251 to 350 m	FIGURE A20
Scale:	NTS			



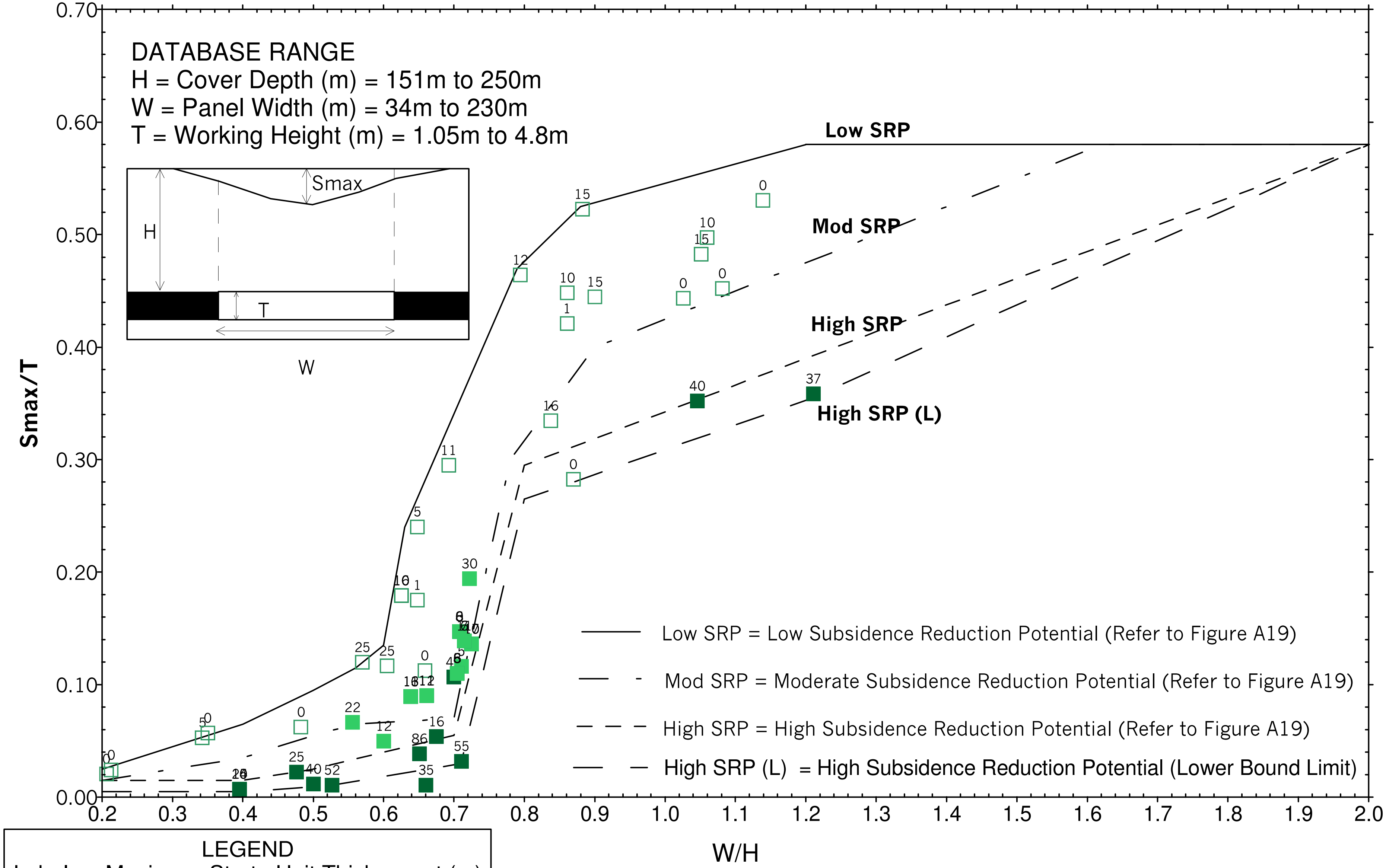
LEGEND
Label = Maximum Strata Unit Thickness, t (m)

Subsidence Reduction Potential (SRP)

Low to Moderate

Moderate to High

Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	**STRATA ENGINEERING (Australia) Pty Ltd**
Drawn:	S. Ditton			
Date:	05/03/06	TITLE:	Project Database of Single Panel Subsidence Linked to the SRP Threshold Limit Lines for H = 70 to 150 m	FIGURE A21
Scale:	NTS			

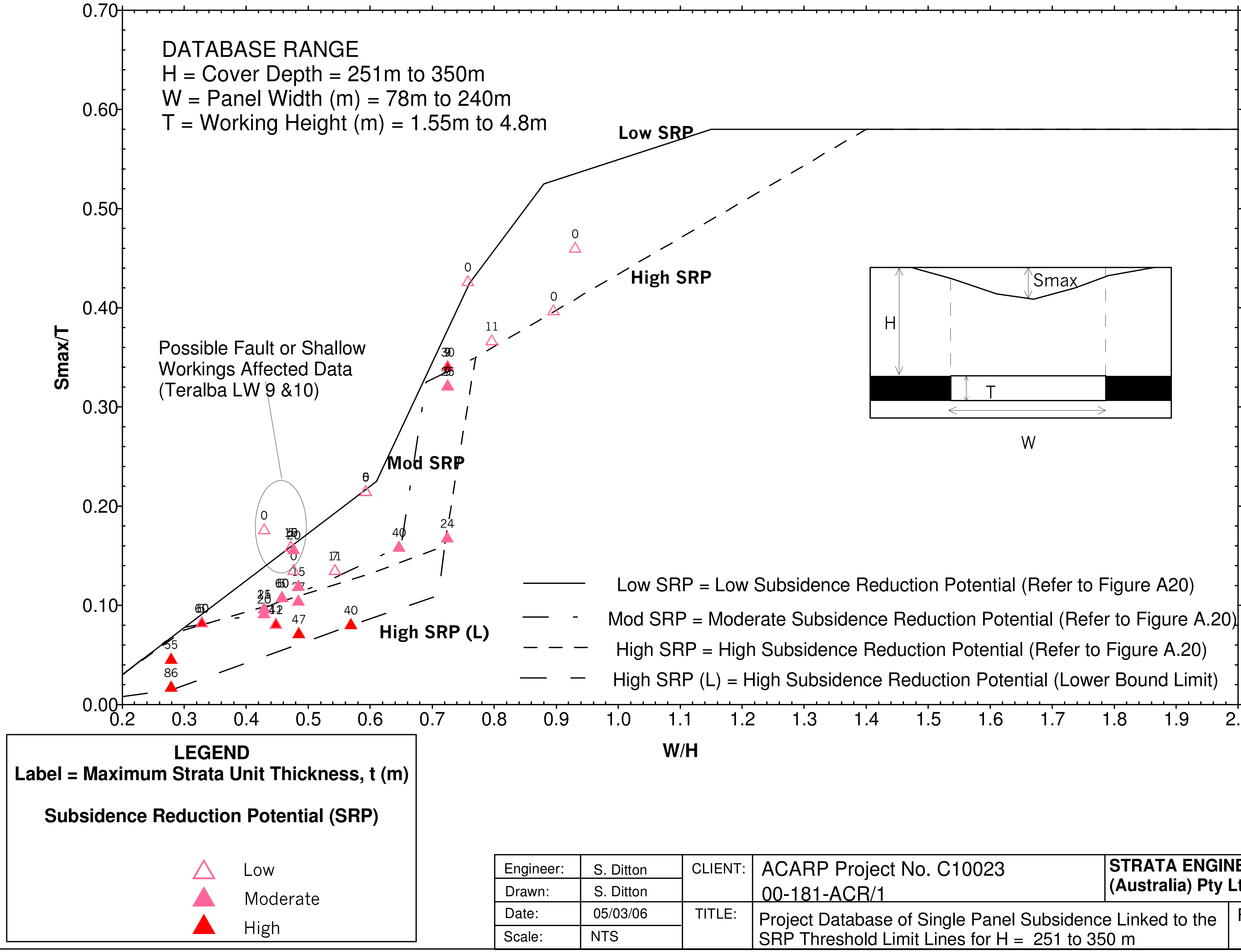


LEGEND
Labels = Maximum Strata Unit Thickness, t (m)

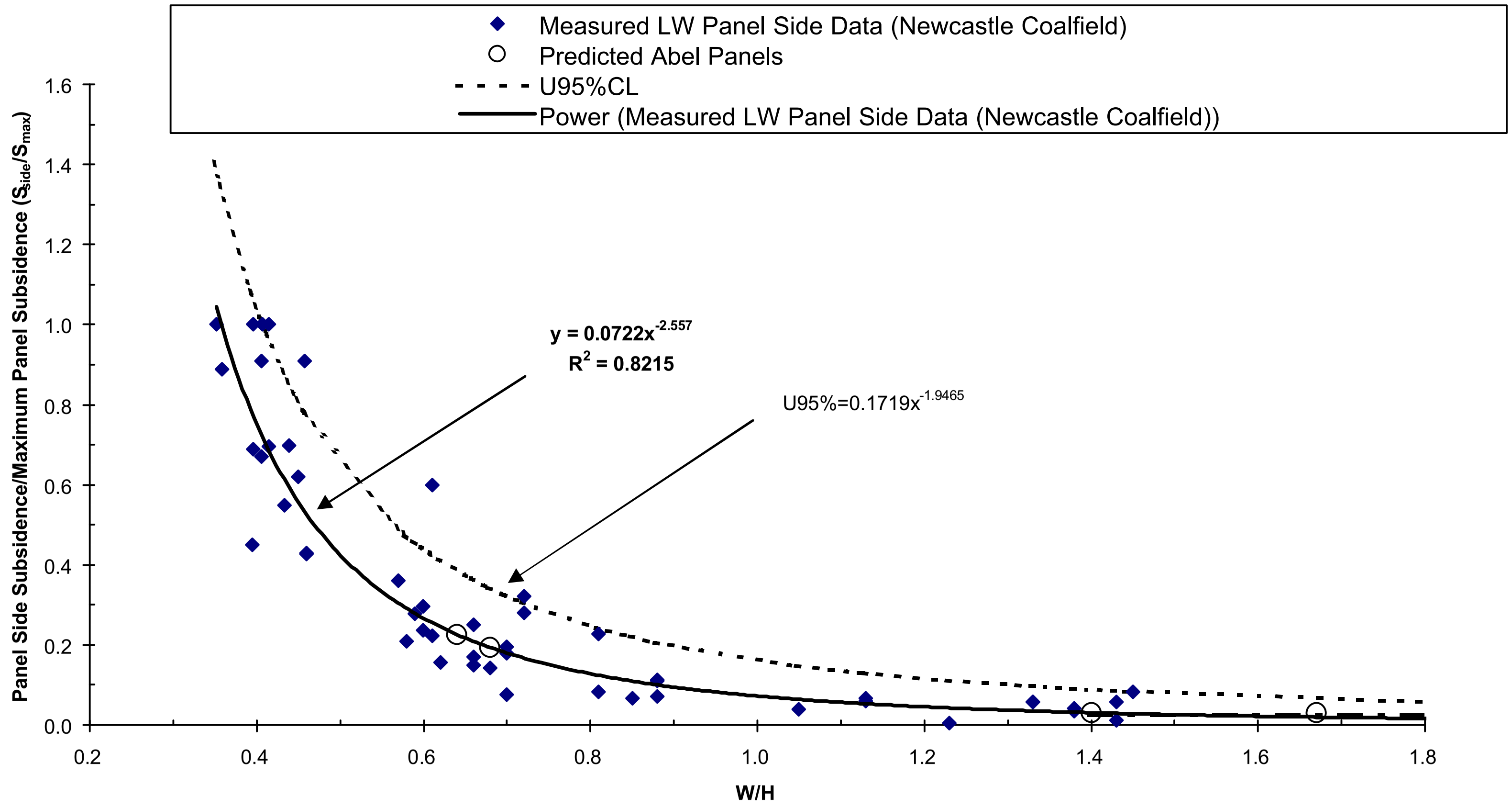
Subsidence Reduction Potential (SRP)

Low
Moderate
High

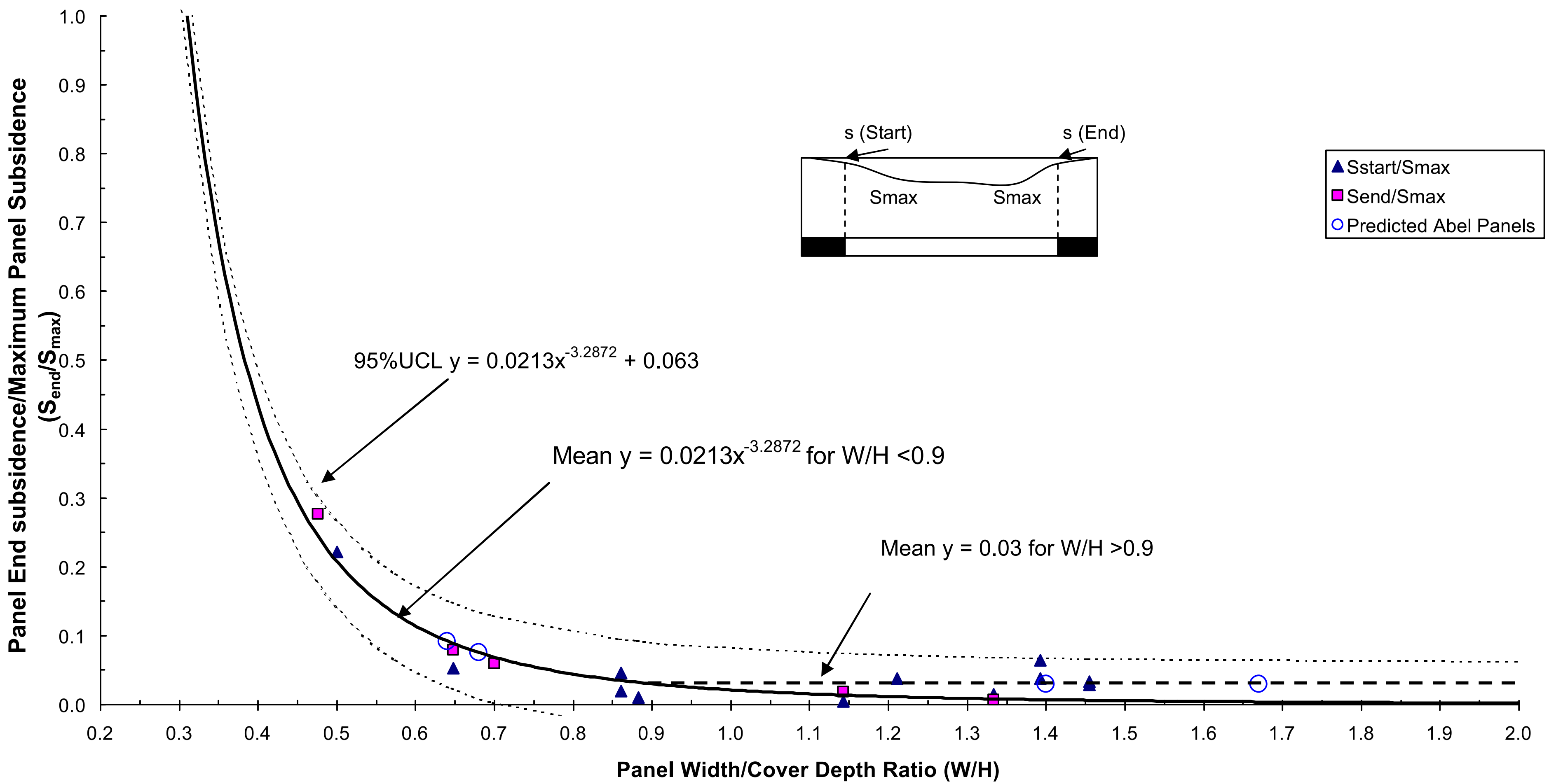
Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S. Ditton			
Date:	05/03/06	TITLE:	Project Database of Single Panel Subsidence Linked to the SRP Threshold Limit Lines for H = 151 to 250 m	FIGURE A22
Scale:	NTS			



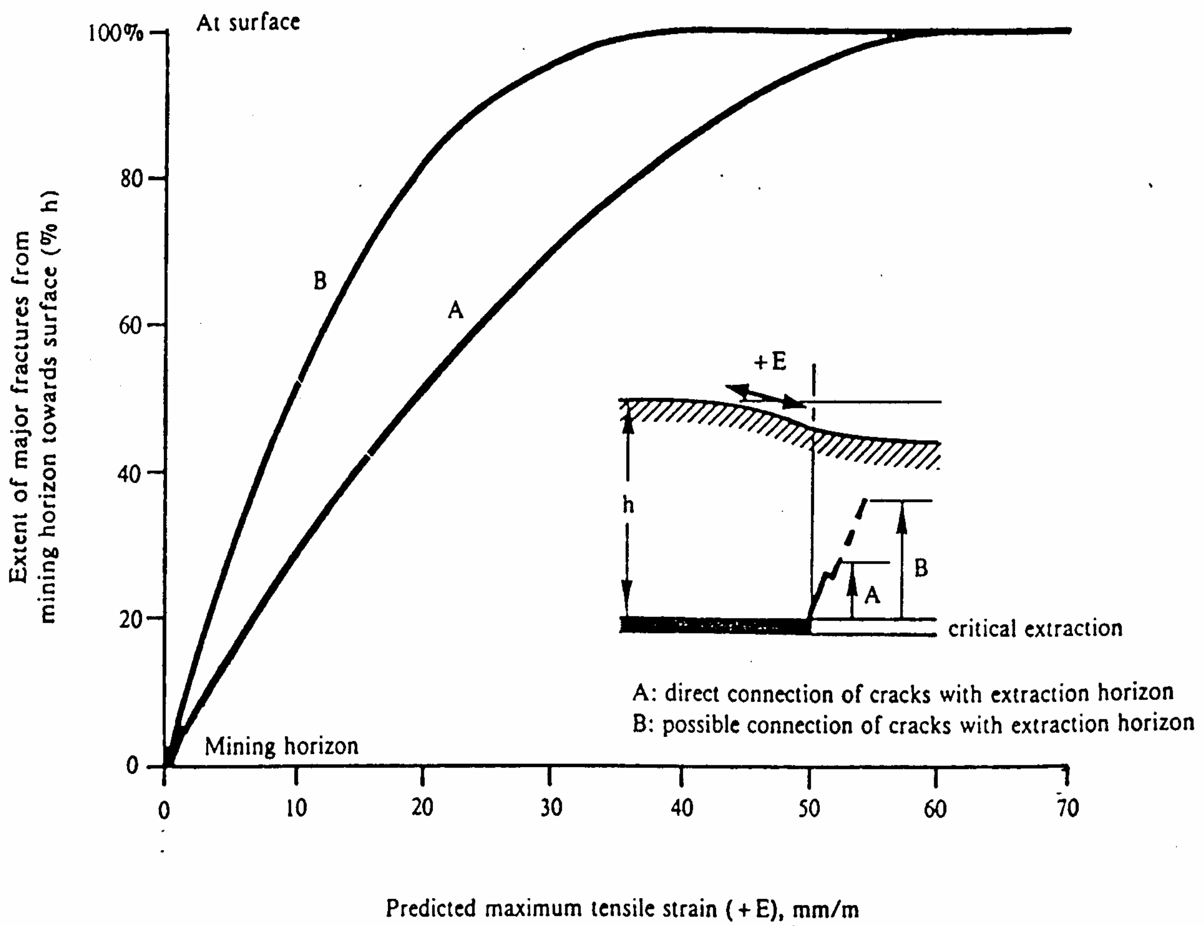
Engineer:	S. Ditton	CLIENT:	ACARP Project No. C10023 00-181-ACR/1	**STRATA ENGINEERING (Australia) Pty Ltd**	
Drawn:	S. Ditton				
Date:	05/03/06	TITLE:	Project Database of Single Panel Subsidence Linked to the SRP Threshold Limit Lines for H = 251 to 350 m		FIGURE A23
Scale:	NTS				



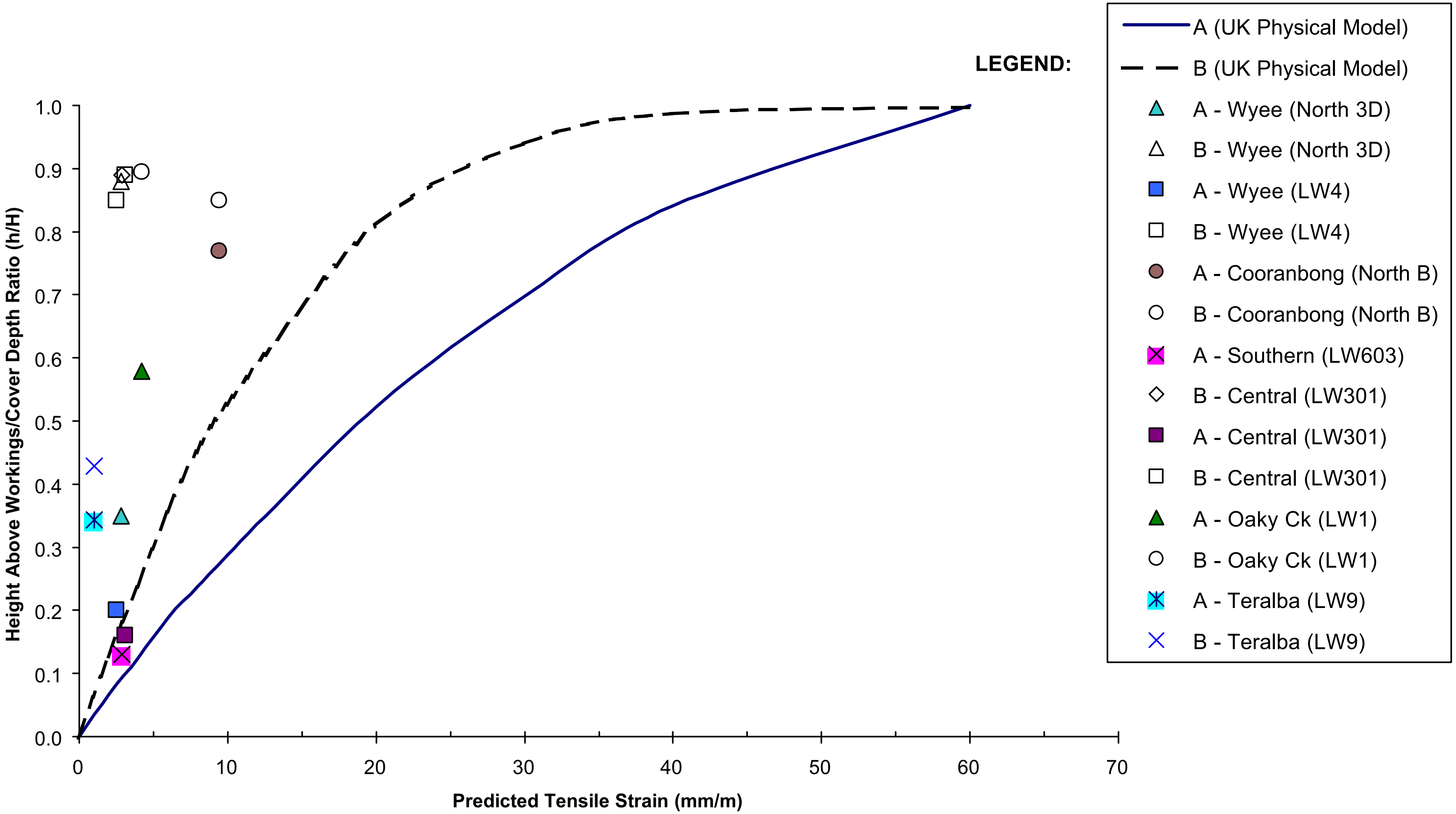
ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		00-181-ACR/1	
DATE:	7/02/2006	TITLE:	Empirical Prediction Model for Goaf Edge Subsidence Prediction Above Panel Crossline	FIGURE: A24
SCALE:	NTS			



ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**
DRAWN:	S.Ditton		00-181-ACR/1	**(Australia) Pty Ltd**
DATE:	7/02/2006	TITLE:	Empirical Prediction Model for Goaf Edge Subsidence	FIGURE:
SCALE:	NTS		Prediction Above End of Panel Centreline	A25



ENGINEER:	S. Ditton	CLIENT:	ACARP Project No. C10023	**STRATA ENGINEERING**
DRAWN:	S. Ditton		Subsidence Prediction Review	**(Australia) Pty Ltd**
DATE:	23/09/2002	TITLE:	Empirically Based Sub-Surface Fracturing Model	FIGURE:
SCALE:	NTS		Presented in Whittaker & Reddish (1989)	**A26**

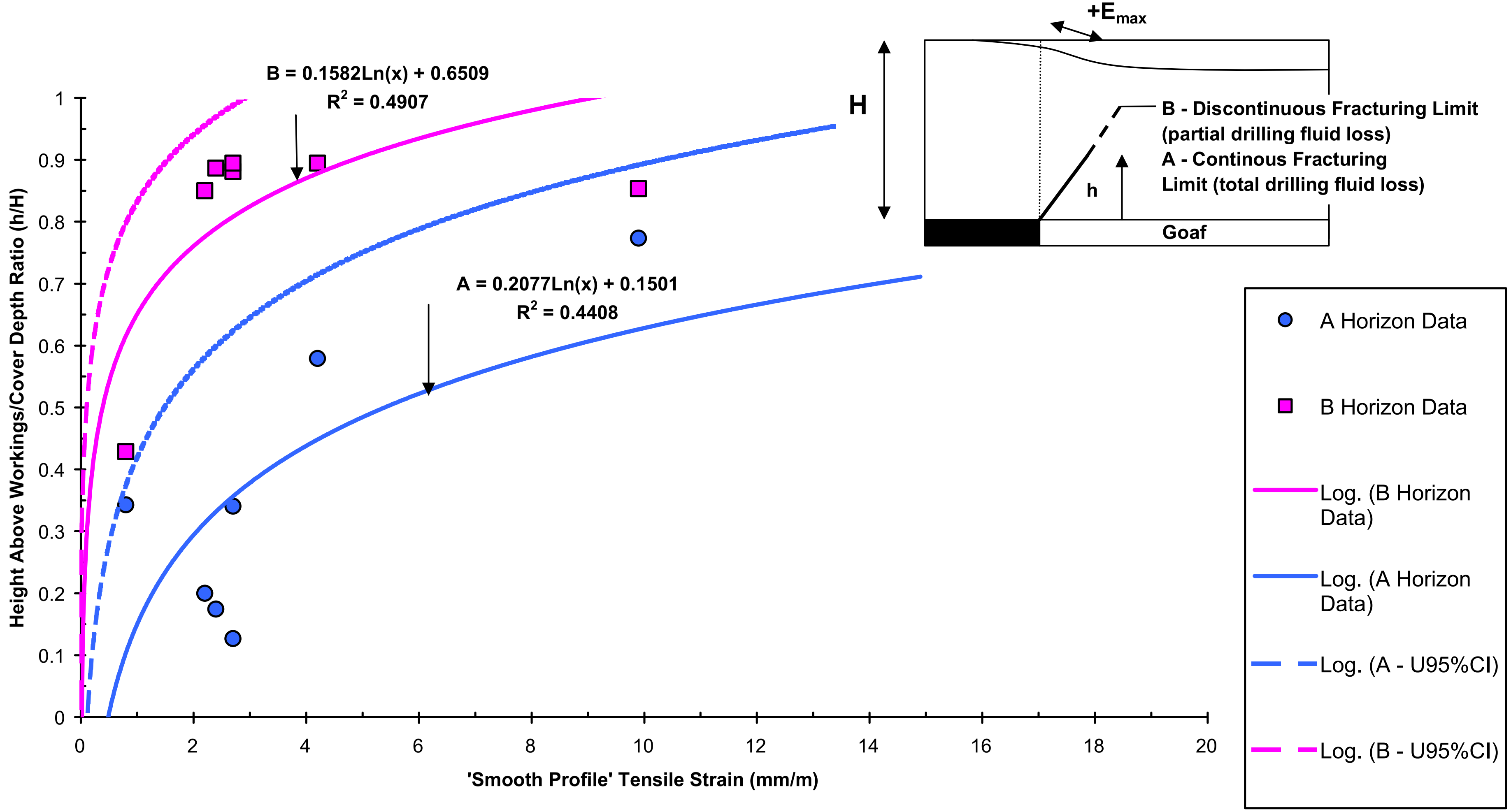


<u>Legend Key</u>

A - Maximum Continuous Fracturing Height

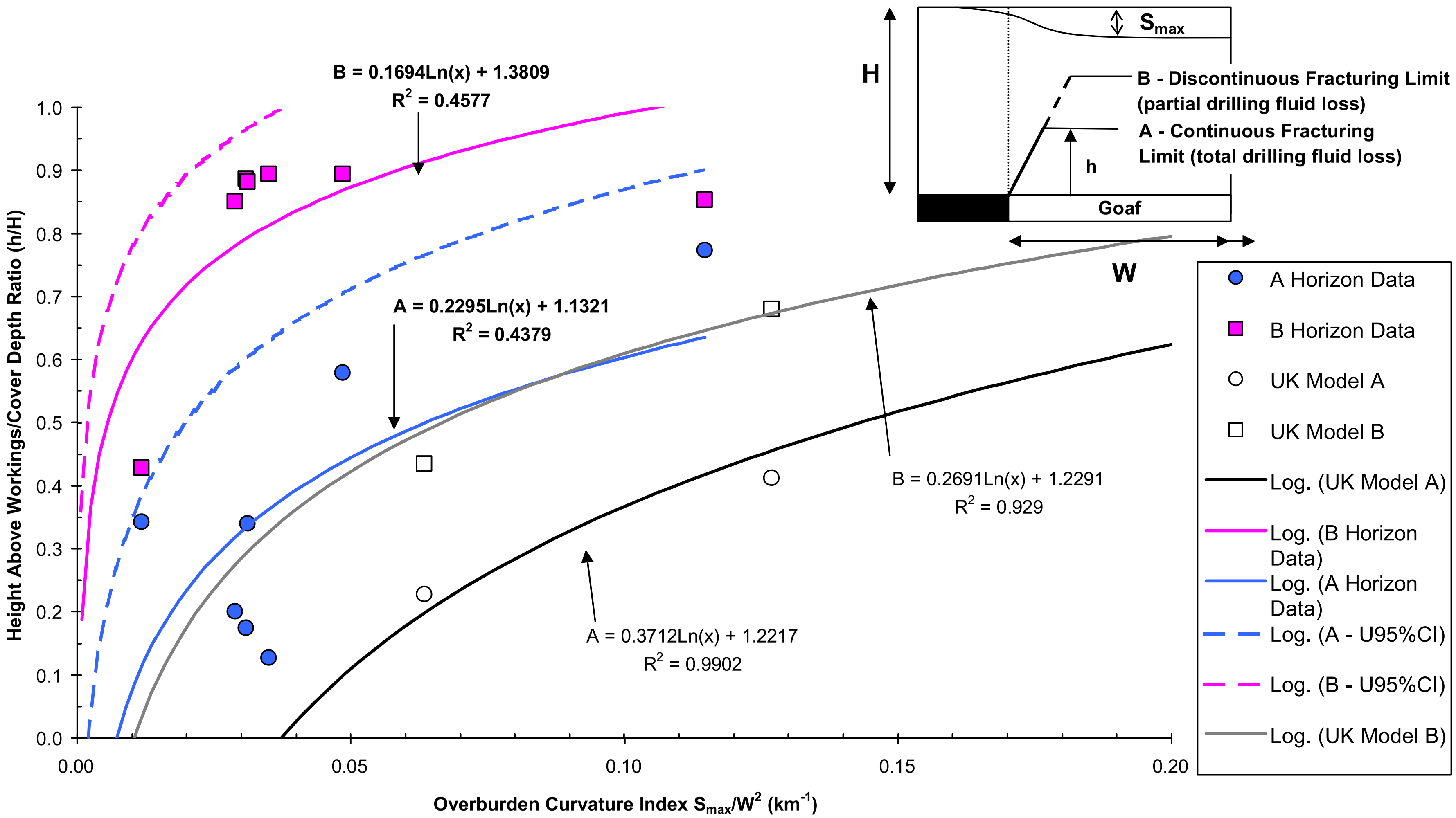
B - Maximum Discontinuous Fracturing Height

ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023 Subsidence Prediction Review	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	4/02/2003	TITLE:	Whittaker and Reddish Physical Sub-Surface Fracture Model and Australian Drilling Data Above Extracted LWs	FIGURE: **A27**
SCALE:				



NOTE : Based on drilling fluid losses over goafed areas

ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023 Subsidence Prediction Review	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	4/02/2003	TITLE:	Empirical Sub-Surface Fracture Height Above a Longwall Panel Based on Maximum Tensile Strain (Smooth Profiles)	FIGURE: **A28**
SCALE:				



ENGINEER:	S.Ditton	CLIENT:	ACARP Project No. C10023 Subsidence Prediction Review	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	4/02/2003	TITLE:	Empirical Prediction Model for Sub-Surface Fracture Height Above a LW Panel Based on S_{max}/W^2 (Curvature Index)	FIGURE: **A29**
SCALE:				

APPENDIX B

Aboriginal Artefact Sites and Rock Shelter Location Details

Moolarben UG 4
Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Exfoliation	Weathering	Aspect	Height (m)	Width (m)	Depth (m)	Deposit
10/11/2005		UG4 T1	nil									
10/11/2005		UG4 T2	nil									
10/11/2005		UG4 T3	nil									
10/11/2005	1	UG4 T4	MC1	763261	6430141	moderate	moderate	West	5.5	31	6.6	140 - 250 mm
10/11/2005	2	UG4 T4	MC2	763339	6430233	low	moderate	Northwest	5	39.8	5.7	30 - 150 mm
11/11/2005	3	UG4 T4	MC4	763740	6429836	nil	not recorded	SSW	0.9	5.1	1.65	590mm at dripline
11/11/2005	4	UG4 T4	MC8	763673	6429849	moderate	high	South	3	8.5	2.6	400mm at dripline
11/11/2005	5	UG4 T4	MC10	763496	6429968	low	moderate	South	3	17	4.2	> 750mm
14/11/2005	6	UG4 T4	MC11	763397	6430325			South	4.5	19.3	2.8	
14/11/2005	7	UG4 T4	PAD_1	763564	6430390	low	high	Northwest	1.2	3.1	4.5	600mm at dripline, not taken inside shelter due to snake
10/11/2005	8	UG4 T4	RS1	763288	6430166.121	high	not noted	Northwest	3.5	16.6	3.5	shallow
10/11/2005	9	UG4 T4	RS2	763299	6430184.589	high	not noted	Northwest	5	25.5	4	shallow
10/11/2005		UG4 T4	RS3			skipped in sequence						
10/11/2005	10	UG4 T4	RS4	763698	6429880							
10/11/2005	11	UG4 T4	RS5	763779	6429849	high	not noted	South	4	13.5		500mm
11/11/2005	12	UG4 T4	RS6	763724	6429929	low	not noted	W	1.2	3.1	1.4	500mm at dripline
11/11/2005	13	UG4 T4	RS7	763625	6429911	low	moderate	SW	2	7.3	2.2	none - rock
11/11/2005	14	UG4 T4	RS8	763520	6429965	high	low	S	0.9	8.6	1.4	>75mm
11/11/2005	15	UG4 T4	RS9	763481	6429978	low	high	S	4	7	3.2	none - rock
11/11/2005	16	UG4 T4	RS10	763620	6429917	high	high	S	6	13.4	21.8	sandy deposit over rock
11/11/2005	17	UG4 T4	RS11	763512	6429960	high	high	S	7.5	23.6	4.7	none - rock
11/11/2005	18	UG4 T4	RS12	763486	6429967	moderate	moderate	S	3.5	22	3.9	shallow
11/11/2005	19	UG4 T4	RS13	763366	6429951	high	moderate	S	6.7	14.5	3.8	shallow
11/11/2005	20	UG4 T4	RS14	763339	6429990	low	not noted	SE	5	23.5	7.6	none - rock
11/11/2005	21	UG4 T4	RS15	763341	6429993	high	not noted	S	10	15	9	none - rock
11/11/2005	22	UG4 T4	RS16	763274	6430006	low	not noted	SW	5	17	9	none - rock
14/11/2005	23	UG4 T4	RS17	763371	6430260							
14/11/2005	24	UG4 T4	RS18	763397	6430294	high	not noted	Northwest	3	7.8	1.17	465mm at rear of shelter
14/11/2005	25.1	UG4 T4	RS19 (a)	763499	6430394	low	not noted	North	3.5	8.9	5.3	shallow
14/11/2005	25.2	UG4 T4	RS19 (b)	763499	6430394	low	not noted	North	2	11.2	3	none - rock
14/11/2005	26	UG4 T4	RS20	763551	6430383	high	high	Northwest	2	8.9	1.5 - 2.7	none - rock
14/11/2005	27	UG4 T4	RS21	763571	6430394	low	low	Northwest	1.6	6.1	5.4	none - rock
14/11/2005	28	UG4 T4	RS22	763611	6430394	high	high	North	2	6.4	1.9	shallow
19/11/2005	29	UG4 T5	RS1	762687	6429669	low	moderate	NE	2.2	2	1.8	rock at rear and dripline
19/11/2005	30	UG4 T5	RS2	762692	6429684	low	moderate	E	1.2	3.4	2.7	rock at rear and dripline
19/11/2005	31	UG4 T5	RS3	762694	6429657	low	low	NE	1	2.5	2.5	rock at rear and dripline
19/11/2005	32	UG4 T5	RS4	762812	6429640.201	moderate	moderate	S	2.5	2.6	2.6	40mm at rear, 60mm at dripline
19/11/2005	33	UG4 T5	RS5	762742	6429712.32	moderate	moderate	SW	2	5	1.9	rock at rear and dripline
19/11/2005	34	UG4 T5	RS6	762663	6429813.622	low	low	SW	1.8	5	3	rock at rear and dripline
19/11/2005	35	UG4 T5	RS7	762653	6429833.48	moderate	low	W	1.5	4.5	2.4	rock at rear and dripline
19/11/2005	36	UG4 T5	RS8	762644	6429891.52	high	moderate	W	2.6	5.5	5.5	30mm at dripline, rock at rear
19/11/2005	37	UG4 T5	RS9	762644	6429917.111	low	moderate	W	2	11	2.5	30mm at rear, 90mm at drip
19/11/2005	38	UG4 T5	RS10	762897	6429666.655	low	moderate	NW	1	3	2.2	350mm at rear, 180mm at dripline
19/11/2005	39	UG4 T5	RS11	762642	6429982.397	moderate	moderate	W	2.5	7.6	2	200mm at rear, 40mm at drip
19/11/2005	40	UG4 T5	RS12	762663	6430059.336	high	low	S	2.8	4	2.9	200mm at rear, 250mm at dripline
19/11/2005	41	UG4 T5	RS13	762650	6430059.843	moderate	moderate	N	1.4	2.8	2.5	rock at rear and dripline
19/11/2005	42	UG4 T5	RS14	762646	6430099.065	high	moderate	W	2	4.6	2.8	60mm at rear, 230mm at dripline
19/11/2005	43	UG4 T5	RS15	762644	6430122.725	moderate	moderate	W	2	3.8	2	80mm at rear, 60mm at dripline
19/11/2005	44	UG4 T5	RS16	762632	6430205.657	high	moderate	W	2	4	2	rock at rear and dripline
19/11/2005	45	UG4 T5	RS17	762624	6430212.683	low	low	W	2	3.8	1.6	rock at rear and dripline
19/11/2005	46	UG4 T5	RS18	762506	6430235.333	high	moderate	NE	1.6	3.9	2.1	rock at rear, 140mm/ 120mm at dripline
19/11/2005	47	UG4 T5	RS19	762533	6430119.267	moderate	high	E	1.5	11	2.5	360mm at rear, 230mm at drip
19/11/2005	48	UG4 T5	RS20	762526	6430090.62	high	low	E	2.6	6	2	70mm at rear and dripline
19/11/2005	49	UG4 T5	RS21	762548	6430048.075	low	high	NW	1	3.5	4.4	35mm at back, 250mm at dripline
19/11/2005	50	UG4 T5	RS22	762558	6430037.635	low	high	E	2	2	3	40mm at rear and dripline
19/11/2005	51	UG4 T5	RS23	762621	6429813	moderate	moderate	E	1.2	3	2.5	60mm at rear, 80mm at dripline
19/11/2005	52	UG4 T5	RS24	762638	6429725.442	moderate	moderate	NE	1.4	4	1.8	80mm at rear, 150mm at dripline
19/11/2005	53	UG4 T5	RS25	762620	6429753.234	high	moderate	N	0.8	4	2	40mm at rear, 50mm at dripline
19/11/2005	54	UG4 T5	RS26	762583	6429827.906	low	moderate	SW	1.3	7	2.7	rock at rear and dripline
19/11/2005	55	UG4 T5	RS27	762579	6429866.691	low	moderate	E	0.8	3.8	2.2	200mm at rear, 150mm at dripline
19/11/2005	56	UG4 T5	RS28	762570	6429946.039	moderate	high	E	2.5	5.2	1.7	50mm at rear, 200mm at dripline
19/11/2005	57	UG4 T5	RS29	762574	6429961.742	moderate	low	E	1	2.5	2	60mm at rear, 70mm at dripline
19/11/2005	58	UG4 T5	RS30	762550	6430007.799	moderate	moderate	NE	2.1	3.1	2.1	rock at rear, 50mm at dripline
19/11/2005	59	UG4 T5	RS31	762559	6430010.21	low	high	E	1.8	4	1	150mm at rear, 70mm at dripline
19/11/2005	60	UG4 T5	RS32	762538	6430060.685	low	moderate	E	1.4	3.7	1.3	rock at rear and dripline
19/11/2005	61	UG4 T5	RS33	762499	6430202.349	moderate	low	E	1	4	2	rock at rear and dripline
19/11/2005	62	UG4 T5	RS34	762487	6430326	high	low	NE	0.6	2	3	rock at rear and dripline
19/11/2005	63	UG4 T5	RS35	762470	6430345	low	high	NE	2.5	6	2.5	rock at rear and dripline

Moolarben UG 4
Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Moisture	Animal Activity
10/11/2005		UG4 T1	nil				
10/11/2005		UG4 T2	nil				
10/11/2005		UG4 T3	nil				
10/11/2005	1	UG4 T4	MC1	763261	6430141	nil	no
10/11/2005	2	UG4 T4	MC2	763339	6430233	nil	no
11/11/2005	3	UG4 T4	MC4	763740	6429836	nil	yes - wombat hole at rear of shelter
11/11/2005	4	UG4 T4	MC8	763673	6429849	nil	no
11/11/2005	5	UG4 T4	MC10	763496	6429968	yes - back of shelter, western end & at ground level. Twigs & branches in shelter & animal scat. Floor is flat, sandy & discoloured	yes - wombat hole & 'roo camp in shelter
14/11/2005	6	UG4 T4	MC11	763397	6430325		yes - wombat holes
14/11/2005	7	UG4 T4	PAD_1	763564	6430390	nil	yes - snake track
10/11/2005	8	UG4 T4	RS1	763288	6430166.121	nil	no
10/11/2005	9	UG4 T4	RS2	763299	6430184.589	nil	no
10/11/2005		UG4 T4	RS3				
10/11/2005	10	UG4 T4	RS4	763698	6429880		
10/11/2005	11	UG4 T4	RS5	763779	6429849	nil	no
11/11/2005	12	UG4 T4	RS6	763724	6429929	nil	wombat
11/11/2005	13	UG4 T4	RS7	763625	6429911	damp in RHS (S/E) corner	no
11/11/2005	14	UG4 T4	RS8	763520	6429965	nil	animal activity
11/11/2005	15	UG4 T4	RS9	763481	6429978	nil	no
11/11/2005	16	UG4 T4	RS10	763620	6429917	nil	birds nests, goanna tracks, wallaby scat, insect tracks
11/11/2005	17	UG4 T4	RS11	763512	6429960	nil	no
11/11/2005	18	UG4 T4	RS12	763486	6429967	nil	wallaby, bird & lizard tracks
11/11/2005	19	UG4 T4	RS13	763366	6429951	nil	no
11/11/2005	20	UG4 T4	RS14	763339	6429990	nil	no
11/11/2005	21	UG4 T4	RS15	763341	6429993	nil	no
11/11/2005	22	UG4 T4	RS16	763274	6430006	nil	no
14/11/2005	23	UG4 T4	RS17	763371	6430260		
14/11/2005	24	UG4 T4	RS18	763397	6430294	nil	no
14/11/2005	25.1	UG4 T4	RS19 (a)	763499	6430394	yes - damp on roof, watermarks on rocks to west	no
14/11/2005	25.2	UG4 T4	RS19 (b)	763499	6430394	nil	no
14/11/2005	26	UG4 T4	RS20	763551	6430383	nil	no
14/11/2005	27	UG4 T4	RS21	763571	6430394	nil	no
14/11/2005	28	UG4 T4	RS22	763611	6430394	through ceiling and rear wall	wombat scat
19/11/2005	29	UG4 T5	RS1	762687	6429669	absent	no
19/11/2005	30	UG4 T5	RS2	762692	6429684	absent	no
19/11/2005	31	UG4 T5	RS3	762694	6429657	absent	no
19/11/2005	32	UG4 T5	RS4	762812	6429640.201	absent	no
19/11/2005	33	UG4 T5	RS5	762742	6429712.32	absent	no
19/11/2005	34	UG4 T5	RS6	762663	6429813.622	absent	no
19/11/2005	35	UG4 T5	RS7	762653	6429833.48	absent	no
19/11/2005	36	UG4 T5	RS8	762644	6429891.52	absent	no
19/11/2005	37	UG4 T5	RS9	762644	6429917.111	absent	no
19/11/2005	38	UG4 T5	RS10	762897	6429666.655	under front portion, behind dripline approx 20%	no
19/11/2005	39	UG4 T5	RS11	762642	6429982.397	absent	no
19/11/2005	40	UG4 T5	RS12	762663	6430059.336	absent	no
19/11/2005	41	UG4 T5	RS13	762650	6430059.843	absent	no
19/11/2005	42	UG4 T5	RS14	762646	6430099.065	absent	no
19/11/2005	43	UG4 T5	RS15	762644	6430122.725	absent	no
19/11/2005	44	UG4 T5	RS16	762632	6430205.657	absent	no
19/11/2005	45	UG4 T5	RS17	762624	6430212.683	50%	no
19/11/2005	46	UG4 T5	RS18	762506	6430235.333	through midsection via crack in rock, 10%	no
19/11/2005	47	UG4 T5	RS19	762533	6430119.267	absent	no
19/11/2005	48	UG4 T5	RS20	762526	6430090.62	absent	no
19/11/2005	49	UG4 T5	RS21	762548	6430048.075	absent	no
19/11/2005	50	UG4 T5	RS22	762558	6430037.635	absent	wombat holes at front
19/11/2005	51	UG4 T5	RS23	762621	6429813	absent	no
19/11/2005	52	UG4 T5	RS24	762638	6429725.442	within shelter, 30%	wasp nests
19/11/2005	53	UG4 T5	RS25	762620	6429753.234	absent	no
19/11/2005	54	UG4 T5	RS26	762583	6429827.906	absent	no
19/11/2005	55	UG4 T5	RS27	762579	6429866.691	absent	no
19/11/2005	56	UG4 T5	RS28	762570	6429946.039	back of shelter	snake track
19/11/2005	57	UG4 T5	RS29	762574	6429961.742	either side of shelter, 30%	no
19/11/2005	58	UG4 T5	RS30	762550	6430007.799	absent	wasp nests
19/11/2005	59	UG4 T5	RS31	762559	6430010.21	absent	no
19/11/2005	60	UG4 T5	RS32	762538	6430060.685	absent	no
19/11/2005	61	UG4 T5	RS33	762499	6430202.349	absent	no
19/11/2005	62	UG4 T5	RS34	762487	6430326	absent	no
19/11/2005	63	UG4 T5	RS35	762470	6430345	absent	no

Moolarben UG 4
Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Cultural Material	Comment	Photo #
10/11/2005		UG4 T1	nil					
10/11/2005		UG4 T2	nil					
10/11/2005		UG4 T3	nil					
10/11/2005	1	UG4 T4	MC1	763261	6430141	artefact scatter	recent fire (non-Aboriginal). Gently sloping from rear of shelter to flat at dripline. Moderate slope from dripline. Cojoins with RS1.	P_005; P_006
10/11/2005	2	UG4 T4	MC2	763339	6430233	isolated find	no discoloration of ground sediments. Oxidation of wall - possible ochre deposits?	P_007; P_008
11/11/2005	3	UG4 T4	MC4	763740	6429836	artefact scatter	floor is sand & flat. No cultural material found on shelf above shelter	P_010; P_011
11/11/2005	4	UG4 T4	MC8	763673	6429849	artefact scatter	moderate leaf litter & ground cover within shelter. Ground slopes down from west	P_013; P_014
11/11/2005	5	UG4 T4	MC10	763496	6429968	artefact scatter	active percolation at dripline on day of recording	P_016; P_017
14/11/2005	6	UG4 T4	MC11	763397	6430325	artefacts & charcoal associated with smaller wombat hole, north end of shelter	discolouration of roof above charcoal deposit/wombat hole	P_036; P_037; P_038
14/11/2005	7	UG4 T4	PAD_1	763564	6430390	no	high exfoliation outside shelter	P_042
10/11/2005	8	UG4 T4	RS1	763288	6430166.121	no	benching sandstone base. Adjoins RS1	P_002
10/11/2005	9	UG4 T4	RS2	763299	6430184.589	no	sloping sandstone benching floor. Brilliant colours in walls (oxidation). Cojoins with RS1	P_003
10/11/2005		UG4 T4	RS3					
10/11/2005	10	UG4 T4	RS4	763698	6429880			
10/11/2005	11	UG4 T4	RS5	763779	6429849	6 artefacts located on scope from dripline down towards track - MC3	flat floor	
11/11/2005	12	UG4 T4	RS6	763724	6429929	no	flat floor	P_012
11/11/2005	13	UG4 T4	RS7	763625	6429911	no	flat floor	P_015
11/11/2005	14	UG4 T4	RS8	763520	6429965	no	located east of MC10	P_018
11/11/2005	15	UG4 T4	RS9	763481	6429978	no	located immediately above and west of MC10	P_019
11/11/2005	16	UG4 T4	RS10	763620	6429917	no	very steep slope	P_020, P_021
11/11/2005	17	UG4 T4	RS11	763512	6429960	no	exfoliation heaviest at entrance	P_022, P_023
11/11/2005	18	UG4 T4	RS12	763486	6429967	no	immediately below and east of RS11	P_024, P_025
11/11/2005	19	UG4 T4	RS13	763366	6429951	no	heavy leaf litter	P_026
11/11/2005	20	UG4 T4	RS14	763339	6429990	no	red circles above small ledge	P_027, P_028
11/11/2005	21	UG4 T4	RS15	763341	6429993	no	sandy towards front of shelter - sand is damp	P_029
11/11/2005	22	UG4 T4	RS16	763274	6430006	no		P_030
14/11/2005	23	UG4 T4	RS17	763371	6430260			P_033; P_034
14/11/2005	24	UG4 T4	RS18	763397	6430294	no	rocky floor. evidence of percolation at northern end (outside of shelter)	P_035
14/11/2005	25.1	UG4 T4	RS19 (a)	763499	6430394	no	shelter is dry at time of recording. Sandstone bench flooring. High exfoliation outside of dripline. Ground slopes to north of shelter. (	P_039
14/11/2005	25.2	UG4 T4	RS19 (b)	763499	6430394	no	cojoins RS19a. Water marks running down outside rock face	P_040
14/11/2005	26	UG4 T4	RS20	763551	6430383	no	rocky floor, slightly sloping	P_041
14/11/2005	27	UG4 T4	RS21	763571	6430394	no	sandstone benching floor, flat at rear, sloping down to front	P_043
14/11/2005	28	UG4 T4	RS22	763611	6430394	no	leaf litter over floor (flat)	P_044
19/11/2005	29	UG4 T5	RS1	762687	6429669	no	rockshelter	P_173
19/11/2005	30	UG4 T5	RS2	762692	6429684	no	rockshelter	P_172
19/11/2005	31	UG4 T5	RS3	762694	6429657	no	rockshelter	P_171
19/11/2005	32	UG4 T5	RS4	762812	6429640.201	no	rockshelter	P_170
19/11/2005	33	UG4 T5	RS5	762742	6429712.32	no	rockshelter	P_169
19/11/2005	34	UG4 T5	RS6	762663	6429813.622	no	rockshelter	P_167
19/11/2005	35	UG4 T5	RS7	762653	6429833.48	no	rockshelter	P_166
19/11/2005	36	UG4 T5	RS8	762644	6429891.52	no	rockshelter	P_165
19/11/2005	37	UG4 T5	RS9	762644	6429917.111	no	rockshelter	P_164
19/11/2005	38	UG4 T5	RS10	762897	6429666.655	no	rockshelter	P_
19/11/2005	39	UG4 T5	RS11	762642	6429982.397	no	rockshelter	P_163
19/11/2005	40	UG4 T5	RS12	762663	6430059.336	no	overhang	P_162
19/11/2005	41	UG4 T5	RS13	762650	6430059.843	no	outcrop	P_161
19/11/2005	42	UG4 T5	RS14	762646	6430099.065	no	overhang	P_160
19/11/2005	43	UG4 T5	RS15	762644	6430122.725	no	overhang	P_159
19/11/2005	44	UG4 T5	RS16	762632	6430205.657	no	outcrop	P_158
19/11/2005	45	UG4 T5	RS17	762624	6430212.683	no	overhang	P_157
19/11/2005	46	UG4 T5	RS18	762506	6430235.333	no		P_128
19/11/2005	47	UG4 T5	RS19	762533	6430119.267	no	rockshelter	P_155
19/11/2005	48	UG4 T5	RS20	762526	6430090.62	no	overhang	P_154
19/11/2005	49	UG4 T5	RS21	762548	6430048.075	no	outcrop	P_152
19/11/2005	50	UG4 T5	RS22	762558	6430037.635	no	outcrop	P_151
19/11/2005	51	UG4 T5	RS23	762621	6429813	no	outcrop	P_150
19/11/2005	52	UG4 T5	RS24	762638	6429725.442	no	rockshelter	P_142
19/11/2005	53	UG4 T5	RS25	762620	6429753.234	no	outcrop	P_144
19/11/2005	54	UG4 T5	RS26	762583	6429827.906	no	rockshelter	P_143
19/11/2005	55	UG4 T5	RS27	762579	6429866.691	no	rockshelter	P_145
19/11/2005	56	UG4 T5	RS28	762570	6429946.039	no	overhang	P_146
19/11/2005	57	UG4 T5	RS29	762574	6429961.742	no	overhang	P_149
19/11/2005	58	UG4 T5	RS30	762550	6430007.799	no	rockshelter	P_147
19/11/2005	59	UG4 T5	RS31	762559	6430010.21	no	outcrop	P_148
19/11/2005	60	UG4 T5	RS32	762538	6430060.685	no	rockshelter	P_153
19/11/2005	61	UG4 T5	RS33	762499	6430202.349	no	rockshelter	P_156
19/11/2005	62	UG4 T5	RS34	762487	6430326	no	overhang	P_129
19/11/2005	63	UG4 T5	RS35	762470	6430345	no	shelf in rockwall. Overhang	P_130

Moolarben UG 4
Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Exfoliation	Weathering	Aspect	Height (m)	Width (m)	Depth (m)	Deposit
19/11/2005	64	UG4 T5	RS36	762461	6430369	high	high	NE	2.2	4	1.5	rock at rear, 140mm at dripling
19/11/2005	65	UG4 T5	RS37	762427	6430414	low	moderate	NE	1	5	2	rock at rear and dripline
19/11/2005	66	UG4 T5	RS38	762375	6430425	high	moderate	NE	2	4	2	rock at rear, 60mm / 80mm at dripline
19/11/2005	67	UG4 T5	RS39	762361	6430407	low	low	N	2.5	7	3	70mm at rear, 35mm at dripline
19/11/2005	68	UG4 T5	RS40	762347	6430400	high	moderate	N	3.5	10	3	rock at rear and dripline
19/11/2005	69	UG4 T5	RS41	762302	6430391	high	low	NE	1	2	3	rock at rear and dripline
19/11/2005	70	UG4 T5	RS42	762283	6430383	high	low	NW	4	9	4	rock at rear and dripline
19/11/2005	71	UG4 T5	RS43	762265	6430359	high	low	W	2.2	4.5	3	rock at rear and dripline
19/11/2005	72	UG4 T5	RS44	762270	6430326	low	moderate	W	2	7	2.5	rock at rear and dripline
19/11/2005	73	UG4 T5	RS45	762250	6430320	high	low	N	1.3	2.6	4.5	rock at rear and dripline
19/11/2005	74	UG4 T5	RS46	762212	6430556	moderate	moderate	SW	3	5	3	10mm at rear, 150mm at dripline
19/11/2005	75	UG4 T5	RS47	762225	6430567	low	low	NE	105	3.9	1.9	rock at rear, 16mm at dripline
19/11/2005	76	UG4 T5	RS48	762378	6430601	high	high	S	3.8	10	46	240mm at rear, 230mm at dripline
19/11/2005	77	UG4 T5	RS49	762417	6430584	high	high	SW	3	4.9	1.8	270mm at rear, 130mm at dripline
19/11/2005	78	UG4 T5	RS50	762456	6430556	high	moderate	SW	1	5.5	2.5	140mm at rear, rock at dripline
19/11/2005	79	UG4 T5	RS51	762470	6430545	low	high	S	1.3	3.6	3.7	10mm at rear, 130mm at dripline
19/11/2005	80	UG4 T5	RS52	762496	6430539	high	low	SE	1	7.7	2.6	10mm at rear, 170mm at dripline
19/11/2005	81	UG4 T5	RS53	762505	6430494	low	high	W	3.9	7.6	1.8	rock
19/11/2005	82	UG4 T5	RS54	762515	6430488	moderate	low	SE	1.9	2.7	1.5	rock
19/11/2005	83	UG4 T5	RS55	762576	6430480	low	high	S	2.5	5.4	1.6	rock
19/11/2005	84	UG4 T5	RS56	762541	6430394	low	high	SW	2	4.1	2.6	rock at rear, 260mm at dripline
19/11/2005	85	UG4 T5	RS57	762568	6430383	high	moderate	W	1.6	6.7	2	rock at rear, 220mm at dripline
19/11/2005	86	UG4 T5	RS58	762561	6430376	high	high	SW	2.5	14	3.4	130mm at rear, 160mm at dripline
19/11/2005	87	UG4 T5	RS59	762560	6430371	low	high	NW	1	1.2	1.7	360mm at rear, 100mm at drip
19/11/2005	88	UG4 T5	RS60	762575	6430367	low	high	W	1	1.6	2.9	rock at rear, 180mm at dripline
19/11/2005	89	UG4 T5	RS61	762576	6430361	high	high	S	1	3.5	2.3	rock at rear, 340mm at dripline
19/11/2005	90	UG4 T5	RS62	762590	6430372	high	high	W	1.2	4	3.5	200mm at midsection, 200mm at dripline
19/11/2005	91	UG4 T5	RS63	762604	6430376	high	low	S	3	8	2.3	500mm at rear, 300mm at dripline
19/11/2005	92	UG4 T5	RS64	762764	6430016	low	high	S	2.3	10	4.8	rock at rear, 500mm at dripline
19/11/2005	93	UG4 T5	MC1	762883	6429605	low	moderate	W	2.1	7.6	2.5	rock at rear, 70mm at dripline
19/11/2005	94	UG4 T5	MC6	762876	6429660	high	low	W	1.6	10	4.4	22mm at rear, 42mm at drip
15/11/2005	95	UG4 T6	RS1	763076	6431397	low on N side, he	high	NE	0.7	1.6	1.6	< 50mm
15/11/2005	96	UG4 T6	RS2	763015	6431390.245	low	high	NNE	3	11.6	4.3	120mm at dripline
15/11/2005	97	UG4 T6	RS3	762933	6431357.886	low	moderate	NE	2	6	4	10mm in shelter
15/11/2005	98	UG4 T6	RS4	762896	6431313.227	low	low	NW	1	4.8	1.4	nil
15/11/2005	99	UG4 T6	RS5	762895	6431277.233	low	high	S	1.9	3.8	2.2	rock floor
15/11/2005	100	UG4 T6	RS6	762887	6431251.48	low	low	NW	1.5	11.8	5	shallow - rock floor
15/11/2005	101	UG4 T6	RS7	762885	6431241.959	low	high	W	2.2	14	4	shallow - rock floor
15/11/2005	102	UG4 T6	RS8	762881	6431244.522	low	low	NW	1.6	4.4	2.3	nil
15/11/2005	103	UG4 T6	RS9	762875	6431194.479	high	low	N	3	4.4	3.3	shallow - rock floor
15/11/2005	104	UG4 T6	RS10	762858	6431168.565	high	high	W	2.6	15.7	4	> 200mm at dripline and inside shelter
15/11/2005	105	UG4 T6	RS11	762846	6431164.016	low	low	N	1.6	6.8	4.5	120mm at dripline
15/11/2005	106	UG4 T6	RS12	762805	6431204.295	low	high	N	1.5	10.45	3.5	shallow - rock floor
15/11/2005	107	UG4 T6	RS13	762749	6431197.344	low	high	N	1	6.7	3	170mm at dripline
15/11/2005	108	UG4 T6	RS14	762839	6431054	moderate	moderate	N	3	26	3	rock floor
15/11/2005	109	UG4 T6	MC1	763085	6431398.653	moderate	moderate	NW	3	9.5	9	140mm at dripline; 420mm inside shelter
17/11/2005	110	UG4 T7	MC1	761945	6430057	moderate	low	West	2.2	4.6	2.4	gravel deposit
17/11/2005	111	UG4 T7	MC3	761882	6430106.192	moderate	moderate	West	1.3	4.2	2	50mm at dripline
17/11/2005	112	UG4 T7	RS1	762017	6430125.937	low	moderate	West	1.3	7.4	2.6	shallow gravel deposit
17/11/2005	113	UG4 T7	RS2	762019	6430114.191	low	high	West	0.6	3.5	1.6	gravel deposit
17/11/2005	114	UG4 T7	RS3	761868	6430090.72	moderate	high	West	1.5	4.6	2.9	none - rocky
17/11/2005	115	UG4 T7	RS4	761995	6430232	moderate	low	N	1.4	1.9	3	none - rocky
16/11/2005	116	UG4 T8	MC1	763751	6428826.742	moderate	high	S	2.2	11.5	4.2	shallow sandy deposit
16/11/2005	117	UG4 T8	RS1	763766	6428986.039	high	high	W	1.1	9.3	3.6	none - rocky
16/11/2005	118	UG4 T8	RS2	763747	6428928.35	moderate	moderate	W	1.3	5.8	1.7	none - rocky
16/11/2005	119	UG4 T8	RS3	763722	6428866.408	low	moderate	NW	1.8	4.9	3.9	shallow gravelly deposit
16/11/2005	120	UG4 T8	RS4	763724	6428835.419	low	moderate	S	1.7	2.9	3.3	shallow gravelly deposit
16/11/2005	121	UG4 T8	RS5	763725	6428825.922	low	high	SW	1.6	2.7	2.2	shallow sandy deposit
16/11/2005	122	UG4 T8	RS6	763801	6428802.391	high	low	SW	2.4	6.1	2.8	shallow sandy deposit
16/11/2005	123	UG4 T8	RS7	763808	6428790.959	moderate	moderate	S	2.8	4.9	2.2	shallow sandy deposit
16/11/2005	124	UG4 T8	RS8	763868	6428743.096	moderate	moderate	S	4	6.4	3.3	shallow deposit to west
16/11/2005	125	UG4 T8	RS9	763937	6428720.867	moderate	moderate	S	2.6	6.9	2.8	shallow gravelly deposit
16/11/2005	126	UG4 T8	RS10	763946	6428719.113	high	high	S	6	22.8	9	shallow sandy deposit
16/11/2005	127	UG4 T8	RS11	763973	6428715.232	low	high	S	6	9.6	6.4	shallow sandy deposit
21/11/2005	128	UG4 T9	RS1	762550	6428866	high	moderate	NW	2	4.2	2.6	rock
21/11/2005	129	UG4 T9	RS2	762498	6428796	moderate	high	W	1	1.8	1.5	sandy gravel over rock
21/11/2005	130	UG4 T9	RS3	762394	6428755	low	high	W	1.8	6.5	3.3	120mm at rear, 550mm at dripline
21/11/2005	131	UG4 T9	RS4	762396	6428758	moderate	high	S	1.3	2.9	2.3	sandy gravel over rock
21/11/2005	132	UG4 T9	RS5	762386	6428740	moderate	low	W	1.2	9.6	1.8	110mm at drip, rock at rear

Moolarben UG 4
Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Moisture	Animal Activity
19/11/2005	64	UG4 T5	RS36	762461	6430369	70%	no
19/11/2005	65	UG4 T5	RS37	762427	6430414	absent	no
19/11/2005	66	UG4 T5	RS38	762375	6430425	absent	no
19/11/2005	67	UG4 T5	RS39	762361	6430407	absent	rabbit burrows at rear
19/11/2005	68	UG4 T5	RS40	762347	6430400	absent	wasp nests
19/11/2005	69	UG4 T5	RS41	762302	6430391	absent	no
19/11/2005	70	UG4 T5	RS42	762283	6430383	throughout shelter, 70%	no
19/11/2005	71	UG4 T5	RS43	762265	6430359	90%	no
19/11/2005	72	UG4 T5	RS44	762270	6430326	absent	no
19/11/2005	73	UG4 T5	RS45	762250	6430320	absent	no
19/11/2005	74	UG4 T5	RS46	762212	6430556	absent	no
19/11/2005	75	UG4 T5	RS47	762225	6430567	absent	no
19/11/2005	76	UG4 T5	RS48	762378	6430601	absent	no
19/11/2005	77	UG4 T5	RS49	762417	6430584	absent	no
19/11/2005	78	UG4 T5	RS50	762456	6430556	absent	no
19/11/2005	79	UG4 T5	RS51	762470	6430545	absent	no
19/11/2005	80	UG4 T5	RS52	762496	6430539	absent	no
19/11/2005	81	UG4 T5	RS53	762505	6430494	absent	no
19/11/2005	82	UG4 T5	RS54	762515	6430488	absent	no
19/11/2005	83	UG4 T5	RS55	762576	6430480	absent	no
19/11/2005	84	UG4 T5	RS56	762541	6430394	absent	no
19/11/2005	85	UG4 T5	RS57	762568	6430383	water marks down front of shelter, 40%	no
19/11/2005	86	UG4 T5	RS58	762561	6430376	water marks down front of shelter, 20% under dripline	no
19/11/2005	87	UG4 T5	RS59	762560	6430371	absent	hole in rear of shelter
19/11/2005	88	UG4 T5	RS60	762575	6430367	absent	no
19/11/2005	89	UG4 T5	RS61	762576	6430361	absent	wombat scat
19/11/2005	90	UG4 T5	RS62	762590	6430372	absent	animal tracks
19/11/2005	91	UG4 T5	RS63	762604	6430376	absent	no
19/11/2005	92	UG4 T5	RS64	762764	6430016	absent	animal tracks
19/11/2005	93	UG4 T5	MC1	762883	6429605	absent	no
19/11/2005	94	UG4 T5	MC6	762876	6429660	absent	wombat hole rear centre of shelter
15/11/2005	95	UG4 T6	RS1	763076	6431397	not noted	wombat scat
15/11/2005	96	UG4 T6	RS2	763015	6431390.245	no	no
15/11/2005	97	UG4 T6	RS3	762933	6431357.886	no	no
15/11/2005	98	UG4 T6	RS4	762896	6431313.227	no	no
15/11/2005	99	UG4 T6	RS5	762895	6431277.233	no	no
15/11/2005	100	UG4 T6	RS6	762887	6431251.48	no	wasp nests, 'roo & possum tracks
15/11/2005	101	UG4 T6	RS7	762885	6431241.959	no	emu scat
15/11/2005	102	UG4 T6	RS8	762881	6431244.522	no	no
15/11/2005	103	UG4 T6	RS9	762875	6431194.479	no	no
15/11/2005	104	UG4 T6	RS10	762858	6431168.565	no	no
15/11/2005	105	UG4 T6	RS11	762846	6431164.016	water dripping down wall to SW (RHS) from overhead spring	no
15/11/2005	106	UG4 T6	RS12	762805	6431204.295	water dripping down wall to LHS from overhead spring	no
15/11/2005	107	UG4 T6	RS13	762749	6431197.344	no	no
15/11/2005	108	UG4 T6	RS14	762839	6431054	no	no
15/11/2005	109	UG4 T6	MC1	763085	6431398.653	through hole in roof of shelter	no
17/11/2005	110	UG4 T7	MC1	761945	6430057	no	no
17/11/2005	111	UG4 T7	MC3	761882	6430106.192	no	wombat hole at back of shelter
17/11/2005	112	UG4 T7	RS1	762017	6430125.937	no	no
17/11/2005	113	UG4 T7	RS2	762019	6430114.191	no	wombat holes
17/11/2005	114	UG4 T7	RS3	761868	6430090.72	damp soil @ north end	no
17/11/2005	115	UG4 T7	RS4	761995	6430232	no	no
16/11/2005	116	UG4 T8	MC1	763751	6428826.742	no	no
16/11/2005	117	UG4 T8	RS1	763766	6428986.039	water marks to S end, dry inside shelter	no
16/11/2005	118	UG4 T8	RS2	763747	6428928.35	water marks into shelter	no
16/11/2005	119	UG4 T8	RS3	763722	6428866.408	damp on roof of shelter approx. 1m in from dripline	wasp nests
16/11/2005	120	UG4 T8	RS4	763724	6428835.419	no	wombat holes at back of shelter
16/11/2005	121	UG4 T8	RS5	763725	6428825.922	no	no
16/11/2005	122	UG4 T8	RS6	763801	6428802.391	possible damp on roof of shelter	no
16/11/2005	123	UG4 T8	RS7	763808	6428790.959	no	no
16/11/2005	124	UG4 T8	RS8	763868	6428743.096	no	possum droppings
16/11/2005	125	UG4 T8	RS9	763937	6428720.867	no	wallaby/pig scratchings
16/11/2005	126	UG4 T8	RS10	763946	6428719.113	no	wallaby & bird scat, wasp nest
16/11/2005	127	UG4 T8	RS11	763973	6428715.232		
21/11/2005	128	UG4 T9	RS1	762550	6428866	absent	wasp nests
21/11/2005	129	UG4 T9	RS2	762498	6428796	absent	no
21/11/2005	130	UG4 T9	RS3	762394	6428755	absent	wallaby and lizard tracks
21/11/2005	131	UG4 T9	RS4	762396	6428758	absent	no
21/11/2005	132	UG4 T9	RS5	762386	6428740	absent	no

Moolarben UG 4
Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Cultural Material	Comment	Photo #
19/11/2005	64	UG4 T5	RS36	762461	6430369	no	overhang	P_131
19/11/2005	65	UG4 T5	RS37	762427	6430414	no	rockshelter	P_132
19/11/2005	66	UG4 T5	RS38	762375	6430425	no	overhang	P_133
19/11/2005	67	UG4 T5	RS39	762361	6430407	no	overhang	P_134
19/11/2005	68	UG4 T5	RS40	762347	6430400	no	overhang	P_135
19/11/2005	69	UG4 T5	RS41	762302	6430391	no	outcrop	P_136
19/11/2005	70	UG4 T5	RS42	762283	6430383	no	overhang	P_137
19/11/2005	71	UG4 T5	RS43	762265	6430359	no	overhang	P_138
19/11/2005	72	UG4 T5	RS44	762270	6430326	no	rockshelter	P_139
19/11/2005	73	UG4 T5	RS45	762250	6430320	no	outcrop	P_142
19/11/2005	74	UG4 T5	RS46	762212	6430556	no	rockshelter	P_108
19/11/2005	75	UG4 T5	RS47	762225	6430567	no	outcrop	P_110
19/11/2005	76	UG4 T5	RS48	762378	6430601	no	overhang	P_111
19/11/2005	77	UG4 T5	RS49	762417	6430584	no	overhang	P_112
19/11/2005	78	UG4 T5	RS50	762456	6430556	no	overhang	P_113
19/11/2005	79	UG4 T5	RS51	762470	6430545	no	rockshelter	P_114
19/11/2005	80	UG4 T5	RS52	762496	6430539	no	outcrop	P_115
19/11/2005	81	UG4 T5	RS53	762505	6430494	no	overhang	P_116
19/11/2005	82	UG4 T5	RS54	762515	6430488	no	outcrop	P_117
19/11/2005	83	UG4 T5	RS55	762576	6430480	no	rockshelter	P_118
19/11/2005	84	UG4 T5	RS56	762541	6430394	no	outcrop	P_119
19/11/2005	85	UG4 T5	RS57	762568	6430383	no	outcrop	P_120
19/11/2005	86	UG4 T5	RS58	762561	6430376	no	outcrop	P_121
19/11/2005	87	UG4 T5	RS59	762560	6430371	no	outcrop	P_122
19/11/2005	88	UG4 T5	RS60	762575	6430367	no	outcrop	P_123
19/11/2005	89	UG4 T5	RS61	762576	6430361	no	outcrop	P_124
19/11/2005	90	UG4 T5	RS62	762590	6430372	no	outcrop	P_125
19/11/2005	91	UG4 T5	RS63	762604	6430376	no	overhang. Leaf litter in shelter, lichen on boulders	P_126
19/11/2005	92	UG4 T5	RS64	762764	6430016	no	rockshelter	P_127
19/11/2005	93	UG4 T5	MC1	762883	6429605	artefact scatter downslope from dripline	rockshelter	
19/11/2005	94	UG4 T5	MC6	762876	6429660	two artefacts	heavy exfoliation in front of shelter, rocks on floor throughout shelter	P_109
15/11/2005	95	UG4 T6	RS1	763076	6431397	no	flat sandy floor over rock base	P_049; P_050; P_051
15/11/2005	96	UG4 T6	RS2	763015	6431390.245	no	sandy floor sloping down to East. Rock floor at rear	P_052
15/11/2005	97	UG4 T6	RS3	762933	6431357.886	no	concave floor, benching at rear	P_056
15/11/2005	98	UG4 T6	RS4	762896	6431313.227	no	slightly sloping floor, grass growing on dripline	P_057
15/11/2005	99	UG4 T6	RS5	762895	6431277.233	no	sloping benched floor	P_058
15/11/2005	100	UG4 T6	RS6	762887	6431251.48	no	sloping benched floor	P_059
15/11/2005	101	UG4 T6	RS7	762885	6431241.959	no	sloping benched floor	P_060
15/11/2005	102	UG4 T6	RS8	762881	6431244.522	no	sloping benched floor	P_061
15/11/2005	103	UG4 T6	RS9	762875	6431194.479	no	open both ends, floor slopes away to east	P_062
15/11/2005	104	UG4 T6	RS10	762858	6431168.565	no	flate s/stone floor	P_063
15/11/2005	105	UG4 T6	RS11	762846	6431164.016	no	flat at back of shelter, slopes down to dripline	P_064
15/11/2005	106	UG4 T6	RS12	762805	6431204.295	no	flat at back of shelter, slopes down to dripline	P_065
15/11/2005	107	UG4 T6	RS13	762749	6431197.344	no	floor slopes from west	P_068
15/11/2005	108	UG4 T6	RS14	762839	6431054	no	narrow ledge elevated above ground	P_067
15/11/2005	109	UG4 T6	MC1	763085	6431398.653	isolated find	flat floor at front of shelter near dripline	P_053; P_054; P_055
17/11/2005	110	UG4 T7	MC1	761945	6430057	artefact scatter at front of shelter	slopes down from N to flat at dripline	P_090; P_091; P_092
17/11/2005	111	UG4 T7	MC3	761882	6430106.192	artefact scatter at front of shelter	leaf litter in shelter. Possible that artefacts have been kicked up by wombat	P_094
17/11/2005	112	UG4 T7	RS1	762017	6430125.937	no	leaf litter in shelter. Narrow shelter. Flat floor	P_088
17/11/2005	113	UG4 T7	RS2	762019	6430114.191	no	disturbed deposit	P_089
17/11/2005	114	UG4 T7	RS3	761868	6430090.72	no	overhang, outcrop. Ground slopes from south and north around outcrop	P_093
17/11/2005	115	UG4 T7	RS4	761995	6430232	no	ground slopes slightly to North	
16/11/2005	116	UG4 T8	MC1	763751	6428826.742	artefacts	oxidation in shelters. Flat ground in front of shelters	P_082
16/11/2005	117	UG4 T8	RS1	763766	6428986.039	no	sandstone benches	P_069
16/11/2005	118	UG4 T8	RS2	763747	6428928.35	no		P_070
16/11/2005	119	UG4 T8	RS3	763722	6428866.408	no	leaf litter. Ground slopes down gently	P_071
16/11/2005	120	UG4 T8	RS4	763724	6428835.419	no	branches & leaf litter at east end	P_072
16/11/2005	121	UG4 T8	RS5	763725	6428825.922	no	semi-circular shelter created by collapsed overhang. Leaves & debris through shelter	P_073
16/11/2005	122	UG4 T8	RS6	763801	6428802.391	no	leaf litter	P_080
16/11/2005	123	UG4 T8	RS7	763808	6428790.959	no	small shelter 'cut' into rockwall, benching s/stone floor	P_074
16/11/2005	124	UG4 T8	RS8	763868	6428743.096	no	rock floor	P_079
16/11/2005	125	UG4 T8	RS9	763937	6428720.867	no	ground slopes down from east to nearly flat at dripline. Thick leaf litter	P_083
16/11/2005	126	UG4 T8	RS10	763946	6428719.113	no	steep sloping floor (collapsed/weathered benches) - elevated shelter above and east of RS9	P_084
16/11/2005	127	UG4 T8	RS11	763973	6428715.232			
21/11/2005	128	UG4 T9	RS1	762550	6428866	no	steep slope from rear	P_174
21/11/2005	129	UG4 T9	RS2	762498	6428796	no	flat	P_175
21/11/2005	130	UG4 T9	RS3	762394	6428755	no	from N	P_176
21/11/2005	131	UG4 T9	RS4	762396	6428758	no	slight slope from rear	P_177
21/11/2005	132	UG4 T9	RS5	762386	6428740	no	flat	P_178

Moolarben UG 4

Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Exfoliation	Weathering	Aspect	Height (m)	Width (m)	Depth (m)	Deposit
21/11/2005	133	UG4 T9	RS6	762378	6428719	high	high	NW	3	13.3	5.9	shallow layer of red dirt over rock
21/11/2005	134	UG4 T9	RS7	762359	6428765	high	moderate	NE	2.4	8.6	8.3	70mm at rear, 100-400mm at dripline
21/11/2005	135	UG4 T9	RS8	762353	6428771	moderate	moderate	N	2.4	4.2	2.7	rock
21/11/2005	136	UG4 T9	RS9	762342	6428774	high	low	N	2	8.7	2.7	230mm at front, rock at rear
21/11/2005	137	UG4 T9	RS10	762292	6428792	low	moderate	N	2.1	7.3	3.2	170mm at rear, rock at dripline
21/11/2005	138	UG4 T9	RS11	762198	6428737	moderate	moderate	NW	1.9	3	3.8	rock
21/11/2005	139	UG4 T9	RS12	762193	6428732	moderate	moderate	SE	2.4	4	4.2	rock
21/11/2005	140	UG4 T9	RS13	762156	6428746	moderate	moderate	N	0.8	2.8	1.8	sandy gravel over rock
21/11/2005	141	UG4 T9	RS14	762495	6428921	low	low	SE	0.7	5	2.1	100mm at rear, 180mm at dripline
21/11/2005	142	UG4 T9	RS15	762441	6428923	low	low	E	1.4	2.4	3.3	100mm at rear and dripline
21/11/2005	143	UG4 T9	RS16	762446	6428951	moderate	low	NE	1	1.4	1.8	rock
21/11/2005	144	UG4 T9	RS17	762478	6428954	moderate	low	S	0.6	3.1	1.6	130mm at dripline, rock at rear
		UG4 T10	nil									
17/11/2005	145	UG4 T11	MC1	762846	6427860	high	moderate	NW	2.4	13.3	5.7	up to 60mm throughout
22/11/2005	146	UG4 T12	RS1	762956	6432325	low	low	W	2	7.5	2	rock
22/11/2005	147	UG4 T12	RS2	762941	6432206	moderate	low	N	1	3.5	2	rock
22/11/2005	148	UG4 T12	RS3	762942	6432203	low	low	N	3	4.5	1.5	rock
22/11/2005	149	UG4 T12	RS4	762916	6432205	moderate	low	W	1.5	3.5	2.2	rock
22/11/2005	150	UG4 T12	RS5	762913	6432185	refer MC3						
22/11/2005	151	UG4 T12	RS6	762913	6432153	moderate	low	S	3	3	7	300mm at rear, 200mm at dripline
22/11/2005		UG4 T12	RS7			not a rockshelter						
22/11/2005	152	UG4 T12	RS8	762902	6432158	high	low	N	1.3	3	3	rock
22/11/2005		UG4 T12	RS9			not a rockshelter						
22/11/2005	153	UG4 T12	RS10	762890	6432136	high	moderate	NW	1.2	4	3	rock
22/11/2005	154	UG4 T12	RS11	762875	6432147	low	high	SE	1.1	2	2	shallow sandy deposit over rock
22/11/2005	155	UG4 T12	RS12	762878	6432127	ref MC4						
22/11/2005	156	UG4 T12	RS13	762884	6432089	low	low	N	2.2	9	3	rock
22/11/2005	157	UG4 T12	RS14	762864	6432085	low	low	E	3.5	7	4	rock
22/11/2005	158	UG4 T12	RS15	762855	6432129	low	low	S	1.6	2	1.6	220mm at dripline, rock at rear
22/11/2005	159	UG4 T12	RS16	762860	6432147	low	low	S	2	4	1.8	rock
22/11/2005	160	UG4 T12	RS17	762856	6432116	low	low	N	1	3	1.5	rock
22/11/2005	161	UG4 T12	RS18	762858	6432072	ref MC7						
22/11/2005	162	UG4 T12	RS19	762873	6432035	low	low	NW	0.94	3	3.3	rock
22/11/2005	163	UG4 T12	RS20	762925	6432019	low	low	SE	6.2	4.9	4.28	rock
22/11/2005	164	UG4 T12	RS21	762899	6432023	low	low	S	2.25	7.6	3.25	nil at rear, 90mm at front
22/11/2005	165	UG4 T12	RS22	762876	6432021	low	low	S	4.1	7	2	rock
22/11/2005	166	UG4 T12	RS23	762899	6432006	low	low	N	2.9	2.6	1.89	rock
22/11/2005	167	UG4 T12	RS24	762897	6431993	moderate	low	S	2.5	6.2	1.9	210mm at rear, 160mm at front
22/11/2005	168	UG4 T12	RS25	762905	6431976	ref MC5						
22/11/2005	169	UG4 T12	RS26	762898	6431982	low	low	W	1.54	2.7	2.14	rock
22/11/2005	170	UG4 T12	RS27	762869	6431969	ref MC6						
22/11/2005	171	UG4 T12	RS28	762880	6431961	low	moderate	S	1.5	7	3.1	90mm at rear, 160mm at dripline
22/11/2005	172	UG4 T12	RS29	762878	6431948	low	low	SW	1.54	3.53	1.74	190mm at rear, 90mm at dripline
22/11/2005	173	UG4 T12	MC3	762913	6432185	low	low	N	4	20	5	rock
22/11/2005	174	UG4 T12	MC4	762878	6432127			W				100mm at rear, 230mm at dripline
22/11/2005	175	UG4 T12	MC5	762905	6431976	low	low	W	1.8	7.85	3.9	125mm at rear, 140mm at front
22/11/2005	176	UG4 T12	MC6	762869	6431969	low	low	W	2.3	8.7	3	130mm at front, rock at rear
22/11/2005	177	UG4 T12	RS30	762858	6432072	moderate	moderate	SW	1.9	4.14	5.2	80mm at rear, 200mm at dripline

Moolarben UG 4

Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Moisture	Animal Activity
21/11/2005	133	UG4 T9	RS6	762378	6428719	water dripping over shelter	no
21/11/2005	134	UG4 T9	RS7	762359	6428765	absent	snake holes, rabbit scat
21/11/2005	135	UG4 T9	RS8	762353	6428771	grass and trees growing on shelter floor	no
21/11/2005	136	UG4 T9	RS9	762342	6428774	absent	no
21/11/2005	137	UG4 T9	RS10	762292	6428792	absent	wasp nests
21/11/2005	138	UG4 T9	RS11	762198	6428737	crack in roof from rear to front may let water in. Steep slope from rear - looks like a dry waterfall	no
21/11/2005	139	UG4 T9	RS12	762193	6428732	absent	no
21/11/2005	140	UG4 T9	RS13	762156	6428746	absent	no
21/11/2005	141	UG4 T9	RS14	762495	6428921	absent	roo scratchings
21/11/2005	142	UG4 T9	RS15	762441	6428923	absent	no
21/11/2005	143	UG4 T9	RS16	762446	6428951	absent	no
21/11/2005	144	UG4 T9	RS17	762478	6428954	absent	no
		UG4 T10	nil				
17/11/2005	145	UG4 T11	MC1	762846	6427860	water marks to south of shelter	rabbits
22/11/2005	146	UG4 T12	RS1	762956	6432325	absent	no
22/11/2005	147	UG4 T12	RS2	762941	6432206	absent	no
22/11/2005	148	UG4 T12	RS3	762942	6432203	absent	no
22/11/2005	149	UG4 T12	RS4	762916	6432205	absent	no
22/11/2005	150	UG4 T12	RS5	762913	6432185		
22/11/2005	151	UG4 T12	RS6	762913	6432153	absent	no
22/11/2005		UG4 T12	RS7				
22/11/2005	152	UG4 T12	RS8	762902	6432158	absent	no
22/11/2005		UG4 T12	RS9				
22/11/2005	153	UG4 T12	RS10	762890	6432136	absent	no
22/11/2005	154	UG4 T12	RS11	762875	6432147	absent	no
22/11/2005	155	UG4 T12	RS12	762878	6432127		
22/11/2005	156	UG4 T12	RS13	762884	6432089	absent	no
22/11/2005	157	UG4 T12	RS14	762864	6432085	absent	no
22/11/2005	158	UG4 T12	RS15	762855	6432129	absent	no
22/11/2005	159	UG4 T12	RS16	762860	6432147	absent	no
22/11/2005	160	UG4 T12	RS17	762856	6432116	absent	no
22/11/2005	161	UG4 T12	RS18	762858	6432072		
22/11/2005	162	UG4 T12	RS19	762873	6432035	absent	no
22/11/2005	163	UG4 T12	RS20	762925	6432019	absent	no
22/11/2005	164	UG4 T12	RS21	762899	6432023	absent	no
22/11/2005	165	UG4 T12	RS22	762876	6432021	absent	no
22/11/2005	166	UG4 T12	RS23	762899	6432006	absent	no
22/11/2005	167	UG4 T12	RS24	762897	6431993	absent	no
22/11/2005	168	UG4 T12	RS25	762905	6431976		
22/11/2005	169	UG4 T12	RS26	762898	6431982	absent	no
22/11/2005	170	UG4 T12	RS27	762869	6431969		
22/11/2005	171	UG4 T12	RS28	762880	6431961	absent	wombat burrow at rear
22/11/2005	172	UG4 T12	RS29	762878	6431948	absent	no
22/11/2005	173	UG4 T12	MC3	762913	6432185	absent	rabbits
22/11/2005	174	UG4 T12	MC4	762878	6432127		
22/11/2005	175	UG4 T12	MC5	762905	6431976	absent	no
22/11/2005	176	UG4 T12	MC6	762869	6431969	absent	no
22/11/2005	177	UG4 T12	RS30	762858	6432072	absent	snake hole at rear and front

Moolarben UG 4
Rock Shelter Sites

Date	#	Location	R/S	Easting	Northing	Cultural Material	Comment	Photo #
21/11/2005	133	UG4 T9	RS6	762378	6428719	no	steep slope from rear	P_179
21/11/2005	134	UG4 T9	RS7	762359	6428765	no	flat	P_180
21/11/2005	135	UG4 T9	RS8	762353	6428771	no	elevated above lower valley	P_181
21/11/2005	136	UG4 T9	RS9	762342	6428774	no	rockfall in front of shelter	P_182
21/11/2005	137	UG4 T9	RS10	762292	6428792	no	sandstone benching at front, weathered at rear	P_183
21/11/2005	138	UG4 T9	RS11	762198	6428737	no	steep slope from rear	P_184
21/11/2005	139	UG4 T9	RS12	762193	6428732	no	slight slope from rear	P_185
21/11/2005	140	UG4 T9	RS13	762156	6428746	no	rockfall in front of shelter	P_186
21/11/2005	141	UG4 T9	RS14	762495	6428921	no	flat	P_187
21/11/2005	142	UG4 T9	RS15	762441	6428923	no	flat	P_188
21/11/2005	143	UG4 T9	RS16	762446	6428951	no	rockfall in front of shelter	P_189
21/11/2005	144	UG4 T9	RS17	762478	6428954	no	flat	P_190
		UG4 T10	nil					
17/11/2005	145	UG4 T11	MC1	762846	6427860	artefacts, grinding grooves, rock art	ground is flat in shelter	P_99 to P_107
22/11/2005	146	UG4 T12	RS1	762956	6432325	no	outcrop	P_191
22/11/2005	147	UG4 T12	RS2	762941	6432206	no	overhang	P_192
22/11/2005	148	UG4 T12	RS3	762942	6432203	no	above RS2	P_197
22/11/2005	149	UG4 T12	RS4	762916	6432205	no		P_198
22/11/2005	150	UG4 T12	RS5	762913	6432185			
22/11/2005	151	UG4 T12	RS6	762913	6432153	no	leaf litter. Overhang	P_201
22/11/2005		UG4 T12	RS7					no photo
22/11/2005	152	UG4 T12	RS8	762902	6432158	no	rockshelter	P_202
22/11/2005		UG4 T12	RS9					no photo
22/11/2005	153	UG4 T12	RS10	762890	6432136	no	overhang	P_203
22/11/2005	154	UG4 T12	RS11	762875	6432147	no	recent signs of campfire in shelter	P_204
22/11/2005	155	UG4 T12	RS12	762878	6432127			
22/11/2005	156	UG4 T12	RS13	762884	6432089	no		no photo
22/11/2005	157	UG4 T12	RS14	762864	6432085	no		no photo
22/11/2005	158	UG4 T12	RS15	762855	6432129	no		no photo
22/11/2005	159	UG4 T12	RS16	762860	6432147	no		no photo
22/11/2005	160	UG4 T12	RS17	762856	6432116	no		no photo
22/11/2005	161	UG4 T12	RS18	762858	6432072			
22/11/2005	162	UG4 T12	RS19	762873	6432035	no		no photo
22/11/2005	163	UG4 T12	RS20	762925	6432019	no		no photo
22/11/2005	164	UG4 T12	RS21	762899	6432023	no		no photo
22/11/2005	165	UG4 T12	RS22	762876	6432021	no		no photo
22/11/2005	166	UG4 T12	RS23	762899	6432006	no		no photo
22/11/2005	167	UG4 T12	RS24	762897	6431993	no		no photo
22/11/2005	168	UG4 T12	RS25	762905	6431976			
22/11/2005	169	UG4 T12	RS26	762898	6431982	no	outcrop	no photo
22/11/2005	170	UG4 T12	RS27	762869	6431969			
22/11/2005	171	UG4 T12	RS28	762880	6431961	no	rockshelter	no photo
22/11/2005	172	UG4 T12	RS29	762878	6431948	no	no slope. Outcrop	no photo
22/11/2005	173	UG4 T12	MC3	762913	6432185	artefacts on dripline and downslope		P_199; P_200
22/11/2005	174	UG4 T12	MC4	762878	6432127			
22/11/2005	175	UG4 T12	MC5	762905	6431976	3 artefacts in shelter		no photo
22/11/2005	176	UG4 T12	MC6	762869	6431969	28 artefacts in front of RHS and down slope from shelter	rockshelter	no photo
22/11/2005	177	UG4 T12	RS30	762858	6432072	no		no photo

Location	#	Easting	Northing	Exfoliation	Aspect	Height M	Width M	Depth M	Comment
UG4 T8	PAD 1	763846	6428750	low	SW	1.8	8.9	2.4	moderate weathering, grasses growing above & along shelter wall, no damp, flat floor, sandy deposit (400mm at dripline), wombat hole adjacent to shelter

Moolarban UG4						
Significant Archaeological Sites						
Location	**AS#**	**E**	**N**	**Category**	**Comment**	**?**
Stage 1: Underground No 4	AS1	763332	6431357	S1MC254	artefact scatter	2
Stage 1: Underground No 4	AS2	762878	6429620	S1MC256	artefact scatter	23
Stage 1: Underground No 4	AS3	762876	6429660	S1MC261	Rockshelter &artefact	2
Stage 1: Underground No 4	AS4	762010	6430705	S1MC264	grinding grooves&artefacts	78
Stage 1: Underground No 4	AS5	761945	6430063	S1MC267	Rockshelter &artefact	10
Stage 1: Underground No 4	AS6	763749	6428829	S1MC271	rockshelter&artefacts	8
Stage 1: Underground No 4	AS7	762822	6427883	S1MC280	rockshelter &artefacts	45
Stage 1: Underground No 4	AS8	762865	6432219	S1MC281	artefact scatter	11
Stage 1: Underground No 4	AS9	762851	6432207	S1MC282	artefact scatter	65
Stage 1: Underground No 4	AS10	762912	6432185	S1MC283	rockshelter &artefacts	6
Stage 1: Underground No 4	AS11	762877	6432127	S1MC284	rockshelter &artefacts	8
Stage 1: Underground No 4	AS12	762905	6431976	S1MC285	rockshelter &artefacts	2
Stage 1: Underground No 4	AS13	762868	6431969	S1MC286	rockshelter &artefacts	28
Stage 1: Underground No 4	AS14	763846	6428750	PAD 11	Potential Archaeological Deposit	0

RS#	Easting	Northing	Z	Location	Subsidence(m)	XL Tilt(mm/m)	Direction	L Strains(mm/m	Curvatures(km	Radius of C (km	XL HD (mm)	CL Tilt(mm/m)	CL Strain(mm/m	CL Curvatur
1	763261	6430141	0	North	1.175	22.0	East	0.1	0.01	2.63	107	1.2	0.02	0.002
2	763339	6430233	0	North	1.908	-2.6	West	3.6	0.36	4.10	-13	-0.2	-0.02	-0.002
3	763740	6429836	0	North	0.010	-0.5	West	-0.2	-0.02	124.33	-1	0.7	-0.25	-0.025
4	763673	6429849	0	North	0.168	-4.5	West	-0.2	-0.02	-21.31	-27	5.7	-0.77	-0.077
5	763496	6429968	0	North	0.311	4.7	East	-2.6	-0.26	-2.08	53	1.6	0.22	0.022
6	763397	6430325	0	North	1.135	-20.8	West	-0.7	-0.07	3.47	-107	-1.1	0.04	0.004
7	763564	6430390	0	North	1.146	21.5	East	0.2	0.02	3.71	99	1.1	0.00	0.000
8	763288	6430166	0	North	1.674	15.6	East	4.1	0.41	2.33	58	1.0	0.04	0.004
9	763299	6430185	0	North	1.799	9.1	East	4.4	0.44	2.72	37	0.7	0.11	0.011
10	763698	6429880	0	North	0.231	-6.4	West	-1.2	-0.12	8.12	-44	4.5	-0.03	-0.003
11	763779	6429849	0	North	0.000	0.0	West	-0.2	-0.02		0	0.1	-0.05	-0.005
12	763724	6429929	0	North	0.225	-7.3	West	-2.3	-0.23	-2.33	-81	1.6	0.21	0.021
13	763625	6429911	0	North	1.292	-18.0	West	5.4	0.54	9.48	-61	17.6	1.62	0.162
14	763520	6429965	0	North	0.517	12.8	East	-3.2	-0.32	-2.75	157	3.1	0.36	0.036
15	763481	6429978	0	North	0.263	2.4	East	-2.2	-0.22	-2.60	22	0.9	0.18	0.018
16	763620	6429917	0	North	1.436	-18.2	West	6.7	0.67	1.34	-59	17.1	2.11	0.211
17	763512	6429960	0	North	0.423	9.5	East	-3.0	-0.30	-1.08	119	2.8	0.29	0.029
18	763486	6429967	0	North	0.269	2.8	East	-2.2	-0.22	-2.59	31	1.3	0.19	0.019
19	763366	6429951	0	North	1.395	-20.0	West	1.3	0.13	-19.90	-100	4.0	0.70	0.070
20	763339	6429990	0	North	1.883	-4.4	West	4.4	0.44	2.68	-22	0.7	0.48	0.048
21	763341	6429993	0	North	1.869	-5.6	West	4.4	0.44	2.35	-27	0.5	0.49	0.049
22	763274	6430006	0	North	1.517	20.1	East	3.1	0.31	7.43	87	1.8	0.48	0.048
23	763371	6430260	0	North	1.586	-18.6	West	3.3	0.33	2.86	-71	-0.8	0.00	0.000
24	763397	6430294	0	North	1.117	-20.8	West	-1.0	-0.10	4.47	-105	-1.1	-0.04	-0.004
25	763499	6430394	0	North	0.283	3.5	East	-2.4	-0.24	-2.23	38	0.2	-0.02	-0.002
26	763551	6430383	0	North	0.885	20.3	East	-2.0	-0.20	1.29	130	1.1	-0.07	-0.007
27	763571	6430394	0	North	1.278	21.5	East	1.5	0.15	3.58	90	1.1	0.02	0.002
28	763611	6430394	0	North	1.820	3.0	East	3.8	0.38	3.52	17	0.2	0.04	0.004
29	762687	6429669	0	North	0.209	0.8	East	0.8	0.08	-3.32	2	8.0	-0.99	-0.099
30	762692	6429684	0	North	0.349	1.4	East	0.9	0.09	-6.35	5	9.4	-0.69	-0.069
31	762694	6429657	0	North	0.128	1.2	East	0.4	0.04	-10.85	6	6.6	-1.77	-0.177
32	762812	6429640	0	North	0.014	-0.1	West	-0.3	-0.03	-84.94	-1	1.5	-0.83	-0.083
33	762742	6429712	0	North	0.652	-3.5	West	0.9	0.09	6.57	-14	10.7	-0.24	-0.024
34	762663	6429814	0	North	1.275	13.5	East	1.6	0.16	5.37	89	7.3	0.45	0.045
35	762653	6429833	0	North	1.210	16.2	East	1.7	0.17	518.26	103	5.3	0.66	0.066
36	762644	6429892	0	North	1.114	24.0	East	0.1	0.01	2.18	151	1.9	0.22	0.022
37	762644	6429917	0	North	1.101	23.7	East	-0.1	-0.01	3.48	152	1.4	0.15	0.015
38	762897	6429667	0	North	-0.001	0.0	West	-0.1	-0.01		0	0.0	-0.01	-0.001
39	762642	6429982	0	North	0.980	27.0	East	-1.3	-0.13	1.41	168	0.5	0.09	0.009
40	762663	6430059	0	North	1.374	25.9	East	0.7	0.07	2.30	120	0.6	-0.05	-0.005
41	762650	6430060	0	North	1.045	26.4	East	-1.9	-0.19	1.77	154	0.1	0.00	0.000
42	762646	6430099	0	North	0.877	25.0	East	-3.7	-0.37	1.51	173	0.6	-0.31	-0.031
43	762644	6430123	0	North	0.811	22.8	East	-4.0	-0.40	7.80	171	1.2	-0.17	-0.017
44	762632	6430206	0	North	0.547	13.1	East	-4.5	-0.45	-0.68	141	0.9	-0.12	-0.012
45	762624	6430213	0	North	0.450	9.5	East	-4.4	-0.44	-0.94	96	0.7	-0.09	-0.009
46	762506	6430235	0	North	1.530	-27.5	West	0.2	0.02	3.61	-106	-1.4	0.01	0.001
47	762533	6430119	0	North	0.830	-18.7	West	-3.3	-0.33	6.66	-146	-1.2	-0.15	-0.015
48	762526	6430091	0	North	0.966	-21.1	West	-3.0	-0.30	3.32	-139	-1.8	-0.16	-0.016
49	762548	6430048	0	North	0.573	-14.2	West	-3.3	-0.33	-2.58	-96	-1.1	0.02	0.002
50	762558	6430038	0	North	0.445	-11.1	West	-3.4	-0.34	-2.28	-70	-0.8	0.01	0.001
51	762621	6429813	0	North	0.573	16.5	East	-2.5	-0.25	-1.85	128	2.8	0.19	0.019
52	762638	6429725	0	North	0.431	7.2	East	0.0	0.00	12.49	45	6.5	-0.09	-0.009
53	762620	6429753	0	North	0.404	9.3	East	-1.4	-0.14	-7.52	66	4.2	0.07	0.007
54	762583	6429828	0	North	0.280	0.6	East	-3.7	-0.37	-2.09	7	0.2	-0.05	-0.005
55	762579	6429867	0	North	0.292	-1.2	West	-4.1	-0.41	-1.90	-3	0.4	-0.06	-0.006
56	762570	6429946	0	North	0.348	-6.3	West	-3.9	-0.39	-2.28	-30	-0.7	0.07	0.007
57	762574	6429962	0	North	0.325	-4.6	West	-4.0	-0.40	-2.17	-21	-0.7	0.05	0.005
58	762550	6430008	0	North	0.538	-13.9	West	-3.3	-0.33	-3.69	-77	-1.1	-0.10	-0.010
59	762559	6430010	0	North	0.425	-10.9	West	-3.5	-0.35	-2.56	-61	-0.8	-0.11	-0.011
60	762538	6430061	0	North	0.736	-17.2	West	-3.2	-0.32	-3.36	-122	-1.5	0.02	0.002
61	762499	6430202	0	North	1.680	-28.0	West	1.7	0.17	3.73	-97	-1.4	0.04	0.004
62	762487	6430326	0	North	2.045	-22.1	West	4.7	0.47	1.85	-62	-1.3	0.10	0.010

RS#	Easting	Northing	Z	Location	Subsidence(m)	XL Tilt(mm/m)	Direction	L Strains(mm/m	Curvatures(km	Radius of C (km	XL HD (mm)	CL Tilt(mm/m)	CL Strain(mm/m	CL Curvatur
63	762470	6430345	0	North	2.310	-9.0	West	2.8	0.53	2.75	-24	-0.8	-0.03	-0.007
64	762461	6430369	0	North	2.388	-4.2	West	2.4	0.46	4.83	-10	-0.3	-0.01	-0.002
65	762427	6430414	0	North	2.348	6.0	East	2.7	0.51	3.96	15	0.5	0.05	0.009
66	762375	6430425	0	North	1.261	28.6	East	-0.7	-0.14	2.21	124	1.6	-0.02	-0.003
67	762361	6430407	0	North	0.923	26.0	East	-1.9	-0.37	1.05	165	1.3	-0.06	-0.012
68	762347	6430400	0	North	0.630	17.4	East	-2.4	-0.46	-1.62	170	0.8	-0.07	-0.014
69	762302	6430391	0	North	0.283	0.3	East	-1.7	-0.32	-2.10	2	-0.1	0.01	0.002
70	762283	6430383	0	North	0.344	-6.5	West	-1.8	-0.35	-1.39	-56	-0.5	0.01	0.001
71	762265	6430359	0	North	0.505	-12.3	West	-1.8	-0.35	-1.75	-116	-0.7	0.02	0.003
72	762270	6430326	0	North	0.434	-10.7	West	-1.7	-0.33	-1.88	-99	-0.6	-0.02	-0.004
73	762250	6430320	0	North	0.717	-16.5	West	-1.7	-0.33	-4.53	-155	-1.0	-0.04	-0.007
74	762212	6430556	0	North	1.624	-24.6	West	0.8	0.15	4.18	-94	-5.3	0.19	0.036
75	762225	6430567	0	North	1.274	-23.1	West	-0.5	-0.09	20.34	-99	-4.8	0.16	0.031
76	762378	6430601	0	North	1.304	23.3	East	-0.4	-0.08	5.03	119	2.2	0.02	0.004
77	762417	6430584	0	North	2.120	16.2	East	2.1	0.40	2.06	53	0.4	-0.04	-0.008
78	762456	6430556	0	North	2.408	-1.0	West	2.1	0.40	7.03	-3	-0.3	-0.01	-0.002
79	762470	6430545	0	North	2.355	-6.0	West	2.6	0.50	3.78	-16	-0.7	-0.02	-0.004
80	762496	6430539	0	North	1.961	-23.3	West	2.1	0.40	2.13	-72	-1.6	0.00	-0.001
81	762505	6430494	0	North	1.750	-27.2	West	1.2	0.23	3.33	-93	-1.4	0.02	0.004
82	762515	6430488	0	North	1.470	-27.1	West	-0.2	-0.04	4.39	-108	-1.5	-0.01	-0.002
83	762576	6430480	0	North	0.387	-8.4	West	-1.8	-0.34	-1.44	-74	-0.5	-0.01	-0.001
84	762541	6430394	0	North	0.821	-18.6	West	-1.7	-0.32	48.29	-150	-1.2	-0.02	-0.005
85	762568	6430383	0	North	0.434	-10.2	West	-1.7	-0.33	-1.54	-93	-0.6	-0.01	-0.002
86	762561	6430376	0	North	0.501	-12.1	West	-1.7	-0.33	-1.81	-112	-0.8	0.00	0.000
87	762560	6430371	0	North	0.514	-12.5	West	-1.7	-0.34	-1.87	-116	-0.8	0.01	0.002
88	762575	6430367	0	North	0.364	-7.3	West	-1.8	-0.34	-1.47	-64	-0.5	0.01	0.002
89	762576	6430361	0	North	0.355	-6.9	West	-1.8	-0.34	-1.48	-60	-0.4	0.02	0.003
90	762590	6430372	0	North	0.292	-2.3	West	-1.7	-0.33	-1.84	-18	-0.2	0.01	0.001
91	762604	6430376	0	North	0.293	2.5	East	-1.7	-0.32	-2.17	20	0.1	-0.01	-0.001
92	762764	6430016	0	North	2.017	-12.4	West	1.8	0.35	2.63	-33	0.6	-0.20	-0.038
93	762883	6429605	0	North	-0.001	0.0	West	0.0	0.00		0	0.0	0.00	0.000
94	762876	6429660	0	North	0.002	0.0	West	-0.2	-0.03	-484.79	0	0.2	-0.04	-0.007
95	763076	6431397	0	North	2.380	-3.6	West	1.9	0.36	3.50	-13	-0.2	-0.01	-0.002
96	763015	6431390	0	North	1.942	18.2	East	1.4	0.27	2.02	118	1.5	-0.01	-0.002
97	762933	6431358	0	North	0.385	10.5	East	-1.7	-0.33	-2.50	45	-1.3	0.09	0.017
98	762896	6431313	0	North	0.298	-0.7	West	-1.4	-0.26	-3.29	-18	-1.8	0.07	0.013
99	762895	6431277	0	North	0.349	-1.7	West	-1.4	-0.27	-2.78	-28	-1.3	0.06	0.012
100	762887	6431251	0	North	0.400	-4.7	West	-1.3	-0.26	-3.16	-49	-1.2	0.08	0.015
101	762885	6431242	0	North	0.416	-5.4	West	-1.3	-0.26	-3.18	-55	-1.1	0.08	0.015
102	762881	6431245	0	North	0.435	-6.4	West	-1.3	-0.26	-3.47	-61	-1.3	0.08	0.015
103	762875	6431194	0	North	0.501	-9.1	West	-1.3	-0.25	-3.25	-90	-0.7	0.07	0.014
104	762858	6431169	0	North	0.682	-13.5	West	-1.2	-0.23	43.23	-120	-0.9	0.05	0.009
105	762846	6431164	0	North	0.868	-16.7	West	-1.0	-0.20	4.87	-114	-1.2	0.06	0.011
106	762805	6431204	0	North	1.555	-16.1	West	1.1	0.21	5.06	-79	-2.7	0.09	0.017
107	762749	6431197	0	North	1.873	7.0	East	2.5	0.49	1.83	35	-0.4	-0.02	-0.004
108	762839	6431054	0	North	0.935	-18.6	West	-1.0	-0.20	2.89	-126	-1.1	-0.05	-0.009
109	763085	6431399	0	North	2.330	-7.0	West	1.8	0.35	2.20	-30	-0.4	-0.02	-0.003
110	761945	6430057	0	North	0.620	-14.6	West	-1.2	-0.23	-4.21	-76	-6.1	0.13	0.026
111	761882	6430106	0	North	1.038	-13.6	West	-1.6	-0.30	-1.73	-71	-17.9	0.20	0.038
112	762017	6430126	0	North	0.373	11.2	East	-1.3	-0.25	-3.38	66	0.4	0.13	0.024
113	762019	6430114	0	North	0.401	11.2	East	-1.4	-0.26	-3.37	67	0.8	0.06	0.011
114	761868	6430091	0	North	1.556	-22.3	West	2.7	0.52	-1.74	-116	-16.5	0.80	0.154
115	761995	6430232	0	North	0.085	5.2	East	-1.2	-0.23	-3.47	37	0.4	0.00	-0.001
116	763751	6428827	0	South	-0.001	0.0	South	0.0	0.00		0	-0.1	-0.07	-0.014
117	763766	6428986	0	South	0.010	0.0	North	0.0	0.00	-676.59	0	-1.4	-0.50	-0.096
118	763747	6428928	0	South	0.018	1.0	North	0.0	-0.01	11.79	6	-1.3	-0.23	-0.045
119	763722	6428866	0	South	0.000	0.0	South	-0.1	-0.01		0	-0.2	-0.15	-0.028
120	763724	6428835	0	South	0.007	0.0	North	-0.1	-0.02	199.13	0	-0.8	-0.30	-0.059
121	763725	6428826	0	South	0.011	-0.2	South	-0.1	-0.02	-36.02	-1	-1.2	-0.37	-0.071
122	763801	6428802	0	South	-0.001	0.0	South	0.0	-0.01		0	0.0	0.00	-0.001
123	763808	6428791	0	South	-0.001	0.0	South	0.0	0.00		0	0.0	-0.02	-0.003
124	763868	6428743	0	South	-0.001	0.0	South	0.0	0.00		0	0.0	0.00	0.000

RS#	Easting	Northing	Z	Location	Subsidence(m)	XL Tilt(mm/m)	Direction	XL Strains(mm/m	Curvatures(km	Radius of C (km	XL HD (mm)	CL Tilt(mm/m)	CL Strain(mm/m	CL Curvature
125	763937	6428721	0	South	-0.001	0.0	South	0.0	0.00		0	0.0	0.00	0.000
126	763946	6428719	0	South	-0.001	0.0	South	0.0	0.00		0	0.0	0.00	0.000
127	763973	6428715	0	South	-0.001	0.0	South	0.0	0.00		0	0.0	0.00	0.000
128	762550	6428866	0	South	1.352	-21.9	South	0.2	0.04	3.19	-82	2.6	0.02	0.004
129	762498	6428796	0	South	1.997	-0.5	South	1.6	0.31	35.06	-2	0.1	0.02	0.004
130	762394	6428755	0	South	1.950	4.7	North	2.0	0.38	5.18	12	-0.7	0.01	0.001
131	762396	6428758	0	South	1.966	3.6	North	1.9	0.36	6.13	9	-0.5	0.01	0.003
132	762386	6428740	0	South	1.851	10.2	North	2.3	0.44	3.32	28	-1.5	0.00	0.000
133	762378	6428719	0	South	1.560	20.9	North	1.6	0.31	2.71	64	-2.5	0.03	0.006
134	762359	6428765	0	South	1.995	0.0	North	1.5	0.28	11.78	0	0.1	0.02	0.005
135	762353	6428771	0	South	1.987	-1.3	South	1.6	0.32	8.27	-3	0.4	0.04	0.008
136	762342	6428774	0	South	1.970	-2.5	South	1.8	0.35	6.61	-7	0.6	0.06	0.012
137	762292	6428792	0	South	1.686	-16.9	South	1.9	0.37	2.82	-48	2.0	-0.06	-0.012
138	762198	6428737	0	South	2.055	-2.3	South	1.6	0.32	12.37	-3	-1.1	0.01	0.003
139	762193	6428732	0	South	2.070	-1.3	South	1.7	0.32	12.20	-2	-1.2	0.02	0.004
140	762156	6428746	0	South	2.013	-8.0	South	1.7	0.33	6.07	-14	0.0	0.13	0.024
141	762495	6428921	0	South	0.346	-7.9	South	-1.4	-0.27	-2.14	-64	1.2	-0.12	-0.023
142	762441	6428923	0	South	0.276	-3.2	South	-1.6	-0.30	-1.98	-25	0.4	-0.03	-0.006
143	762446	6428951	0	South	0.300	5.0	North	-1.8	-0.35	-1.65	44	-0.7	-0.03	-0.005
144	762478	6428954	0	South	0.286	4.2	North	-1.7	-0.33	-1.87	34	-0.4	-0.08	-0.015
145	762846	6427860	0	South	0.514	11.7	North	-1.8	-0.35	-0.82	152	-1.8	-0.10	-0.019
146	762956	6432325	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
147	762941	6432206	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
148	762942	6432203	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
149	762916	6432205	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
150	762913	6432185	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
151	762913	6432153	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
152	762902	6432158	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
153	762890	6432136	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
154	762875	6432147	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
155	762878	6432127	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
156	762884	6432089	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
157	762864	6432085	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
158	762855	6432129	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
159	762860	6432147	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
160	762856	6432116	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
161	762858	6432072	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
162	762873	6432035	0	North	-0.001	0.0	West	0.0	0.00	N/A	0	0.0	0.00	0.000
163	762925	6432019	0	North	0.038	2.5	East	-0.5	-0.09	-15.18	13	-0.5	0.00	0.000
164	762899	6432023	0	North	0.002	0.0	West	-0.2	-0.05	-547.42	0	-0.1	-0.02	-0.005
165	762876	6432021	0	North	-0.001	0.0	West	0.0	-0.01		0	0.0	0.00	-0.001
166	762899	6432006	0	North	0.007	0.5	East	-0.3	-0.05	-10.56	2	-0.2	-0.03	-0.005
167	762897	6431993	0	North	0.010	0.8	East	-0.3	-0.05	-10.70	4	-0.3	-0.03	-0.005
168	762905	6431976	0	North	0.027	1.5	East	-0.3	-0.05	-26.91	8	-0.4	0.00	0.001
169	762898	6431982	0	North	0.015	1.2	East	-0.2	-0.04	-17.83	6	-0.4	-0.02	-0.003
170	762869	6431969	0	North	0.002	0.1	East	-0.1	-0.02	-47.65	0	-0.2	-0.02	-0.003
171	762880	6431961	0	North	0.009	0.9	East	-0.2	-0.03	-218.12	4	-0.3	0.01	0.002
172	762878	6431948	0	North	0.012	0.9	East	-0.1	-0.03	38.66	5	-0.2	0.03	0.006
173	762913	6432185	0	North	-0.001	0.0	West	0.0	0.00		0	0.0	0.00	0.000
174	762878	6432127	0	North	-0.001	0.0	West	0.0	0.00		0	0.0	0.00	0.000
175	762905	6431976	0	North	0.027	1.5	East	-0.3	-0.05	-26.93	8	-0.4	0.00	0.001
176	762869	6431969	0	North	0.002	0.1	East	-0.1	-0.02	-50.43	0	-0.2	-0.02	-0.003
177	762858	6432072	0	North	-0.001	0.0	West	0.0	0.00		0	0.0	0.00	0.000

APPENDIX C

Results of Cliff Line Stability Assessments

Table C1a - Mining Impact Classification of Cliff Line CL1 Outside Extraction Limit of LW12

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	m	0 - 0.1	<0.5	0
Differential horizontal movement at crest	mm	0 - 100	50 - 100	5
Mining induced tilt at cliff	mm/m	0 - 2	<2	0
Mining induced strain at cliff	mm/m	0 - 2	<2	5
Cover Depth at base of cliff	m	140 - 150	100 - 200	40
Sub-Total/Maximum Score for Category 1				**50/180**
Category 1 Impact Rating		**Low**		**(0.28)**
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics		Common to Pleasant		10
Ease of Public Viewing		Hard to view		10
Overall Cliff Height	m	5 - 25	<50	0
Cliff Type		Sheer to rounded rock face with large talus		10
Shape of Cliff Face		Shear to rounded rock face		5
Location of cliff relative to others		3 to 5 features		10
Presence of archaeological sites		Related to prominent archaeological site/s		40
Ease of public walking access to cliff base areas exposed to rock falls		Access by walking >500m, no public walkways		4
Ease of public walking access to potentially unstable cliff top areas		Access by walking >500m, no public walkways		4
Ease of public vehicular access to cliff base areas exposed to rock falls		Private road access < 500m		5
Ease of public vehicular access to potentially unstable cliff top areas		No access		0
Dwellings/structures above/below cliff face		Within 1 km of cliff		40
Sub-Total/Maximum Score for Category 2				**138/696**
Category 2 Impact Rating		**Very Low**		**(0.19)**
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	5 - 25	<50	0
Cliff face height	m	3 - 15	<20	0
Talus slope height	m	2 - 10	<20	0
Cliff face length or width	m	10 - 50	>2 x height	8
Cliff face angle to horizontal	o	60 - 85	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas		Sparse, dense vegetation on talus		2
Degree of undercutting or weathering		Face with overhangs 2 - 7m		30
Extent of bedding partings on cliff face		Medium spaced bedding partings		10
Extent of vertical jointing on cliff face		Persistent through cliff		6
In-situ horizontal stress at seam level	MPa	7 - 8	<10	0
Rock strata strength in cliff face (UCS)	MPa	<30 - 50	<30 - 50	25
Location of cliff in relation to watercourses, valleys, and		Not related		0
Location of cliff in relation to geological anomalies		Related to persistent jointing		4
Degree of exposure to weathering agents		Partly sheltered from wind		2
Presence of water flows at base of slope		No streams or creeks		0
Presence of loose and unstable blocks		Many could possibly fall		10
Presence of natural cracks in cliff crest		One		5
Orientation of visible joints relative to cliff line	o	70 - 90	60 - 90	0
Sub-Total/Maximum Score for Category 3				**106/408**
Category 3 Impact Rating		**Low**		**(0.26)**
Total Cliff Line Impact Rating		**VERY LOW**		

Table C1b - Mining Impact Classification of Cliff Line CL1 Above LW12

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	m	0.1 - 2.2	>0.5	30
Differential horizontal movement at crest	mm	100 - 555	>300	30
Mining induced tilt at cliff	mm/m	4 - 37	>10	30
Mining induced strain at cliff	mm/m	1 - 16	>10	30
Cover Depth at base of cliff	m	140 - 150	100 - 200	40
Sub-Total/Maximum Score for Category 1				**160/180 (0.89)**
Category 1 Impact Rating		**Extremely High**		
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics	Common to Pleasant			10
Ease of Public Viewing	Hard to view			10
Overall Cliff Height	m	5 - 25	<50	0
Cliff Type	Sheer to rounded rock face with large talus			10
Shape of Cliff Face	Shear to rounded rock face			5
Location of cliff relative to others	3 to 5 features			10
Presence of archaeological sites	Related to prominent archaeological site/s			40
Ease of public walking access to cliff base areas exposed to rock falls	Access by walking >500m, no public walkways			4
Ease of public walking access to potentially unstable cliff top areas	Access by walking >500m, no public walkways			4
Ease of public vehicular access to cliff base areas exposed to rock falls	Private road access < 500m			5
Ease of public vehicular access to potentially unstable cliff top areas	No access			0
Dwellings/structures above/below cliff face	Within 1 km of cliff			40
Sub-Total/Maximum Score for Category 2				**138/696 (0.19)**
Category 2 Impact Rating		**Very Low**		
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	5 - 25	<50	0
Cliff face height	m	3 - 15	<20	0
Talus slope height	m	2 - 10	<20	0
Cliff face length or width	m	10 - 50	>2 x height	8
Cliff face angle to horizontal	o	60 - 85	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas	Sparse, dense vegetation on talus			2
Degree of undercutting or weathering	Face with overhangs 2 - 7m			30
Extent of bedding partings on cliff face	Medium spaced bedding partings			10
Extent of vertical jointing on cliff face	Persistent through cliff			6
In-situ horizontal stress at seam level	MPa	7 - 8	<10	0
Rock strata strength in cliff face (UCS)	MPa	<30 - 50	<30 - 50	25
Location of cliff in relation to watercourses, valleys, and	Not related			0
Location of cliff in relation to geological anomalies	Related to persistent jointing			4
Degree of exposure to weathering agents	Partly sheltered from wind			2
Presence of water flows at base of slope	No streams or creeks			0
Presence of loose and unstable blocks	Many could possibly fall			10
Presence of natural cracks in cliff crest	One			5
Orientation of visible joints relative to cliff line	o	70 - 90	60 - 90	0
Sub-Total/Maximum Score for Category 3				**106/408 (0.26)**
Category 3 Impact Rating		**Low**		
Total Cliff Line Impact Rating		**MODERATE**		

Table C2 - Mining Impact Classification of Cliff Line CL2 Above LWs 11-12

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	m	0 - 1.975	>0.5	30
Differential horizontal movement at crest	mm	0 - 118	>300	30
Mining induced tilt at cliff	mm/m	0 - 24	>10	30
Mining induced strain at cliff	mm/m	9 - 18	>10	30
Cover Depth at base of cliff	m	150 - 170	100 - 200	40
Sub-Total/Maximum Score for Category 1				**160/180**
Category 1 Impact Rating		**Extremely High**		**(0.89)**
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics	Common to Pleasant			10
Ease of Public Viewing	Hard to view			10
Overall Cliff Height	m	12 - 15	<50	0
Cliff Type	Sheer to rounded rock face with large talus			10
Shape of Cliff Face	Shear to rounded rock face with pagodas			10
Location of cliff relative to others	3 to 5 features			10
Presence of archaeological sites	Related to possible habitation site/s			10
Ease of public walking access to cliff base areas exposed to rock falls	Access by walking >500m, no public walkways			4
Ease of public walking access to potentially unstable cliff top areas	Access by walking >500m, no public walkways			4
Ease of public vehicular access to cliff base areas exposed to rock falls	Private road access < 500m			5
Ease of public vehicular access to potentially unstable cliff top areas	No access			0
Dwellings/structures above/below cliff face	Within 100m of cliff			80
Sub-Total/Maximum Score for Category 2				**153/696**
Category 2 Impact Rating		**Low**		**(0.22)**
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	12 - 15	<50	0
Cliff face height	m	3 - 10	<20	0
Talus slope height	m	0 - 3	<20	0
Cliff face length or width	m	10 - 20	>2 x height	8
Cliff face angle to horizontal	o	60 - 85	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas	sparse, dense vegetation on talus			2
Degree of undercutting or weathering	face with honeycombing and overhangs >2m			10
Extent of bedding partings on cliff face	Minimal bedding partings			5
Extent of vertical jointing on cliff face	Joints persistent through face			6
In-situ horizontal stress at seam level	MPa	7 - 8	<10	0
Rock strata strength in cliff face (UCS)	MPa	<30 - 50	<30 - 50	25
Location of cliff in relation to watercourses, valleys, and	Not related			0
Location of cliff in relation to geological anomalies	Related to persistent jointing			4
Degree of exposure to weathering agents	partly sheltered from wind			2
Presence of water flows at base of slope	no stream or creek			3
Presence of loose and unstable blocks	A few falls are possible			5
Presence of natural cracks in cliff crest	One			5
Orientation of visible joints relative to cliff line	o	70 - 90	60 – 90	0
Sub-Total/Maximum Score for Category 3				**85/408**
Category 3 Impact Rating		**Low**		**(0.21)**
Total Cliff Line Impact Rating		**HIGH**		

Table C3 - Mining Impact Classification of Cliff Line CL3 Above LWs 13 and 14

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	m	0.23 - 1.89	>0.5	30
Differential horizontal movement at crest	mm	220 - 900	>300	30
Mining induced tilt at cliff	mm/m	0 - 30	>10	30
Mining induced strain at cliff	mm/m	11 - 22	>10	30
Cover Depth at base of cliff	m	170 - 180	100 - 200	40
Sub-Total/Maximum Score for Category 1				**160/180**
Category 1 Impact Rating		**Extremely High**		**(0.89)**
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics		Pleasant		20
Ease of Public Viewing		Hard to view		10
Overall Cliff Height	m	20 - 40	<50	0
Cliff Type		Sheer rock face with large talus		10
Shape of Cliff Face		Large overhands notches or recesses		30
Location of cliff relative to others		Major cliff cline		20
Presence of archaeological sites		Related to possible habitation site/s		10
Ease of public walking access to cliff base areas exposed to rock falls		Access by walking > 3 km, no public walkways		2
Ease of public walking access to potentially unstable cliff top areas		Access by walking > 3 km, no public walkways		2
Ease of public vehicular access to cliff base areas exposed to rock falls		Private road access < 500 m		5
Ease of public vehicular access to potentially unstable cliff top areas		No access		0
Dwellings/structures below cliff face		within 5 km		20
Sub-Total/Maximum Score for Category 2				**127/696**
Category 2 Impact Rating		**Very Low**		**(0.18)**
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	20 - 40	<50	0
Cliff face height	m	10 - 30	20 - 50	5
Talus slope height	m	2 - 10	<20	0
Cliff face length or width	m	200 - 500	>10 x height	24
Cliff face angle to horizontal	o	50 - 90	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas		Sparse, dense vegetation on talus		2
Degree of undercutting or weathering		Intricate cross bedding on face and large overhangs up to 10 m		30
Extent of bedding partings on cliff face		Minimal bedding partings		5
Extent of vertical jointing on cliff face		Persistent through face		6
In-situ horizontal stress at seam level	MPa	9 - 10	<10	0
Rock strata strength in cliff face (UCS)	MPa	<30 - 50	<30 - 50	25
Location of cliff in relation to watercourses, valleys, and		Not related		0
Location of cliff in relation to geological anomalies		Related to persistent jointing		4
Degree of exposure to weathering agents		Exposed to wind		4
Presence of water flows at base of slope		No stream or creek		0
Presence of loose and unstable blocks		Many could possibly fall		10
Presence of natural cracks in cliff crest		One		5
Orientation of visible joints relative to cliff line	o	70 - 90	60 - 90	0
Sub-Total/Maximum Score for Category 3				**130/408**
Category 3 Impact Rating		**Moderate**		**(0.31)**
Total Cliff Line Impact Rating		**HIGH**		

Table C4 - Mining Impact Classification of Cliff Line CL4 above LWs 10 and 11

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	m	0.16 - 2.44	>0.5	30
Differential horizontal movement at crest	mm	170 - 510	>300	30
Mining induced tilt at cliff	mm/m	0 - 34	>10	30
Mining induced strain at cliff	mm/m	11 - 22	>10	30
Cover Depth at base of cliff	m	140 - 160	100 - 200	40
Sub-Total/Maximum Score for Category 1				**160/180 (0.89)**
Category 1 Impact Rating		**Extremely High**		
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics	Common to Pleasant			10
Ease of Public Viewing	Hard to view			10
Overall Cliff Height	m	10 - 35	<50	0
Cliff Type	Sheer to rounded rock face with large talus			10
Shape of Cliff Face	Rounded rock face			0
Location of cliff relative to others	3 to 5 features			10
Presence of archaeological sites	Related to prominent archaeological site/s			40
Ease of public walking access to cliff base areas exposed to rock falls	Access by walking > 3 km, no public walkways			5
Ease of public walking access to potentially unstable cliff top areas	Access by walking > 3 km, no public walkways			5
Ease of public vehicular access to cliff base areas exposed to rock falls	Private Road access < 500m			5
Ease of public vehicular access to potentially unstable cliff top areas	Private Road access < 500m			5
Dwellings/structures below cliff face	Within 5 km			20
Sub-Total/Maximum Score for Category 2				**120/696 (0.17)**
Category 2 Impact Rating		**Very Low**		
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	10 - 35	<50	0
Cliff face height	m	3 - 15	<20	0
Talus slope height	m	2 - 10	<20	0
Cliff face length or width	m	10 - 40	>2 x height	16
Cliff face angle to horizontal	o	50 - 80	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas	sparse, dense vegetation on talus			2
Degree of undercutting or weathering	face with honeycombing and small overhangs < 2 m			10
Extent of bedding partings on cliff face	Minimal bedding partings			5
Extent of vertical jointing on cliff face	Joints continuing over several strata layers			3
In-situ horizontal stress at seam level	MPa	9 - 10	<10	0
Rock strata strength in cliff face (UCS)	MPa	<30 - 50	<30 - 50	25
Location of cliff in relation to watercourses, valleys, and	Not related			0
Location of cliff in relation to geological anomalies	Related to persistent jointing			4
Degree of exposure to weathering agents	Partly sheltered from wind			2
Presence of water flows at base of slope	No streams or creeks			0
Presence of loose and unstable blocks	Many could possibly fall			10
Presence of natural cracks in cliff crest	One			5
Orientation of visible joints relative to cliff line	o	70 - 90	60 - 90	0
Sub-Total/Maximum Score for Category 3				**92/408 (0.23)**
Category 3 Impact Rating		**Low**		
Total Cliff Line Impact Rating		**MODERATE**		

Table C5 - Mining Impact Classification of Cliff Line CL5 (i.e. The Drip)

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	m	~0	<50	0
Differential horizontal movement at crest	mm	20-40	<50	0
Mining induced tilt at cliff	mm/m	~0	>10	0
Mining induced strain at cliff	mm/m	~0	>10	0
Cover Depth at base of cliff	m	n/a	>400	0
Sub-Total/Maximum Score for Category 1				**0/180 (0.0)**
Category 1 Impact Rating		**Insignificant**		
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics		Spectacular		120
Ease of Public Viewing		Tourist location		60
Overall Cliff Height	m	30 - 50	<50	0
Cliff Type		Sheer rock face with large talus		10
Shape of Cliff Face		Large overhangs notches or recesses		30
Location of cliff relative to others		Major cliff line		20
Presence of archaeological sites		Prominent shelter site with significant art		60
Ease of public walking access to cliff base areas exposed to rock falls		Access by walking >500 m, public walkways.		12
Ease of public walking access to potentially unstable cliff top areas		Access by walking >500 m, no public walkways		4
Ease of public vehicular access to cliff base areas exposed to rock falls		no road access		0
Ease of public vehicular access to potentially unstable cliff top areas		no road access		0
Dwellings/structures below cliff face		within 5 km		20
Sub-Total/Maximum Score for Category 2				**336/696 (0.48)**
Category 2 Impact Rating			**High**	
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	30 - 50	<50	0
Cliff face height	m	30 - 40	20 - 50	5
Talus slope height	m	2 - 10	<20	0
Cliff face length or width	m	200 - 300	>10xcliff height	24
Cliff face angle to horizontal	o	60 - 90	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas		Sparse, dense vegetation on talus		2
Degree of undercutting or weathering		Large overhangs 5 to 10 m		30
Extent of bedding partings on cliff face		Minimal bedding partings		0
Extent of vertical jointing on cliff face		Minimal persistent jointing in face		5
In-situ horizontal stress at seam level	MPa	3 - 5	<10	0
Rock strata strength in cliff face (UCS)	MPa	30 - 50	30 - 50	20
Location of cliff in relation to watercourses, valleys		Part of cliff clines in gorges or escarpments		12
Location of cliff in relation to geological anomalies		Related to persistent jointing		4
Degree of exposure to weathering agents		Exposed to wind action and next to major river		8
Presence of water flows at base of slope		River or creek with gradient of > 1 in 75		12
Presence of loose and unstable blocks		A few could possibly fall		2
Presence of natural cracks in cliff crest		One		5
Orientation of visible joints relative to cliff line	o	70 - 90	60 - 90	0
Sub-Total/Maximum Score for Category 3				**139/408 (0.34)**
Category 3 Impact Rating		**Moderate**		
Total Cliff Line Impact Rating		**LOW**		

Table C6 - Mining Impact Classification of Cliff Line CL6 Above LWs 6 - 7

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	m	0.2 - 2.0	>0.5	30
Differential horizontal movement at crest	mm	0 - 702	>300	30
Mining induced tilt at cliff	mm/m	0 - 28	>10	30
Mining induced strain at cliff	mm/m	10 - 20	>10	30
Cover Depth at base of cliff	m	150 - 170	100 - 200	40
Sub-Total/Maximum Score for Category 1				**160/180**
Category 1 Impact Rating		**Extremely High**		**(0.89)**
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics	Common to Pleasant			10
Ease of Public Viewing	Hard to view			10
Overall Cliff Height	m	10 - 25	<50	0
Cliff Type	Rounded rock face with large talus slope			0
Shape of Cliff Face	Round rock face			0
Location of cliff relative to others	3 to 5 features			10
Presence of archaeological sites	Related to a possible habitation site/s			10
Ease of public walking access to cliff base areas exposed to rock falls	Access by walking > 3 km, no public walkways			2
Ease of public walking access to potentially unstable cliff top areas	Access by walking > 3 km, no public walkways			2
Ease of public vehicular access to cliff base areas exposed to rock falls	Private road access <500			5
Ease of public vehicular access to potentially unstable cliff top areas	No Access			0
Dwellings/structures below cliff face	Within 5 km			20
Sub-Total/Maximum Score for Category 2				**69/696**
Category 2 Impact Rating		**Very Low**		**(0.10)**
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	10 - 25	<50	0
Cliff face height	m	5 - 15	< 20	0
Talus slope height	m	2 - 10	<20	0
Cliff face length or width	m	10 - 200	>5 x height	16
Cliff face angle to horizontal	o	60 - 90	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas	Sparse, dense vegetation on talus			2
Degree of undercutting or weathering	Face with honeycombing and overhangs 2 to 10 m			30
Extent of bedding partings on cliff face	Medium bedding partings			10
Extent of vertical jointing on cliff face	Persistent joints through cliff face			6
In-situ horizontal stress at seam level	MPa	8 - 9	<10	0
Rock strata strength in cliff face (UCS)	MPa	< 30 - 50	< 30 - 50	25
Location of cliff in relation to watercourses, valleys, and	Not related			0
Location of cliff in relation to geological anomalies	Related to persistent jointing			4
Degree of exposure to weathering agents	Partly sheltered from wind			2
Presence of water flows at base of slope	No stream or creek			0
Presence of loose and unstable blocks	Many could possibly fall			10
Presence of natural cracks in cliff crest	One			5
Orientation of visible joints relative to cliff line	o	70 - 90	60 - 90	0
Sub-Total/Maximum Score for Category 3				**120/408**
Category 3 Impact Rating		**Low**		**(0.28)**
Total Cliff Line Impact Rating		**MODERATE**		

Table C7 - Mining Impact Classification of Cliff Line CL7 to East of LWs 5 and 6

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	m	0 - 0.1	<0.1	5
Differential horizontal movement at crest	mm	0 - 100	50 to 100	5
Mining induced tilt at cliff	mm/m	0 - 1	<1	0
Mining induced strain at cliff	mm/m	0 - 1	<1	0
Cover Depth at base of cliff	m	170 - 180	100 - 200	40
Sub-Total/Maximum Score for Category 1				**50/180 (0.28)**
Category 1 Impact Rating		**Low**		
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics		Common to Pleasant		10
Ease of Public Viewing		Hard to view		10
Overall Cliff Height	m	15 - 35	<50	0
Cliff Type		Sheer to rounded rock face with large talus slope		10
Shape of Cliff Face		Sheer to rounded rock face		5
Location of cliff relative to others		3 to 5 features		10
Presence of archaeological sites		Related to prominent archaeological site/s		40
Ease of public walking access to cliff base areas exposed to rock falls		Access by walking > 3 km, no public walkways		2
Ease of public walking access to potentially unstable cliff top areas		Access by walking > 3 km, no public walkways		2
Ease of public vehicular access to cliff base areas exposed to rock falls		Private road access < 500m		5
Ease of public vehicular access to potentially unstable cliff top areas		Public Road access < 500m		5
Dwellings/structures below cliff face		Within 5 km		20
Sub-Total/Maximum Score for Category 2				**119/696 (0.17)**
Category 2 Impact Rating		**Very Low**		
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	15 - 35	<50	0
Cliff face height	m	5 - 15	<20	0
Talus slope height	m	2 - 10	<20	0
Cliff face length or width	m	10 - 200	>5 x height	16
Cliff face angle to horizontal	o	60 - 90	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas		Sparse, dense vegetation on talus		2
Degree of undercutting or weathering		Small or large overhangs 2-7m		30
Extent of bedding partings on cliff face		Medium spaced bedding partings		10
Extent of vertical jointing on cliff face		Persistent Joints through cliff face		6
In-situ horizontal stress at seam level	MPa	9 - 10	<10	0
Rock strata strength in cliff face (UCS)	MPa	<30 - 50	<30 - 50	25
Location of cliff in relation to watercourses and valleys		Not related		0
Location of cliff in relation to geological anomalies		Related to persistent jointing		4
Degree of exposure to weathering agents		Exposed to wind		4
Presence of water flows at base of slope		No stream or creek		0
Presence of loose and unstable blocks		Many could possibly fall		5
Presence of natural cracks in cliff crest		One		5
Orientation of visible joints relative to cliff line	o	70 - 90	60 - 90	0
Sub-Total/Maximum Score for Category 3				**120/408 (0.29)**
Category 3 Impact Rating		**Low**		
Total Cliff Line Impact Rating		**VERY LOW**		

Table C8 - Mining Impact Classification of Cliff Line CL8 Above of LWs 1 to 5

Impact Parameter	Units	Value or Definition	Category Limits	Weighted Score
Impact Category 1 - Extent of Mining Induced Movements at Cliffs				
Mine subsidence	mm	0 - 1.9	>500	30
Differential horizontal movement at crest	mm	0 - 565	>300	30
Mining induced tilt at cliff	mm/m	0 - 23	>10	30
Mining induced strain at cliff	mm/m	7 - 14	>10	30
Cover Depth at base of cliff	m	170 - 180	100 - 200	40
Sub-Total/Maximum Score for Category 1				**160/180**
Category 1 Impact Rating		**Extremely High**		**(0.89)**
Impact Category 2 – Public Exposure and Aesthetic Quality of Cliff Lines				
Aesthetics		Common to Pleasant		10
Ease of Public Viewing		Hard to view		10
Overall Cliff Height	m	10 - 25	<50	0
Cliff Type		Sheer to rounded rock face with large talus slope		10
Shape of Cliff Face		Sheer to rounded rock face		5
Location of cliff relative to others		3 to 5 features		10
Presence of archaeological sites		Not related		0
Ease of public walking access to cliff base areas exposed to rock falls		Access by walking > 3 km, no public walkways		2
Ease of public walking access to potentially unstable cliff top areas		Access by walking > 3 km, no public walkways		2
Ease of public vehicular access to cliff base areas exposed to rock falls		Private road access < 500m		5
Ease of public vehicular access to potentially unstable cliff top areas		Public Road access < 500m		5
Dwellings/structures below cliff face		Within 5 km		20
Sub-Total/Maximum Score for Category 2				**79/696**
Category 2 Impact Rating		**Very Low**		**(0.11)**
Impact Category 3 - Natural Instability of the Cliff Formation				
Overall height of talus, cliff face & crest	m	10 - 25	<50	0
Cliff face height	m	5 - 15	<20	0
Talus slope height	m	2 - 10	<20	0
Cliff face length or width	m	10 - 50	>5 x height	16
Cliff face angle to horizontal	o	60 - 90	>80	8
Talus slope angle of repose	o	35	>30	2
Vegetation cover on cliff areas		Sparse, dense vegetation on talus		2
Degree of undercutting or weathering		Face with small overhangs up to 2m		10
Extent of bedding partings on cliff face		Medium spaced bedding partings		10
Extent of vertical jointing on cliff face		Persistent through cliff face		6
In-situ horizontal stress at seam level	MPa	4 - 5	<10	0
Rock strata strength in cliff face (UCS)	MPa	<30 - 50	<30 - 50	25
Location of cliff in relation to watercourses and valleys		Not related		0
Location of cliff in relation to geological anomalies		Related to persistent jointing		4
Degree of exposure to weathering agents		Exposed sheltered from wind		4
Presence of water flows at base of slope		No stream or creek		0
Presence of loose and unstable blocks		A few could possibly fall		5
Presence of natural cracks in cliff crest		One		5
Orientation of visible joints relative to cliff line	o	70 - 90	60 - 90	0
Sub-Total/Maximum Score for Category 3				**95/408**
Category 3 Impact Rating		**Low**		**(0.23)**
Total Cliff Line Impact Rating		**MODERATE**		

Extract from ACARP(2000) - Cliff Line Stability Due to Mine Subsidence

10. The Assessment of Mining Impacts on Clifflines

This section presents methods that can be used for the assessment of mining impacts on clifflines and for predicting the likelihood of rockfalls.

10.1. Introduction

The method described in the final report on Stage 1 of this research project, for assessing the impacts of mining on clifflines, involved classifying the cliffs under four separate categories, namely:

1. Overall size and noticeable characteristics of the cliff.
2. Aesthetic quality and degree of public exposure.
3. Natural instability of the cliff formation.
4. Extent of the mining-induced ground movements.

The method covered a wide range of alternatives, but was essentially based on cliffs in the Southern Coalfield with heights up to 100 metres. All other cliffs above this height were included in a single group for the purposes of assessing the impacts.

An alternative, but similar, method of assessment was described by Radloff and Mills, Ref. 7.7, 2001, which classified the cliffs under four separate assessment categories, namely:

1. Physical characteristics.
2. Geological and mining characteristics.
3. Association with environmental features.
4. Human use aesthetics.

The method described by the authors included ratings for cliffs greater than 150 metres in height, which made the method more applicable to the Western Coalfield, where some very high cliffs exist. Since the two methods had many features in common, it was decided to integrate them, and, in that way, arrive at a single method that could have more universal application.

10.2. Development of the Method of Assessment

There was a certain amount of overlap between the first three categories and the method has, therefore, been amended and simplified, by the removal of Category 1, to avoid duplication of factors like cliff height, face length, face angle etc., which appeared in both Category 1 and Category 3. Other factors in Category 1, under the heading notable characteristics, were related to the appearance, and hence the aesthetic qualities, of the cliffs and these factors have been transferred to Category 2. The remainder of the factors, which could affect cliff stability, have been transferred to Category 3.

At the same time, the categories have been extended to include a wider range of values for each of the factors, extending the range of application of the method to include some of the higher cliffs that exist in the Western Coalfield.

The method therefore now employs only three classification categories and these are shown in Tables 10.1 to 10.3 below. Table 10.1 covers various factors that affect the extent of the mining-induced ground movements. Table 10.2 covers various factors that affect the aesthetic quality and degree of public exposure of the clifflines. Table 10.3 covers various factors that affect the natural instability of the cliff formation.

Table 10.1. Extent of the Mining-Induced Ground Movements

Score for each factor	0	1	2	4	6	Weighting
Mining induced vertical subsidence at the cliff	< 50 mm	< 100 mm	100 to 200 mm	200 to 500 mm	> 500 mm	**5**
Mining induced horizontal movement at the cliff	< 50 mm	50 to 100 mm	100 to 200 mm	200 to 300 mm	> 300 mm	**5**
Mining induced tilt at the cliff	< 1 mm/m	< 4 mm/m	< 7 mm/m	< 10 mm/m	> 10 mm/m	**5**
Mining induced strain at the cliff	< 1 mm/m	< 2 mm/m	< 5 mm/m	< 10 mm/m	> 10 mm/m	**5**
Depth of cover at the base of the cliff	> 400 m	300 to 400 m	200 to 300 m	100 to 200 m	< 100 m	**10**

Table 10.2. Aesthetic Quality and Degree of Public Exposure

Score for each factor	0	1	2	4	6	Weighting
Overall aesthetics of cliff formation	common	pleasant	distinctive	superb	spectacular	**20**
Ease of public viewing	very hard to view	hard to `view	easy to view from gravel roads	easy to view from sealed roads	tourist location	**10**
Overall height of cliff	<50m	50m to 75m	75m to 100m	> 100m	> 150m	**10**
Cliff type	rounded rock face with large talus slope	rounded rock face with minimal talus	sheer rock face with large talus	sheer rock face with minimal talus	sheer rock face with no talus	**5**
Shape of cliff face	rounded rock face	sheer rock face	sheer rock face with pagodas	sheer rock face with slender spires	Large overhangs notches or recesses	**5**
Location of cliff relative to others	Single feature	1 or 2 features	3 to 5 features	Major cliff line	Part of escarpment	**5**
Presence of archaeological sites	not related	related to a possible habitation site/s	related to a known habitation site/s	related to a prominent archaeological site/s	prominent shelter site/s with significant art	**10**
Ease of public walking access to cliff base areas exposed to rock falls	limited access, walk > 10km, no public walkways	access by walking >3km, no public walkways	access by walking >500 m, no public walkways	access by walking <500m, no public walkways	access by walking <500m, public walkways	**2**
Ease of public walking access to potentially unstable cliff top areas	limited access, walk > 10km, no public walkways	access by walking >3km, no public walkways	access by walking >500 m, no public walkways	access by walking <500m, no public walkways	access by walking <500m, public walkways	**2**
Ease of public vehicular access to cliff base areas exposed to rock falls	road access greater than 500m	road access less than 500m	4WD road access under cliff	unsealed road access under cliff	sealed road access under cliff	**5**
Ease of public vehicular access to potentially unstable cliff top areas	road access greater than 500m	road access within 500m	4WD road access to clifftop	unsealed road access to clifftop	sealed road access to clifftop	**5**
Buildings/structures above cliff face	within 10 km	within 5 km	within 1 km	within 100m	within 20m	**2**
Buildings/structures below cliff face	within 10 km	within 5 km	within 1 km	within 100m	within 20m	**5**
Dwellings above cliff face	within 10 km	within 5 km	within 1 km	within 100m	within 20m	**10**
Dwellings below cliff face	within 10 km	within 5 km	within 1 km	within 100m	within 20m	**20**

Table 10.3 Natural Instability of the Cliff Formation

Score for each factor	0	1	2	4	6	Weighting
Overall height of talus, cliff face, and crest slope.	< 50m	50m to 75m	75m to 100m	> 100m	> 150m	2
Cliff face height	< 20m	20m to 50m	50m to 75m	75m to 100m	> 100m	5
Talus slope height	< 20m	20m to 50m	50m to 75m	75m	> 100m	1
Cliff face length, or width	< cliff height	> cliff height	> 2 x cliff height	> 5 x cliff height	> 10 x cliff height	4
Cliff face angle	< 70o	> 70o	> 80o	> 90o	> 100o	4
Talus slope angle of repose	< 15o 1 in 3.73	> 15o 1 in 3.73	> 30o 1 in 1.73	> 40o 1 in 1.2	> 45o 1 in 1	1
Vegetation cover on cliff areas	dense vegetation and trees on talus and cliff	dense vegetation on talus and sparse vegetation on cliff	dense vegetation and trees on talus, none on cliff	sparse vegetation and trees on talus, none on cliff	no vegetation or trees on talus or cliffs	2
Degree of undercutting or weathering	clean sheer rock face	sheer rock face with small overhangs up to 1m	face with honeycomb weathering and small overhangs up to 2m	delicate honeycomb face or large overhangs i.e. 2m to 4m	delicate honeycomb face or large overhangs > 4m	5
Extent of horizontal jointing on cliff face	clean rock face no joints	minimal jointing > 20m	moderately jointed 10m to 20m	heavily jointed < 10m	Severely jointed < 5m	5
Extent of vertical jointing on cliff face	no continuous joints	joints continuing over several strata layers	continuously jointed over full height of cliff	several continuous joint systems	continuous open joints or fissures	3
In situ horizontal stress at seam level	< 10 MPa	10 to 20 MPa	20 to 30 MPa	30 to 40 MPa	> 40 MPa	5
Type of rock strata – rock strength	UCS >100 MPa	UCS > 75 < 100 MPa	UCS > 50 < 75 MPa	UCS > 30 < 50 MPa	UCS < 30 MPa	5
Location of cliff in relation to watercourses and valleys	not related	related to small creeks and minor tributaries	related to bluffs lining small valleys	part of major cliff lines lining valleys with talus	part of major cliff lines in gorges or escarpments	2
Location of cliff in relation to geological anomalies	not related	related to small faults & dykes < 500 mm	related to continuous vertical jointing	related to major faults & dykes > 500 mm	related to major thrust faults > 500 mm	2
Degree of exposure to ongoing weathering agents	not exposed to winds or creeks or streams	partly sheltered from winds and creeks or streams	exposed to winds and to small creeks or streams	exposed to wind action and next to major river	exposed to strong wind action and next to major river	2
Presence of water flows at base of slope	no stream or creek	stream or creek with gradient of less than 1 in 100	stream or creek with gradient of more than 1 in 100	river or creek with gradient of more than 1 in 75	river or creek with gradient > 1 in 50	3
Presence of loose & unstable blocks on cliff	few unlikely to fall	few could possibly fall	many could possibly fall	few likely to fall	many likely to fall	5
Loose and unstable blocks on talus	few unlikely to fall	few could possibly fall	many could possibly fall	few likely to fall	many likely to fall	2
Presence of natural cracks in cliff crest	none	one	two or three	several	many	5
Orientation of natural cracks relative to cliff line	no cracks or 90o to 60o	60o to 40o	40o to 20o	10o to 20o	< 10o	5

10.3. Application of the Method of Assessment to each Category

These tables allow the impact to be assessed under each category, using a point scoring system in which each factor is given a score and a weighting. The scores for each factor are then multiplied by the weighting and the resultant numbers for each factor are added to give a total score for each category. The scores are then expressed as a proportion of the highest possible score for the category, which is obtained by adding all of the weightings and multiplying the total by 6, i.e. the highest possible score for each factor. The proportions are then used to determine the impact classifications under each category using Table 10.4.

Table 10.4. Impact Classifications

Proportion of maximum score	Ranking	Classification
0 - 0.1	1	insignificant
0.1 - 0.2	2	very low
0.2 - 0.3	3	low
0.3 - 0.4	4	moderate
0.4 - 0.5	5	high
0.5 - 0.6	6	very high
> 0.6	7	extremely high

The maximum score for Table 10.1 is 180. The maximum score for Table 10.2 is 696 and the maximum score for Table 10.3 is 408. If the score for a particular cliffline is an exact decimal proportion that puts it at the top of one classification or the bottom of the next classification, then, the higher classification should be used. Factors relating to the position of the cliffline relative to the longwall and the widths of panels and pillars are reflected in the levels of ground movement given in Table 10.1 and have not been included separately.

10.4. Preparation of an Overall Impact Assessment

The classifications under each category can be combined to give an overall impact assessment for each cliffline using Tables 10.5 to 10.11. These tables have been compiled based upon the observation that if the extent of mining is extremely high, then, no matter what the classifications are within the other categories, the overall impact can not be insignificant. Similarly even if the extent of mining is insignificant, the overall impact can be as high as moderate if the classifications under the other categories are either very high or extremely high.

Tables 10.5 to 10.11 represent each of the mining classifications from an extremely high mining impact to an insignificant mining impact. The overall impact can be determined by selecting the table for the appropriate level of mining impact and then using the x and y axes to represent the impact classifications for the other two characteristics. For example, assume the classifications are:

- Aesthetic quality and degree of public exposure very high
- Natural instability of the cliff formation high
- The extent of mining induced ground movement moderate

Then, the overall impact assessment can be obtained by selecting Table 10.8 for the moderate mining impact and by looking up the classification in the square where the very high column meets the high row. In this example, the overall impact would be extremely high.

It should be noted that the overall impact assessment is not a measure of the likelihood of rock falls. This is a function of the extent of the mining-induced ground movements and the natural instability of the cliffline, which is discussed further in Section 10.5, below.

Cliff Impact Assessment Tables for Different Levels of Mining Impact

Table 10.5 - Extremely High Mining impact

EH	EH	VH	H	M	L	VL	I
EH	EH	EH	EH	EH	EH	EH	M
VH	EH	EH	EH	EH	EH	EH	M
H	EH	EH	EH	EH	EH	VH	M
M	EH	EH	EH	EH	EH	H	L
L	EH	EH	EH	EH	H	M	L
VL	EH	EH	VH	H	M	L	VL
I	M	M	M	L	L	VL	VL

Table 10.6 - Very High Mining Impact

VH	EH	VH	H	M	L	VL	I
EH	EH	EH	EH	EH	EH	EH	M
VH	EH	EH	EH	EH	EH	VH	M
H	EH	EH	EH	EH	EH	H	L
M	EH	EH	EH	EH	VH	M	L
L	EH	EH	EH	VH	H	M	VL
VL	EH	VH	H	M	M	L	VL
I	M	M	L	L	VL	VL	VL

Table 10.7 - High Mining Impact

H	EH	VH	H	M	L	VL	I
EH	EH	EH	EH	EH	EH	VH	M
VH	EH	EH	EH	EH	EH	H	L
H	EH	EH	EH	EH	VH	H	L
M	EH	EH	EH	VH	H	M	L
L	EH	EH	VH	H	M	L	VL
VL	VH	H	H	M	L	L	VL
I	M	L	L	L	VL	VL	VL

Table 10.8 - Moderate Mining Impact

M	EH	VH	H	M	L	VL	I
EH	EH	EH	EH	EH	EH	H	L
VH	EH	EH	EH	EH	VH	M	L
H	EH	EH	EH	EH	H	M	L
M	EH	EH	EH	H	M	L	VL
L	EH	VH	H	M	L	L	VL
VL	H	M	M	L	L	VL	VL
I	L	L	L	VL	VL	VL	I

Table 10.9 - Low Mining Impact

L	EH	VH	H	M	L	VL	I
EH	EH	EH	EH	EH	H	M	L
VH	EH	EH	EH	VH	H	M	VL
H	EH	EH	VH	H	M	L	VL
M	EH	VH	H	M	M	L	VL
L	H	H	M	M	L	VL	VL
VL	M	M	L	L	VL	VL	VL
I	L	VL	VL	VL	VL	VL	I

Table 10.10 - Very Low Mining Impact

VL	EH	VH	H	M	L	VL	I
EH	EH	EH	VH	H	M	L	VL
VH	EH	VH	H	M	M	L	VL
H	VH	H	H	M	L	L	VL
M	H	M	M	L	L	VL	VL
L	M	M	L	L	VL	VL	VL
VL	L	L	L	VL	VL	VL	I
I	VL	VL	VL	VL	VL	I	I

Table 10.11 - Insignificant Mining Impact

I	EH	VH	H	M	L	VL	I
EH	M	M	M	L	L	VL	VL
VH	M	M	L	L	VL	VL	VL
H	M	L	L	L	VL	VL	VL
M	L	L	L	VL	VL	VL	I
L	L	VL	VL	VL	VL	VL	I
VL	VL	VL	VL	VL	VL	I	I
I	VL	VL	VL	I	I	I	I

The impact assessments are to a certain extent subjective, but the factors used in each category have been quantified, to reduce the subjectivity as far as possible. The method has been designed to provide an overall assessment of the impacts taking into account the extent of the mining-induced ground movements, the aesthetic quality and degree of public exposure of the clifflines and the natural instability of the clifflines.

It is therefore possible that the overall impact could be assessed as moderate, if the quality of the cliffline and the cliff instability were relatively low, even though the likelihood of significant rock falls was very high,. Alternatively, it is possible that the overall impact could be assessed as very high, if the cliffs had a high aesthetic value and a high instability rating, even though the likelihood of rock falls was very low,.

The method has been tested over a wide range of cases and appears to give reasonable results, but it has been designed in such a way that the scores and weightings in the assessment tables can be changed to fine-tune the method in the light of local experience. The levels of impact that are obtained using the method are not intended to be prescriptive in terms of what is, or is not, acceptable in every case and each case must be considered on its merits. What might be acceptable in one mining area might not be acceptable in another. In many cases the acceptability of the impact might rest on the likely extent of damage due to rock falls. In others, the issue of public safety might be the overriding factor.

10.5. The likelihood of Rock Falls

The likelihood of a particular cliff collapse or rock fall is impossible to predict since the stability of the cliff can not be fully determined from the appearance of the rock face. In many cases the apparently unstable rocks will remain standing, whilst the apparently stable rocks will fall. It is clear, however, that rock falls are more likely to occur as the extent of the mining impact increases, particularly where the natural instability of the cliffline is high. It is, therefore, possible to predict the likely extent of rock falls from a statistical perspective.

In the graph shown in Fig. 10.1, the percentages of the lengths of clifflines that experienced rock falls have been plotted against the natural cliff instability classification for a number of recorded cases. It should be noted that there was only one case where 100% of a cliffline experienced falls. All other cases were less than 33%. It can be seen that the percentage of clifflines that experienced rock falls increased as the mining impact increased and as the cliff instability increased. This graph can be used to predict the upper-bound % damage to clifflines based upon the scores from Tables 10.1 and 10.3. For example, if the proportion of mining-induced ground movement, assessed from Table 10.1, was 0.4 and the natural instability of the cliffline was low, then, up to 21% of the cliffline could experience rockfalls.

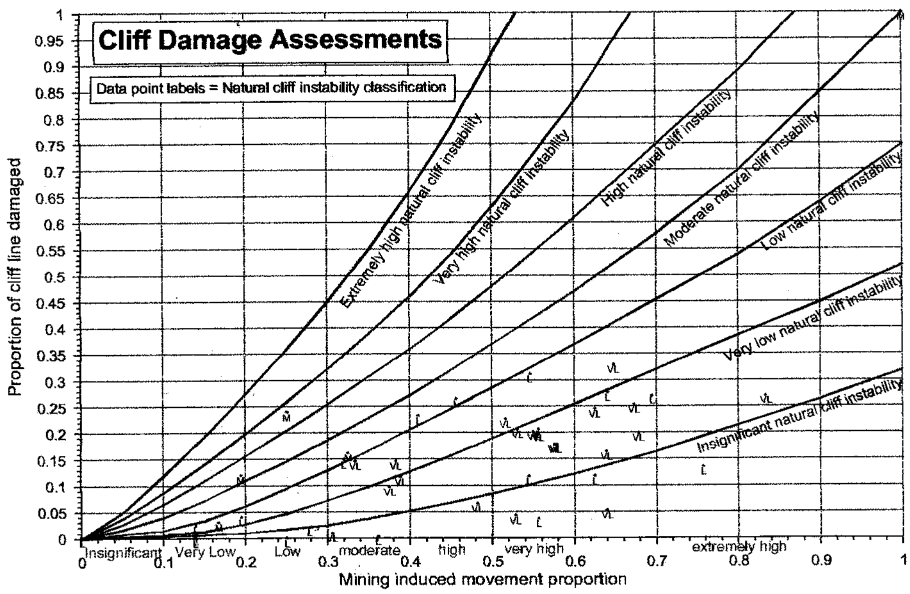


Fig. 10.1 Graph showing the likely incidence of rock falls for different levels of mining impact and different levels of cliffline instability.

It should be noted that the data used in developing the graph shown in Fig 10.1 were from the Southern and Western Coalfields and may not be representative of clifflines elsewhere. It should also be noted that the curves in this graph are upper-bound curves and in many cases the percentage of damage to clifflines could be significantly less than the maximum indicated by the graph. Similar graphs could advantageously be developed for specific mining areas where sufficient local data are available.

10.6. Testing of the method of assessment for subsidence impacts on clifflines

The method of assessment described above has been used to assess the subsidence impacts on a wide variety of clifflines including the following locations:

1. The Cataract and Nepean Gorges over Longwalls 15 to 17 at Tower Colliery.
2. The Bargo River Valley over Longwalls 14 to 19 at Tahmoor Colliery.
3. The Burragorang Valley over pillar extractions at Nattai North Colliery.
4. The clifflines of a tributary of Bullen Creek over Longwall 6 at Baal Bone Colliery.
5. The clifflines of the escarpment over Longwalls 1 to 7 at Angus Place Colliery.
6. The clifflines of the escarpment over Longwalls 8 to 11 at Angus Place Colliery.

The results of some of these analyses are shown in Table 10.12, below.

Photographs of typical cliffs at Tower Colliery, Tahmoor Colliery, Nattai North Colliery, Baal Bone Colliery and Angus Place Colliery are shown in Figs. 10.2 to 10.6, below.

Table 10.12 Some Examples of Cliff Assessment Results

	Tower Colliery Longwall 15	Tahmoor Colliery Longwall 17	Nattai North Pillar Extraction	Baal Bone Colliery Longwall 6	Angus Place Colliery Longwall 7	Angus Place Colliery Longwall 9
Aesthetic Quality	Very Low	Very Low	High	Very low	Low	Low
Natural Instability	Low	Low	Moderate	Very Low	Very Low	Low
Mining Impact	Very Low	Low	Extremely high	Extremely High	Moderate	Very High
Mining Impact Proportion	0.14	0.25	1.00	0.83	0.33	0.56
Overall Assessment	Very Low	Low	Extremely high	Low	Low	High
%Rock Falls	<2.5%	Nil	100%	27%	15%	21%

The cliffs at Baal Bone Colliery were rated as distinctive in terms of the overall aesthetics of the cliff formation, but had a very low total rating for the aesthetic quality and public exposure because of its remote location and relative inaccessibility. Similarly the cliffs at Angus Place Colliery were rated as pleasant in terms of the overall aesthetics of the cliff formation, but had a low total rating for the aesthetic quality and public exposure because of its remote location and relative inaccessibility.

In contrast, the cliffs at Nattai North Colliery were rated as spectacular in terms of the overall aesthetics of the cliff formation and had a high total rating for the aesthetic quality and public exposure because the cliffs can be easily viewed from a public road.

The cliffs at Tower Colliery and Tahmoor Colliery were generally rated as common or pleasant in terms of the overall aesthetics of the cliff formation, but had an insignificant to low total rating for the aesthetic quality and public exposure because the cliffs are not readily accessible to the public.

It can be seen that the greatest amount of damage occurred at the Nattai North Colliery even though the mining impact was also assessed to be extremely high at Baal Bone Colliery over Longwall 6. The reason for this is that the cliffs at Nattai North Colliery had a higher natural instability due to the massive scale of the cliffline, its exposure to ongoing weathering agents and the fact that the base of the cliff was directly undermined.

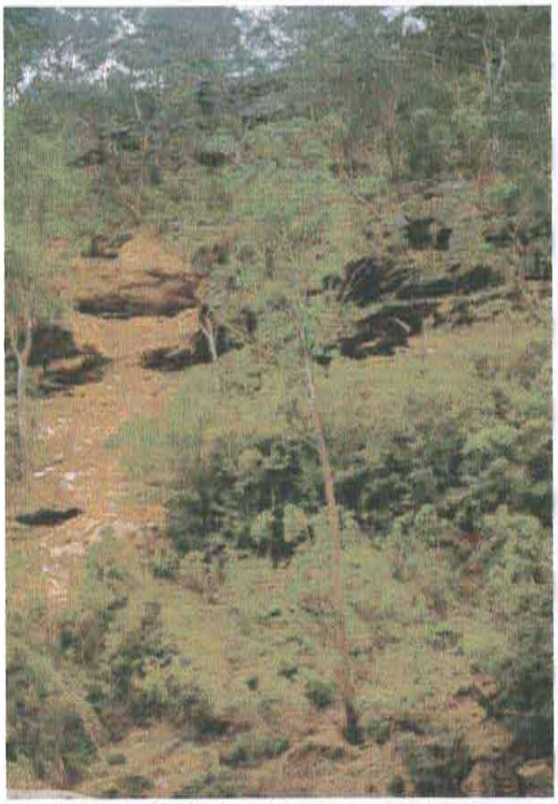


Fig. 10.2 Cliffs in the Cataract Gorge over Longwall 15 at Tower Colliery.

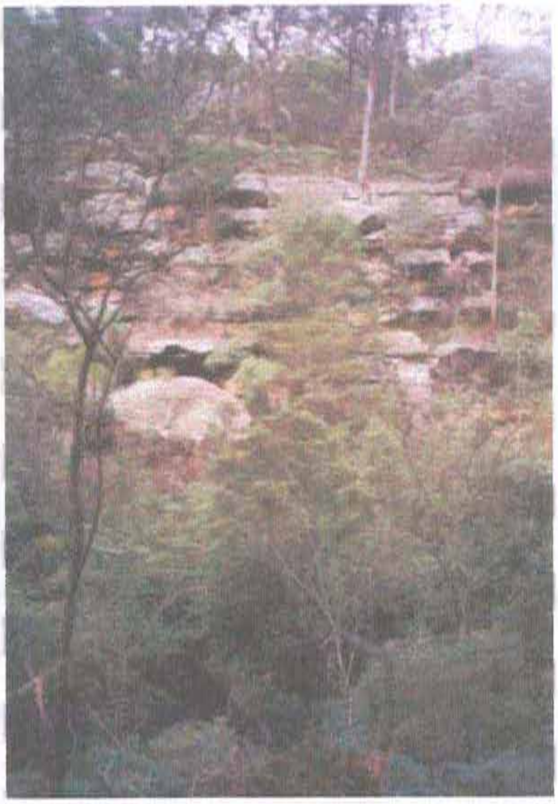


Fig. 10.3 Cliffs in the Bargo River Valley over Longwall 17 at Tahmoor colliery

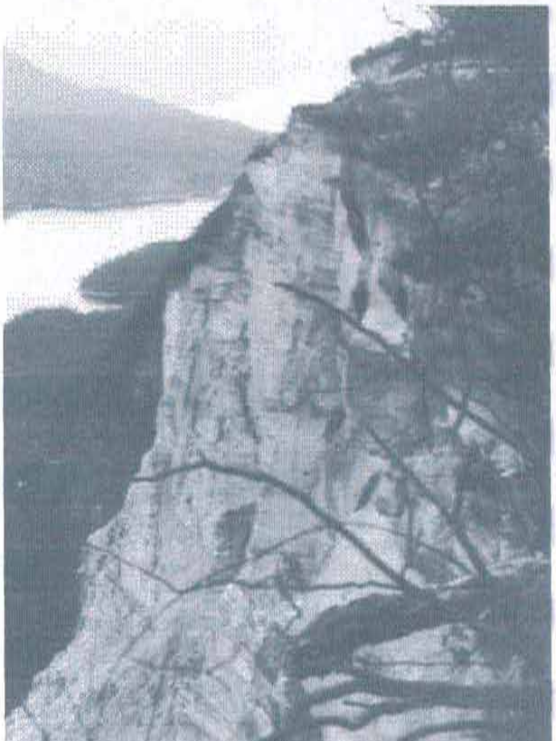


Fig. 10.4 Cliffs in the Burragorang Valley over Pillar Extractions at Nattai Colliery

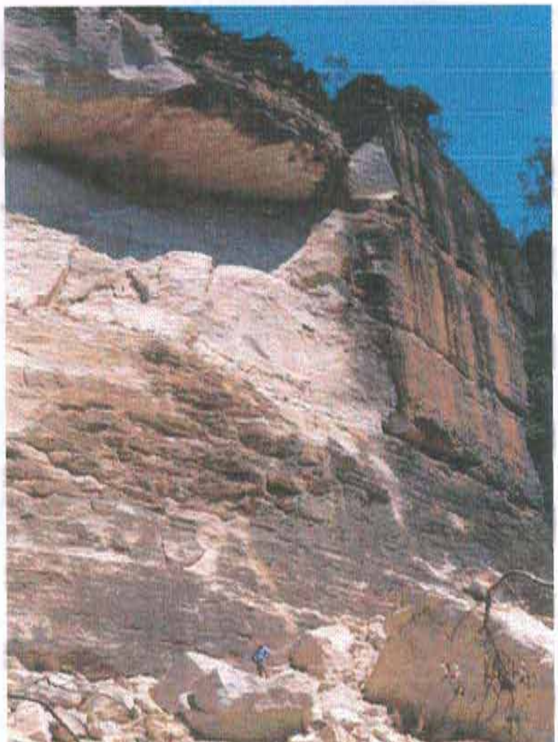


Fig. 10.5 Cliffs in a Tributary of Bullen Creek over Longwall 6 at Baal Bone colliery

Fig. 10.6 Cliffs over Longwall 2 at Angus Place Colliery

Fig. 10.7 Natural Rock Fall at Kings Canyon in Central Australia

The photographs in Figs. 10.1 and 10.4 to 10.6 show typical examples of rock falls that have occurred due to mining and indicate the immediate scarring of the landscape that occurs. Fig. 10.6, however, shows the natural regrowth that occurred on the talus slope within a period of ten years following the rock fall at Angus Place Colliery and it can be seen that nature quickly heals the scars.

For comparison, Fig. 10.7 shows a natural rock fall which occurred several years ago at Kings Canyon in Central Australia, as part of the normal process of erosion in the wall of the canyon. The canyon is a popular tourist attraction and its appeal to visitors has not been adversely affected by the fresh appearance of the rock face.

APPENDIX D

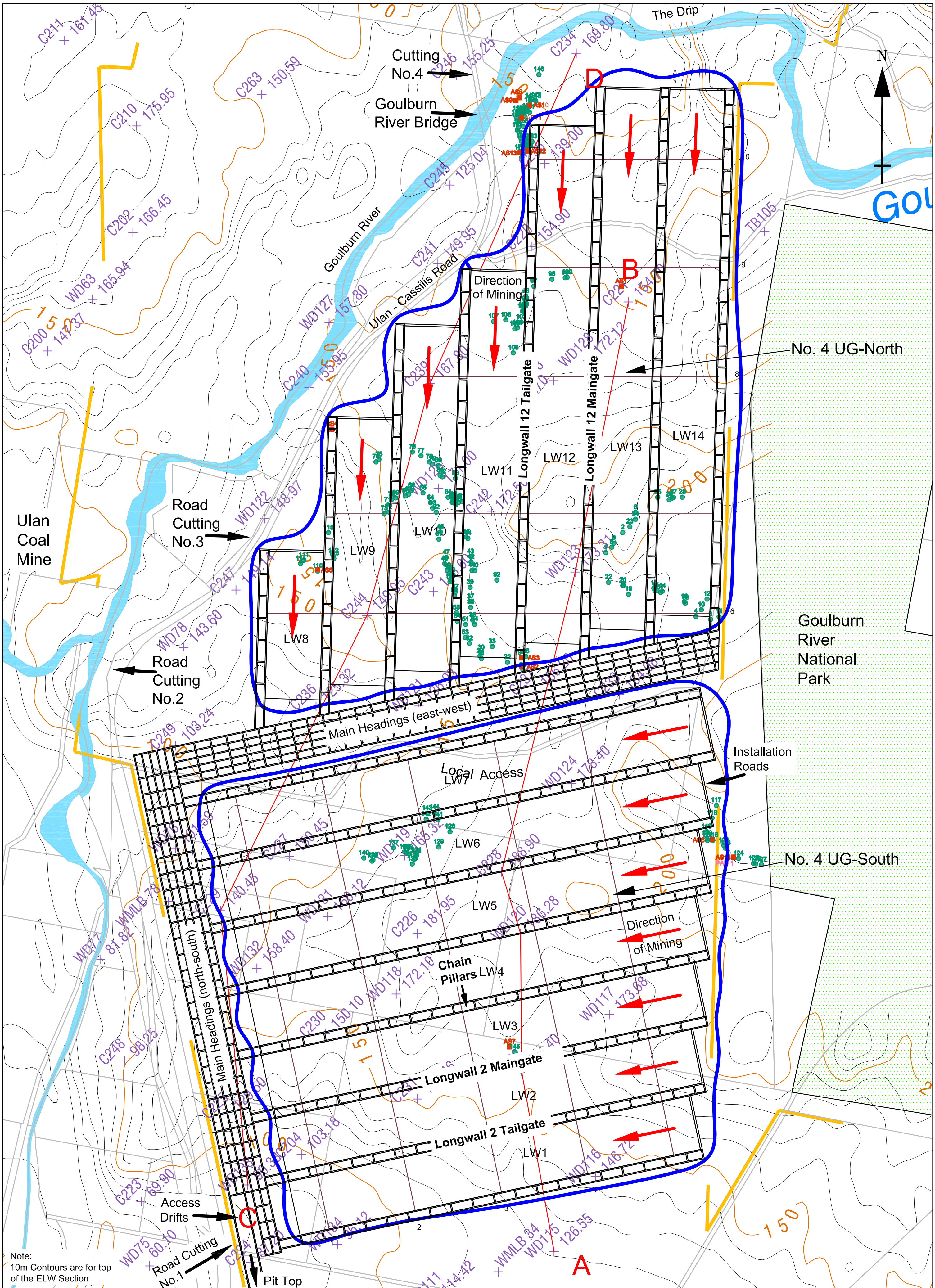
Laboratory Test Results on Bore Core Samples from WMLB34 and WMLB78

Bore	Sample	General	Interval		Moisture	Dry	PLS-Diametral		PLS-Axial		UCS	E	Poissons		
Reference	Reference	Lithology*	From	To	Content(%)	Density	Is (MPa)	Is 50 (Mpa	Is (MPa)	Is 50 (Mpa	(Mpa)	(Gpa)	Ratio	UCS/PLA	E/UCS
WMLB34	GT1	Mudstone	43.33	43.87	4.5	2.19	1.18	1.29	2.61	2.91	57.8	6.9	0.14	20	119
WMLB34	1	Siltstone	44.94	45.02					1.31	1.59					
WMLB34	GT2	Mudstone	47.56	47.88											
WMLB34	2	Siltstone	48.77	48.85			1.75	1.91	1.48	1.80					
WMLB34	GT3	Siltstone	52.01	52.31	2.5	2.4	1.61	1.76	2.47	2.7					
WMLB34	3	Siltstone	52.03	52.10			1.48	1.62	2.18	2.58					
WMLB34	GT4	Sandstone	54.35	54.63	3.6	2.3	1.44	1.58	1.98	2.24					
WMLB34	4	Sandstone	54.50	54.60			2.02	2.20	1.19	1.54				9	
WMLB34	GT5	Sandstone	55.65	55.90	6.8	2.02					13.9	3.6	0.1		259
WMLB34	5	Sandstone	56.02	56.09			1.21	1.32							
WMLB34	GT6	Siltstone	57.44	57.65	2.1	2.4	1.32	1.44	3.1	3.35					
WMLB34	6	Siltstone	58.20	58.27			0.81	0.88	1.21	1.44					
WMLB34	GT7	Conglomerate	61.42	61.72	3.9	2.1					9.3	4.5	0.1		484
WMLB34	7	Sandstone	62.79	62.88					0.34	0.42				22	
WMLB34	8	Conglomerate	65.69	65.78					0.14	0.18					
WMLB34	GT8	Siltstone	66.93	67.23	3.8	2.3	1.62	1.78	2.72	2.98					
WMLB34	9	Sandstone	68.40	68.47			0.05	0.06	1.32	1.59					
WMLB34	GT9	Siltstone	69.48	69.82	2.8	2.38					55.5	14	0.23		252
WMLB34	10	Sandstone	70.44	70.50			0.27	0.29	1.06	1.22					
WMLB34	GT10	Siltstone	72.39	72.72	1.8	2.4	0.92	1.01	3.49	3.75				15	
WMLB34	11	Siltstone	74.00	74.05			0.70	0.76	3.50	3.79					
WMLB34	GT11	Sandstone	75.33	75.68	3.6	2.4	1.29	1.41	2.21	2.37					
WMLB34	12	Siltstone	75.71	75.80			1.68	1.84	1.40	1.73					
WMLB34	13	Siltstone	79.73	79.82			0.07	0.07	0.96	1.21					
WMLB34	14	Sandstone	82.16	82.23			1.07	1.18	1.80	2.18					
WMLB34	GT12	Sandstone	82.27	82.64	2.9	2.47					54.1	17	0.15		314
WMLB34	GT13	Sandstone	84.33	84.66	4	2.4	2.39	2.61	2.62	2.81				19	
WMLB34	15	Sandstone	85.51	85.60			1.28	1.40	0.57	0.72					
WMLB34	16	Sandstone	87.50	87.56			1.41	1.54							
WMLB34	16	mudstone	88.23	88.28			0.67	0.73	1.19	1.29					
WMLB34	18	Sandstone	88.71	88.78			0.60	0.66	1.66	1.97					
WMLB34	19	Sandstone	104.16	104.23			1.61	1.76	1.86	2.26					
WMLB34	20	Siltstone	108.00	108.07			1.72	1.88	1.63	1.91					

Bore Reference	Sample Reference	General Lithology*	Interval		Moisture Content(%)	Dry Density	PLS-Diametral		PLS-Axial		UCS (Mpa)	E (Gpa)	Poissons Ratio	UCS/PLA	E/UCS
			From	To			Is (MPa)	Is 50 (Mpa	Is (MPa)	Is 50 (Mpa					
WMLB78	GT1	Conglomerate	7.67	8.04	8.8	2	0.81	0.89	0.61	0.68					
WMLB78	GT2	Siltstone	15.10	15.37	2.8	2.31					48.2	4.1	0.13		85
WMLB78	GT3	Mudstone	17.48	17.72	4.3	2.3	0.86	0.94	1.76	1.9				25	
WMLB78	GT4	Sandstone	19.00	19.37	6.5	2.3	0.9	0.98	1.4	1.54					
WMLB78	GT5	Mudstone	19.76	20.10	5.6	2.2	1.44	1.57	1.7	1.86					
WMLB78	GT6	Sandstone	22.89	23.37	5.4	2.3	1.55	1.69	2	2.18					
WMLB78	GT7	Sandstone	25.12	25.49	8.6	2.11					16.7	3.1	0.19		186
WMLB78	GT8	Sandstone	34.77	35.05	2.7	2.36					41.6	5.1	0.19		123
WMLB78	GT9	Sandstone	38.61	38.99	3.6	2.2	1.76	1.92	1.84	2.09				20	
WMLB78	GT10	Sandstone	41.81	42.17	4.8	2.2	1.64	1.8	2.08	2.32				14	
WMLB78	GT11	Sandstone	44.03	44.33	5	2.32					32	4.9	0.17		153
WMLB78	GT12	Siltstone	47.15	47.46	3.8	2.4	4.37	4.78	5.43	6.15					
WMLB78	GT13	Mudstone	47.92	48.26	4.3	2.2	1.05	1.15	3.34	3.62					
WMLB78	GT14	Sandstone	49.85	50.13	7.7	2.2	2.81	3.07	2.27	2.49					
WMLB78	GT15	Sandstone	52.88	53.21	6.6	2.2	1.15	1.26	1.23	1.38					
WMLB78	GT16	Mudstone	56.35	56.66	3.4	2.32					28.7	4.6	0.15		160
WMLB78	GT17	Sandstone	58.51	58.82	6.9	2.2	1.7	1.86	1.11	1.23				23	
WMLB78	GT18	Sandstone	59.82	60.15	3.9	2.3	0.64	0.71	1.78	2					
WMLB78	GT19	Sandstone	62.15	62.47	4.1	2.3	0.61	0.67	1.21	1.32				16	
WMLB78	GT20	Sandstone	63.57	63.85	6.6	2.15					21.6	22	0.21		1019
WMLB78	GT21	Sandstone	80.21	80.49	8.6	2.29					14	3	0.23		214

Lithology* Refer to log for detailed description
.= Field Determined
.= Laboratory Determined

FIGURES

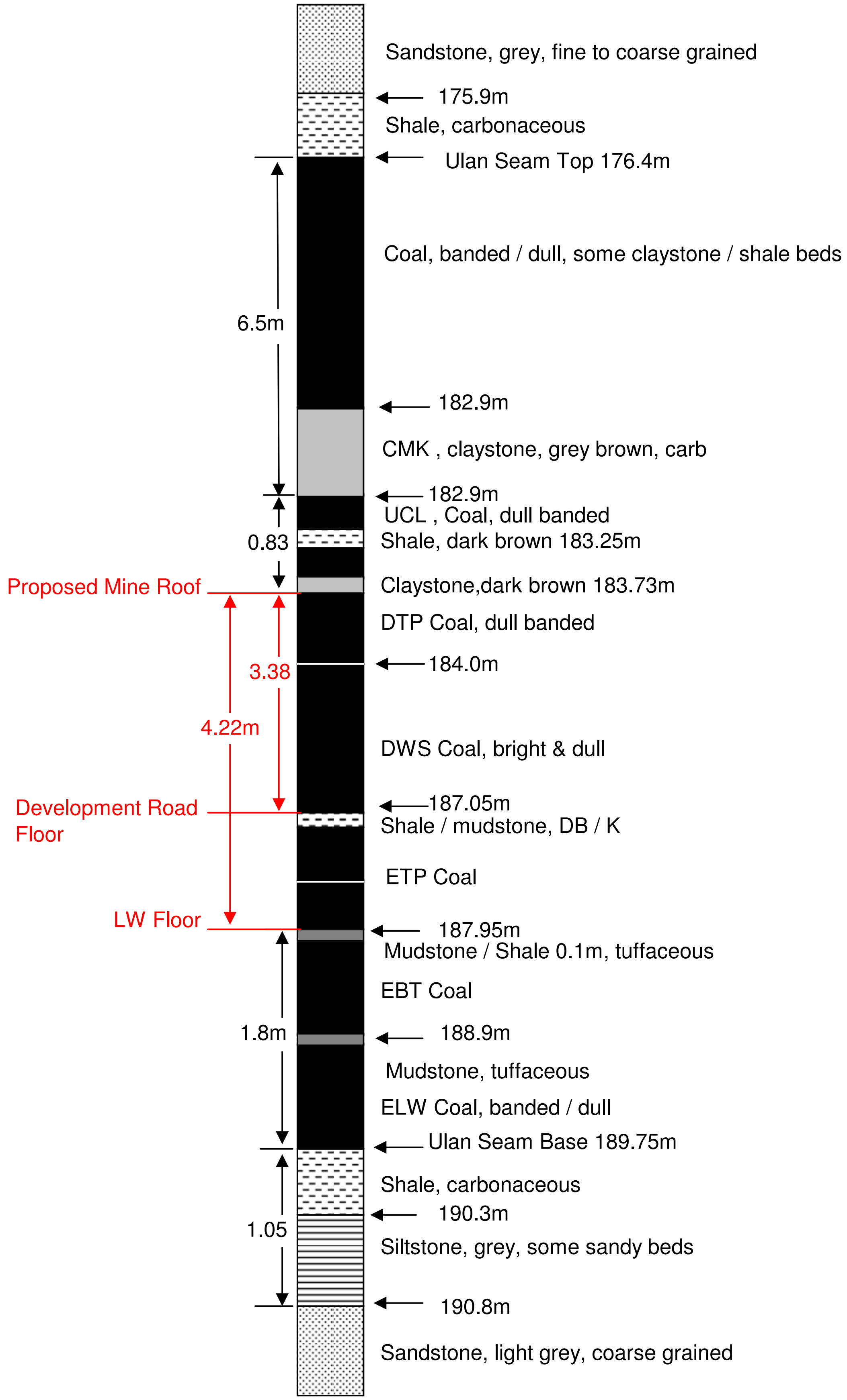


Key:

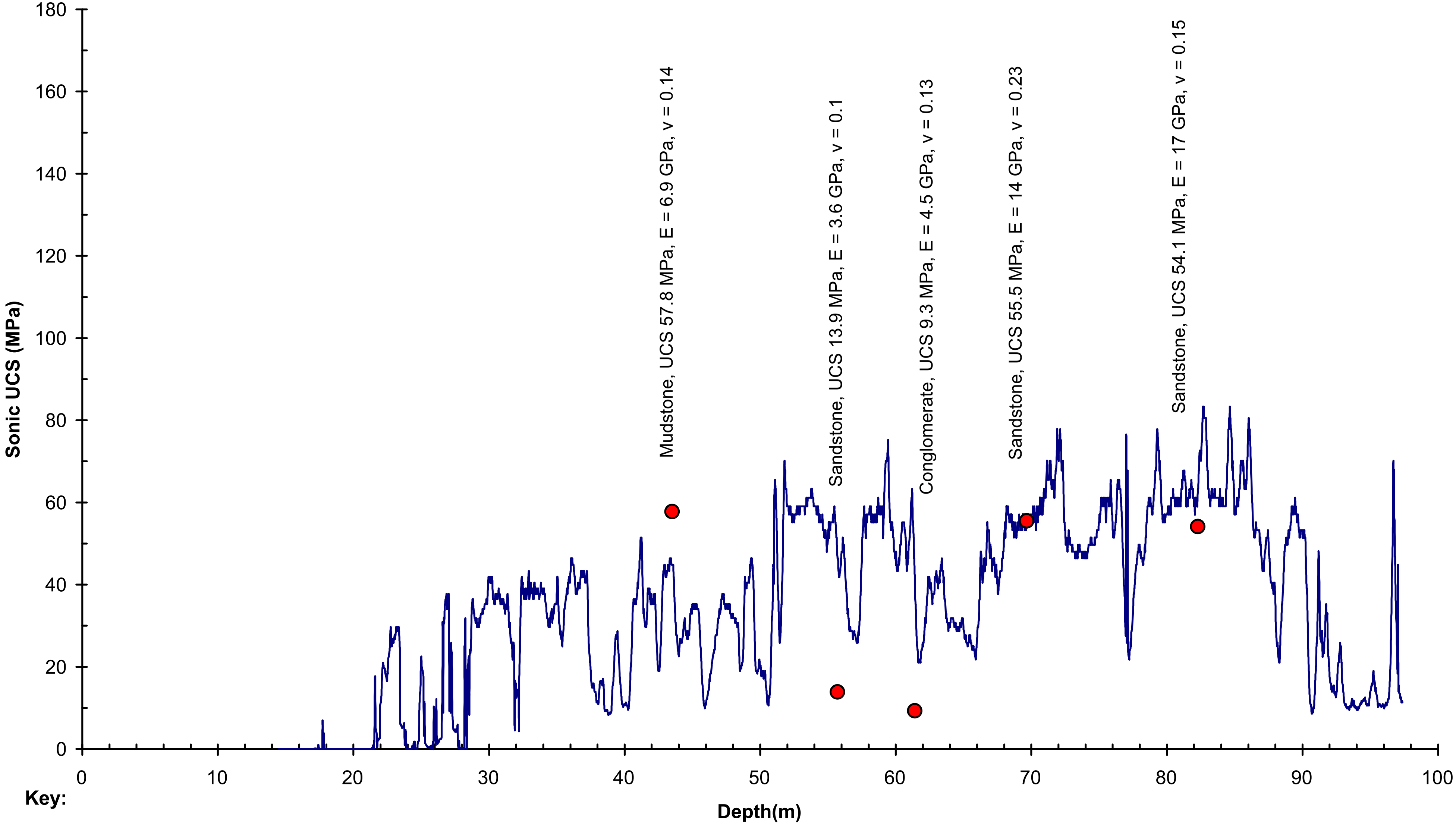
- Borehole Location
- Section Lines
- Aboriginal Heritage Sites (refer to text)
- Maximum Angle of Draw Limit to 20 mm Subsidence

M:\Figures\Moolarben\R04001(WHT)-1

Engineer:	J.Jiang	CLIENT:	Moolarben Coal Mine 04-001(WHT)-1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	N.Paine			
Date:	14.12.05	TITLE:	Moolarben Coal Project Stage 1 Layout and Ulan Seam Cover Depth Contours	FIGURE 1.1
Scale:	1:15,000			



ENGINEER:	S.Ditton	CLIENT:	Moorlaben Coal Mining Pty Ltd	**STRATA ENGINEERING**
DRAWN:	N.Paine		04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	08.02.06	TITLE:	Typical Lithological Section of Mine Workings in Ulan Seam	FIGURE
SCALE:	NTS		(Based on BH C228)	5.1

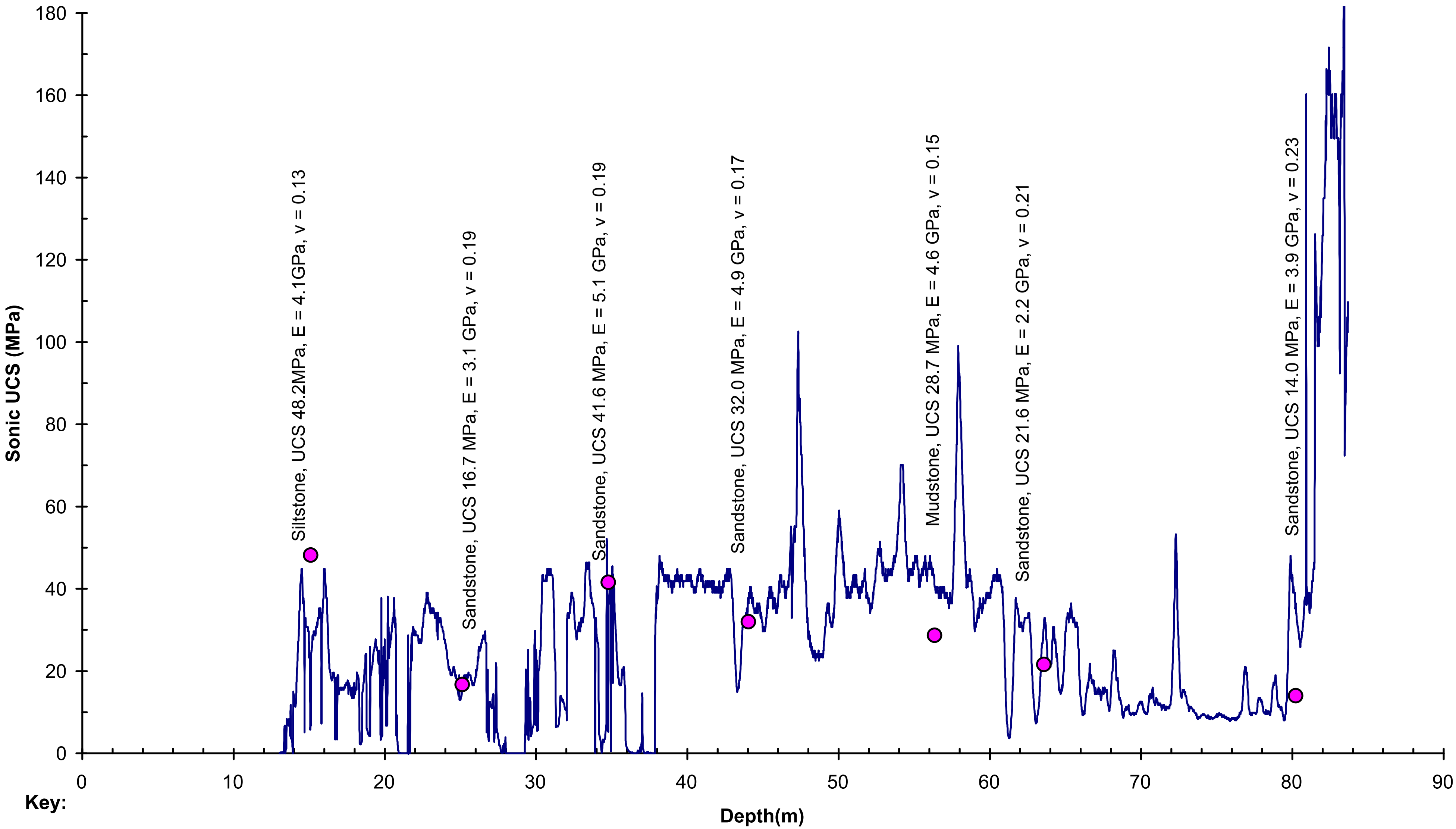


Key:

- UCS = Unconfined Compressive Strength
- E = Young's Modulus
- v = Poissons Ratio

Note: Sonic UCS derived from McNally (1990)

ENGINEER:	S. Ditton	CLIENT:	Moolarben Coal Mines Pty Ltd 04-001-WHT/1	**STRATA ENGINEERING (Australia) Pty Ltd**	
DRAWN:	S. Ditton				
DATE:	10.02.06	TITLE:	Laboratory & Sonic UCS Data for BH WMLB34		FIGURE 5.2a
SCALE:	NTS				

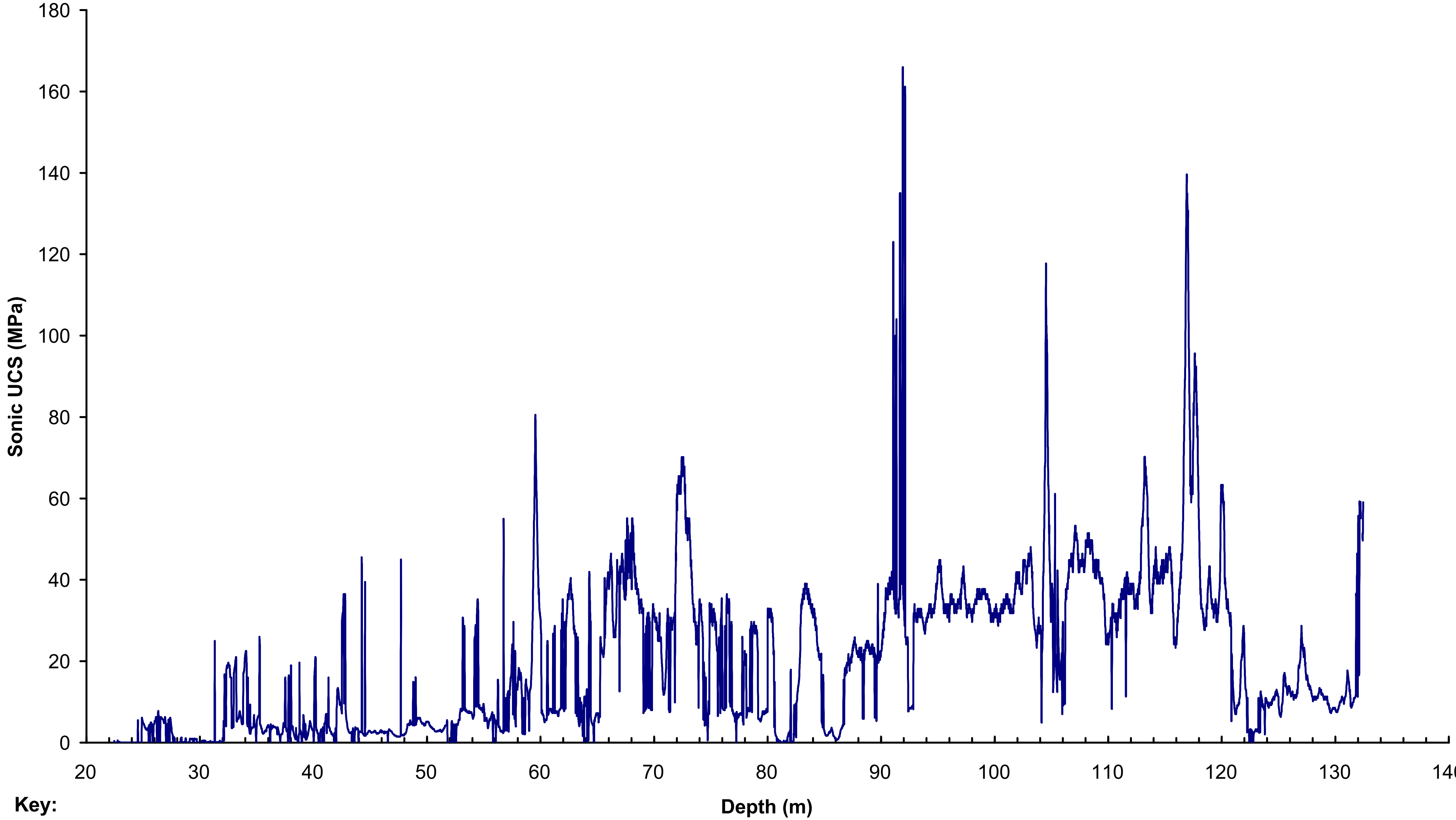


Key:

- UCS = Unconfined Compressive Strength
- E = Young's Modulus
- v = Poissons Ratio

Note: Sonic UCS derived from McNally (1990)

ENGINEER:	S. Ditton	CLIENT:	Moolarben Coal Mines Pty Ltd	**STRATA ENGINEERING**
DRAWN:	S. Ditton		04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	10.02.06	TITLE:	Laboratory & Sonic UCS Data for	FIGURE
SCALE:	NTS		BH WMLB78	5.2b

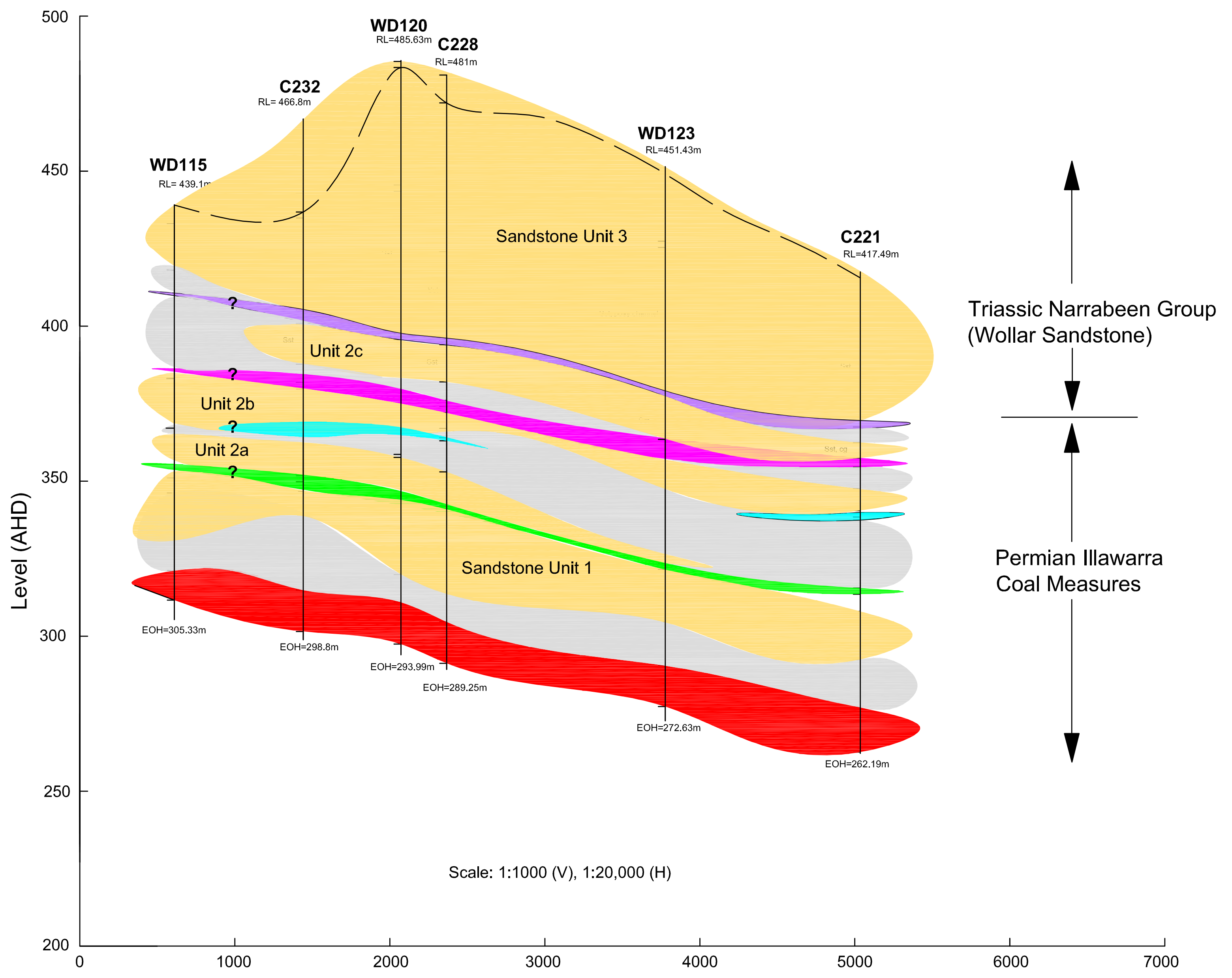


Key:

- UCS = Unconfined Compressive Strength
- E = Young's Modulus
- v = Poissons Ratio

Note: Sonic UCS derived from McNally (1990)

ENGINEER:	S. Ditton	CLIENT:	Moolarben Coal Mines Pty Ltd 04-001-WHT/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S. Ditton			
DATE:	10.02.06	TITLE:	Sonic UCS Data for Borehole TB105	FIGURE 5.2c
SCALE:	NTS			



Key:

Ulan Seam

Irondale Seam

Glen Davis Seam

Goulburn Seam

Middle River Seam

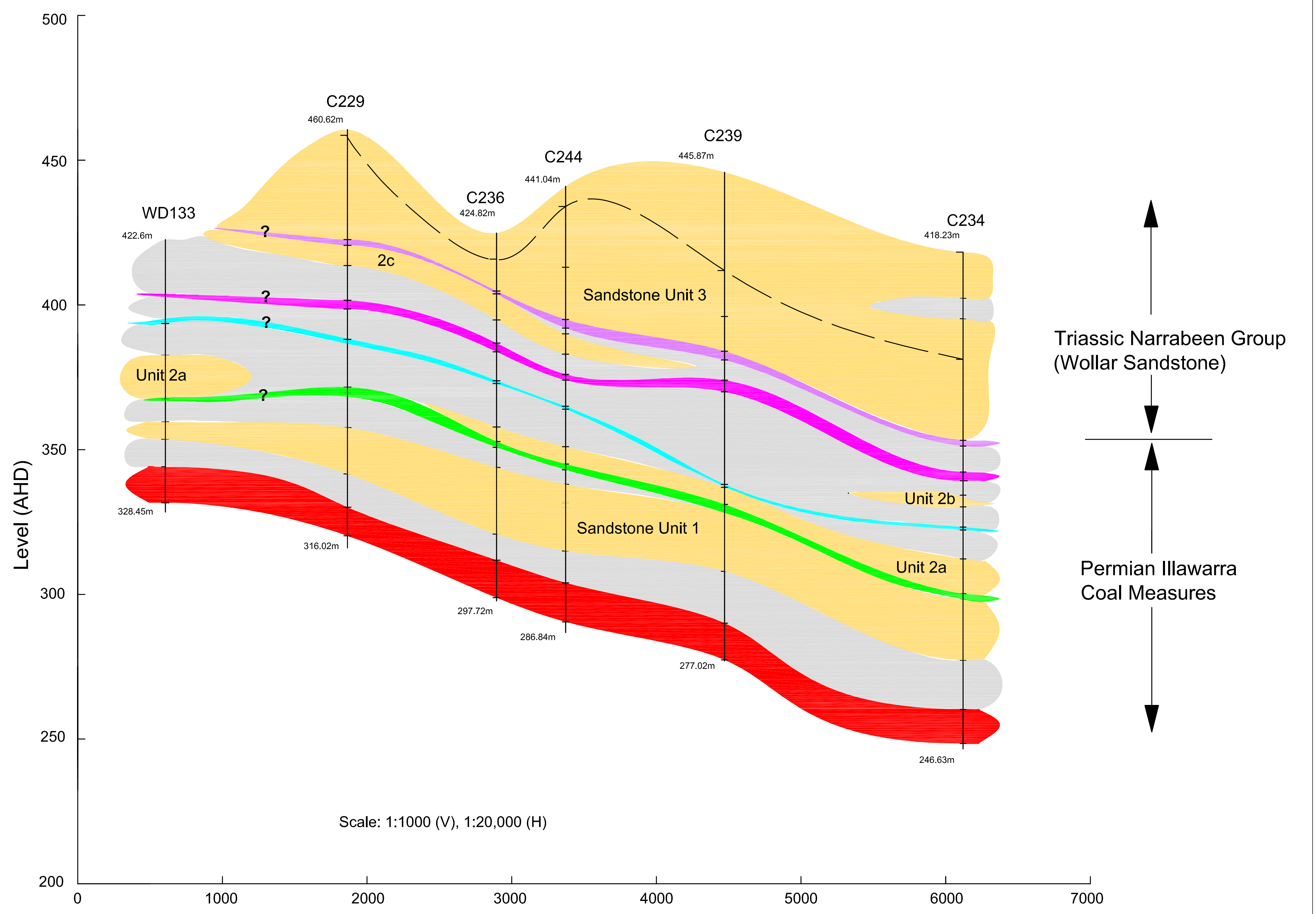
Sandstone

Interbedded Siltstone/Sandstone/Mudstone/Shale

Limit of Extreme Weathering

M:\Figures\Moolarben\R04001(WHT)_1

Engineer:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia Pty Ltd)
Drawn:	N.Paine			
Date:	16.12.05	TITLE:	Interpreted Lithological Section AB (East) for LWs 1 - 14	FIGURE 5.3
Scale:	As Shown			

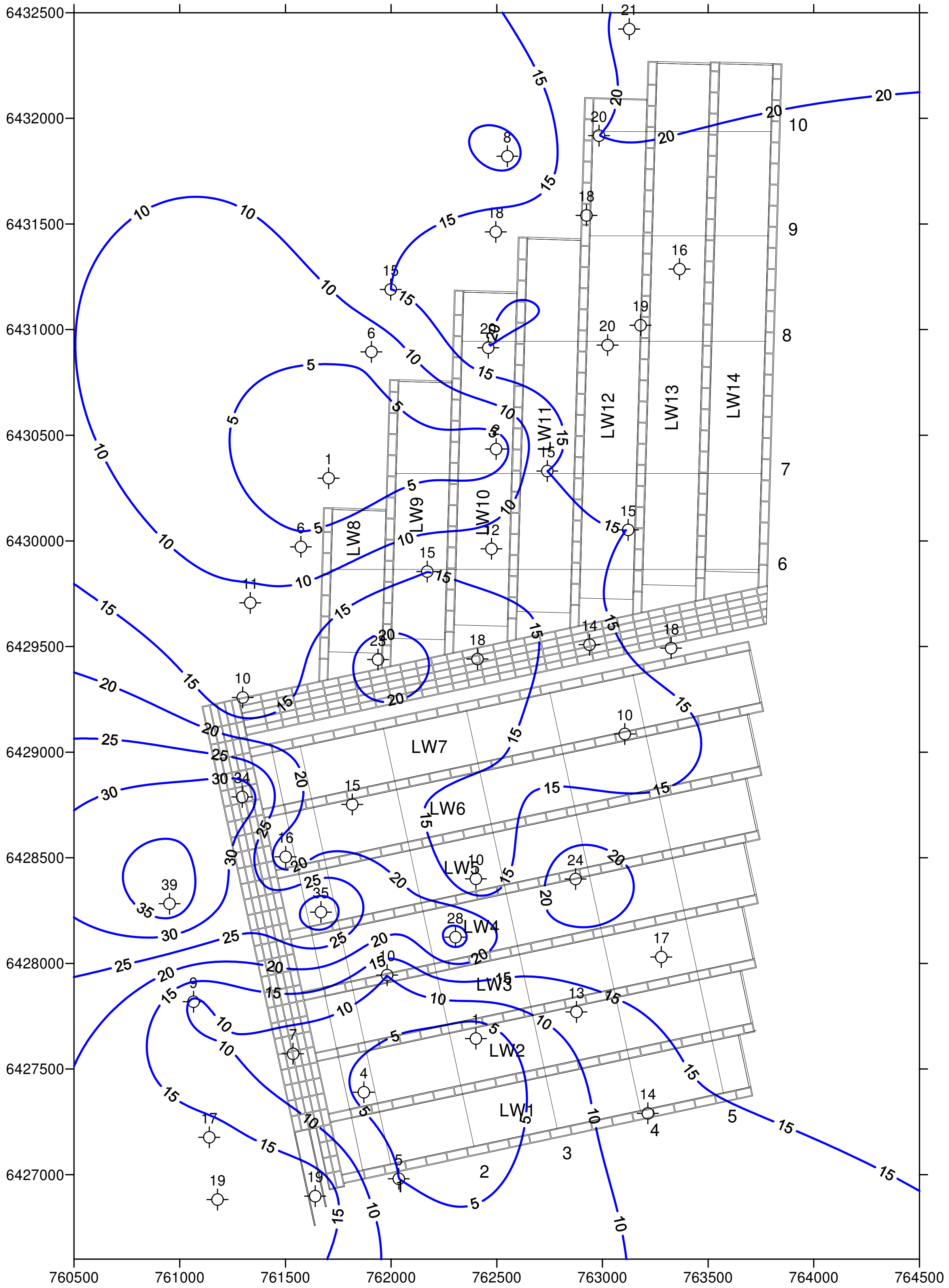


Key:

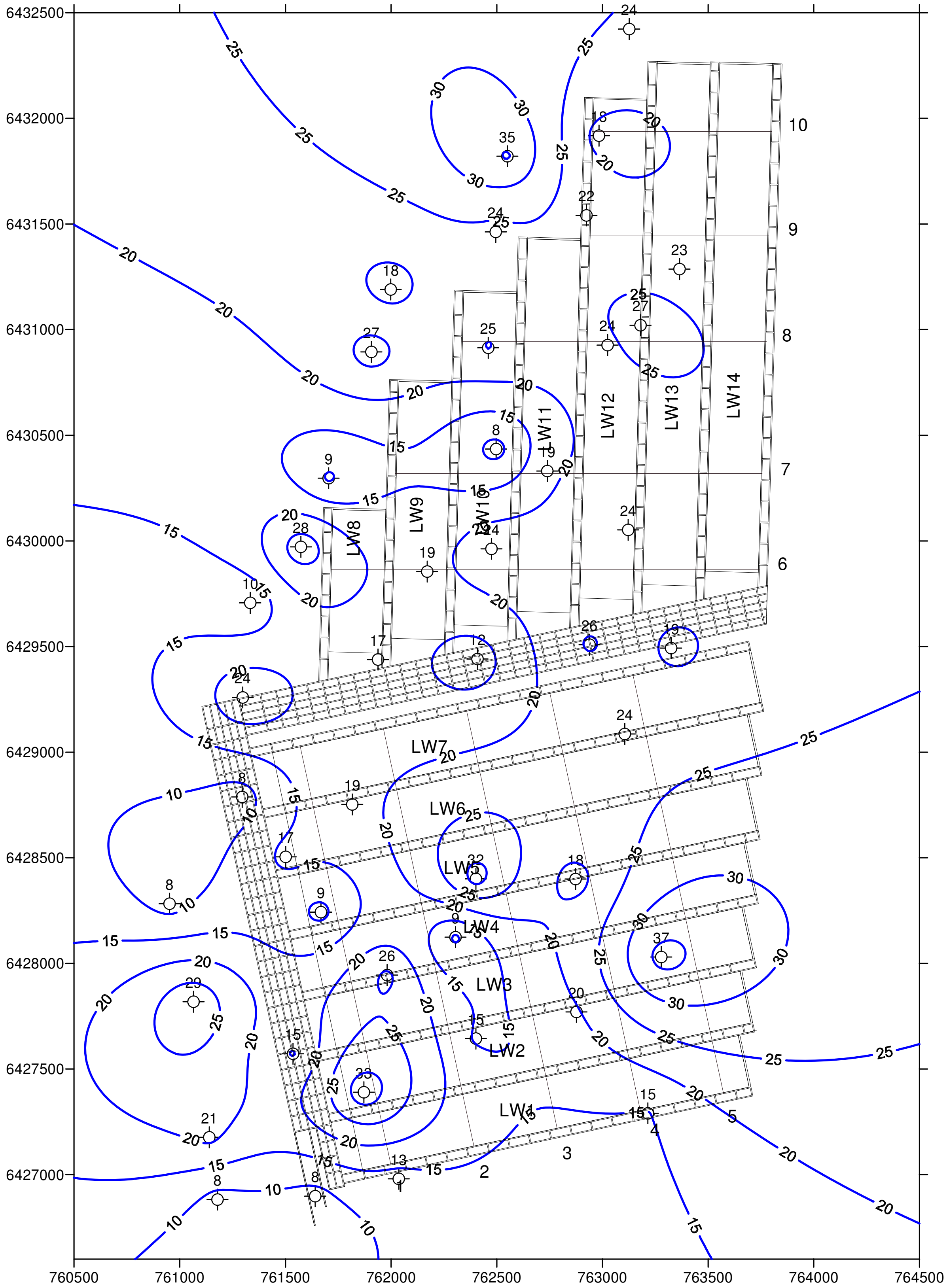
Ulan Seam
Irondale Seam
Glen Davis Seam
Goulburn Seam
Middle River Seam
Sandstone (massive)
Interbedded Siltstone/Sandstone/Mudstone/Shale
Limit of Extreme Weathering

M:\Figures\Moolarben

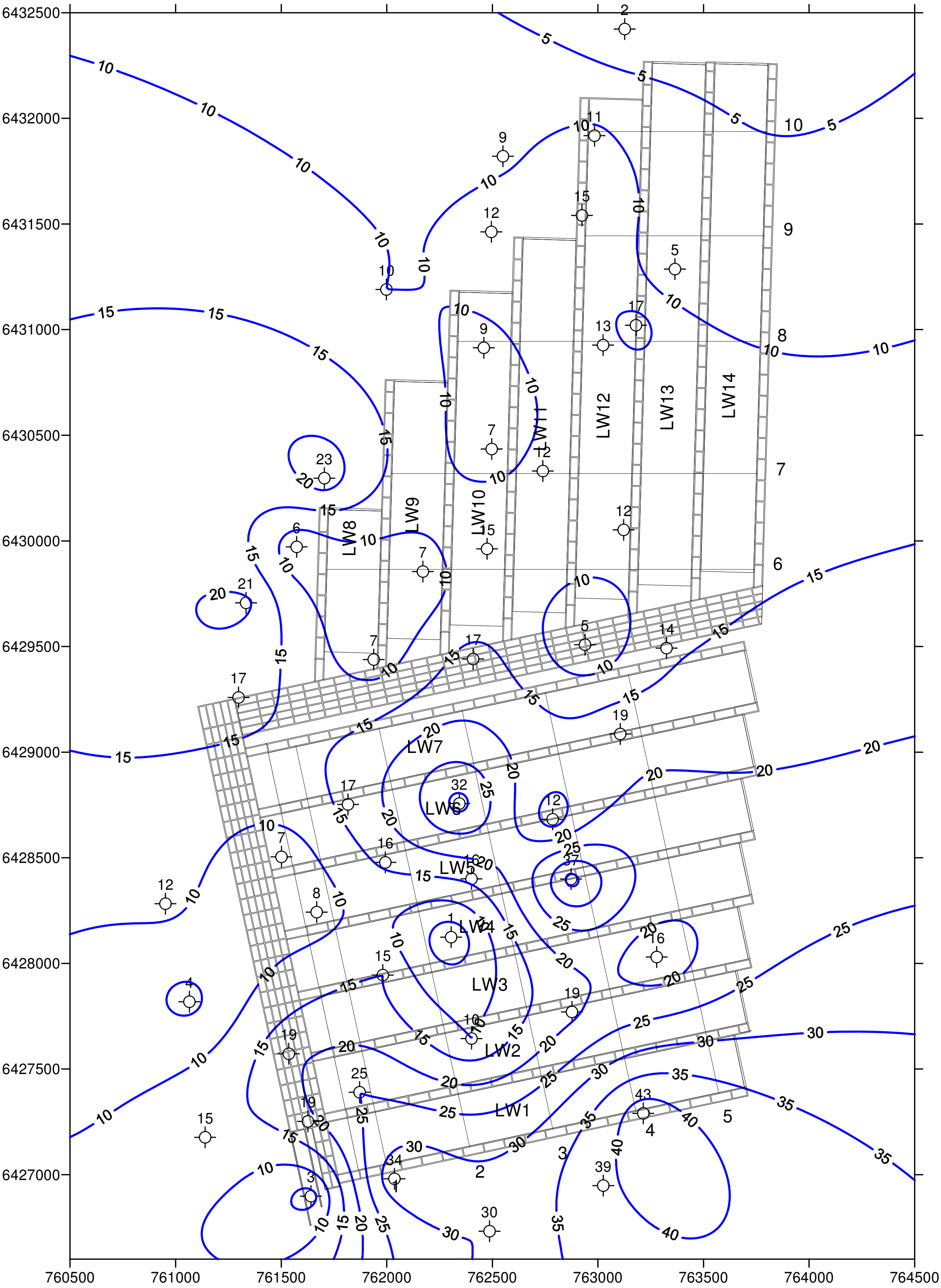
Engineer:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	STRATA ENGINEERING (Australia Pty Ltd)
Drawn:	N.Paine		R04-001-WHT/1	
Date:	16.12.05	TITLE:	Interpreted Lithological Section (west) for LWs 1 - 14	FIGURE 5.4
Scale:	As Shown			



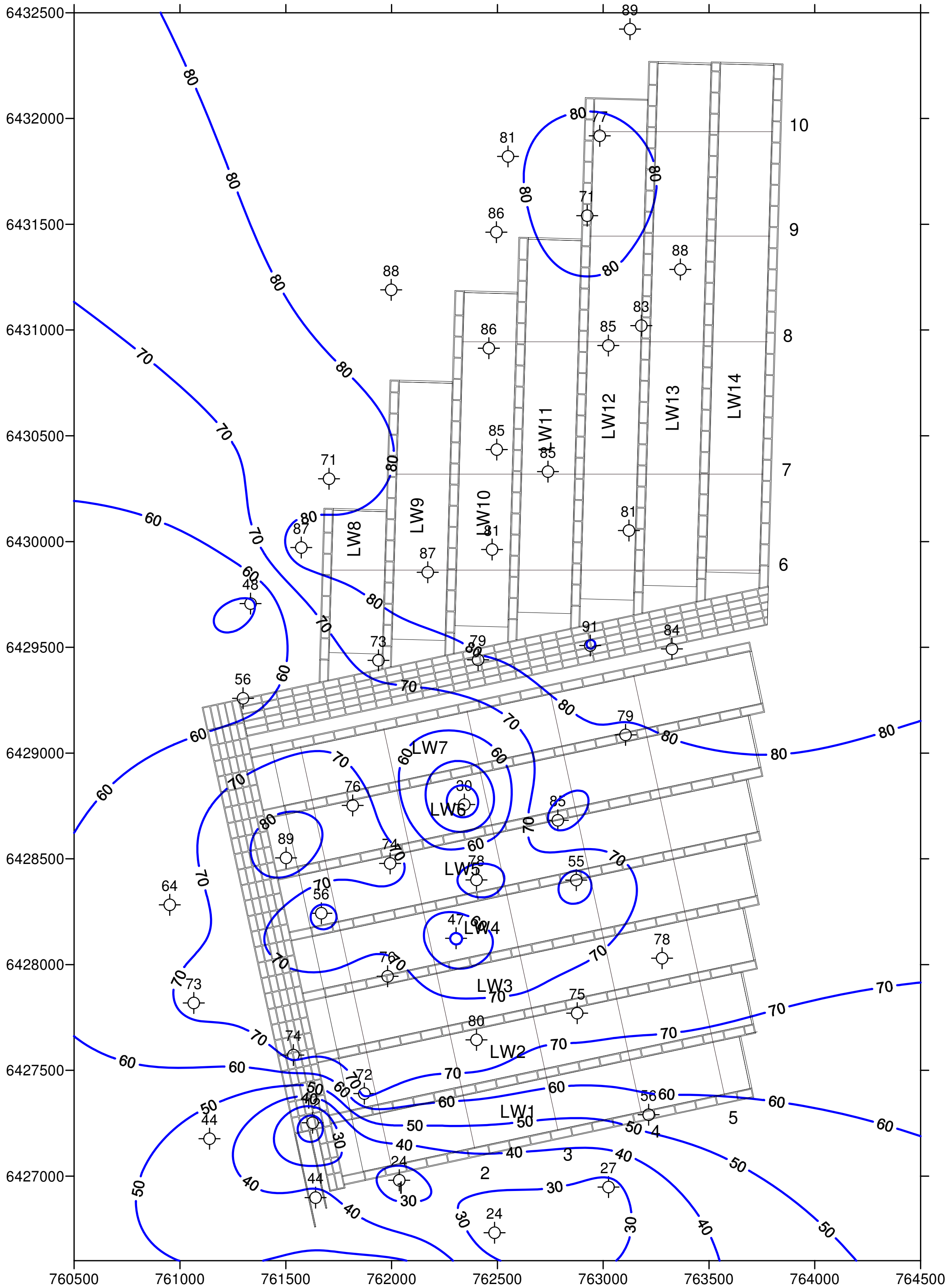
Engineer:	Jin Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	Jin Jiang			
Date:	25.01.06	TITLE:	Interpreted Unit 1 Sandstone Thickness Contours (m)	FIGURE 5.5
Scale:	1:2,000			



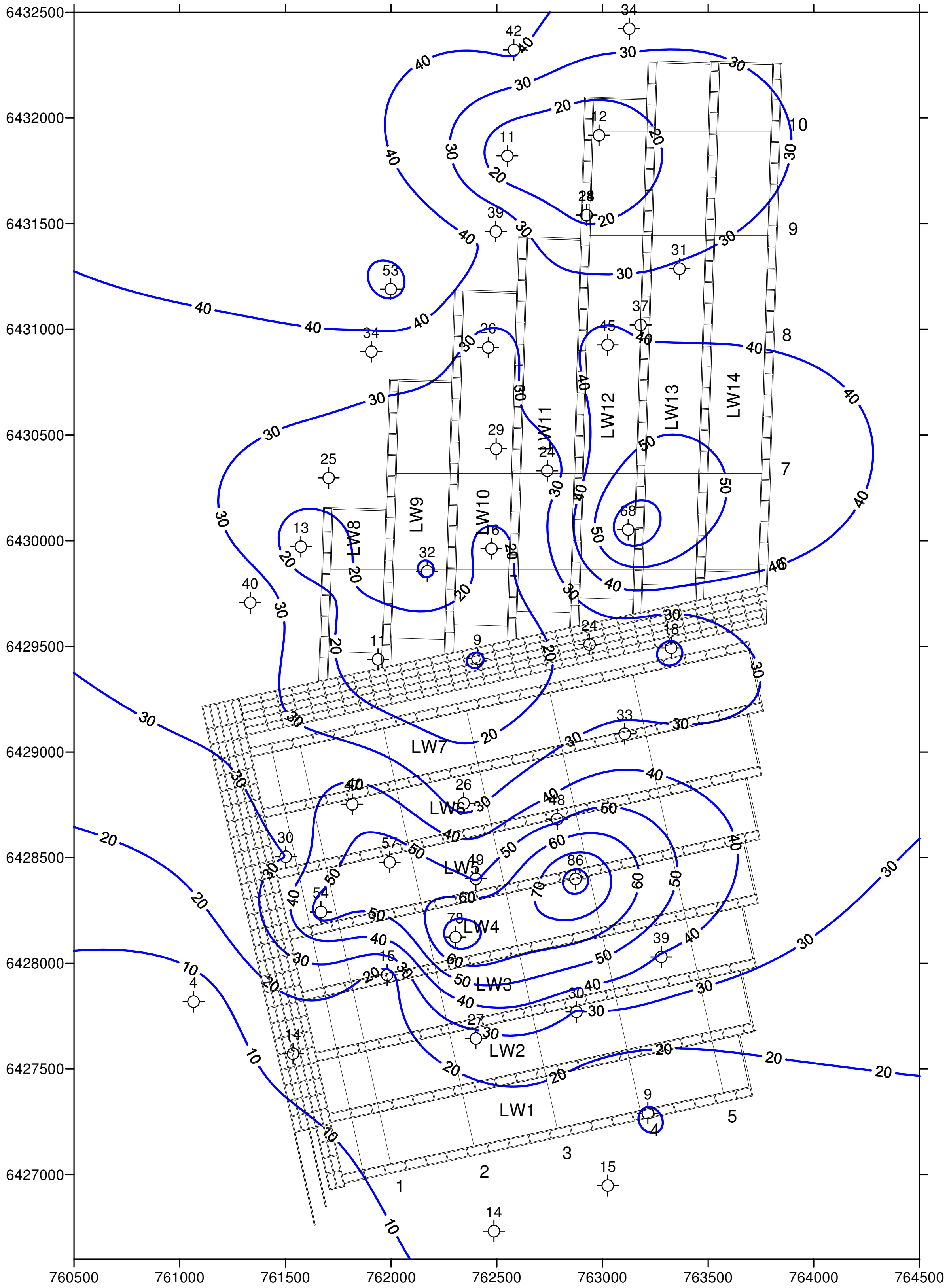
Engineer:	Jin Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	**STRATA ENGINEERING (Australia) Pty Ltd**
Drawn:	Jin Jiang			
Date:	26.01.06	TITLE:	Interpreted Unit 1 Sandstone Distance Above the Proposed LWs 1-14 Contours (m)	FIGURE 5.6
Scale:	1:2,000			



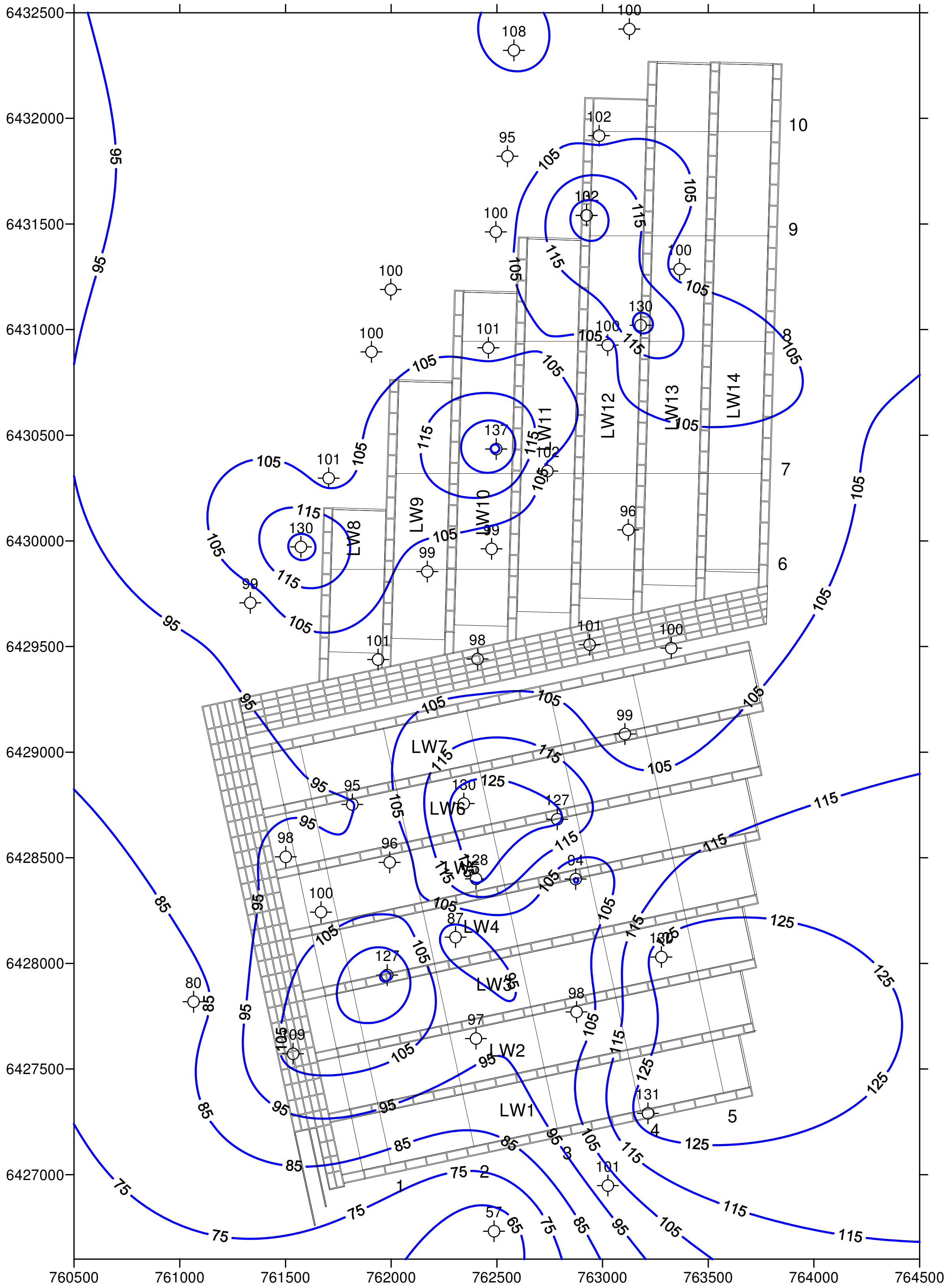
Engineer:	Jin Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	Jin Jiang			
Date:	25.01.06	TITLE:	Interpreted Unit 2 Sandstone Thickness Above the Workings Contours (m)	FIGURE 5.7
Scale:	1:2,000			



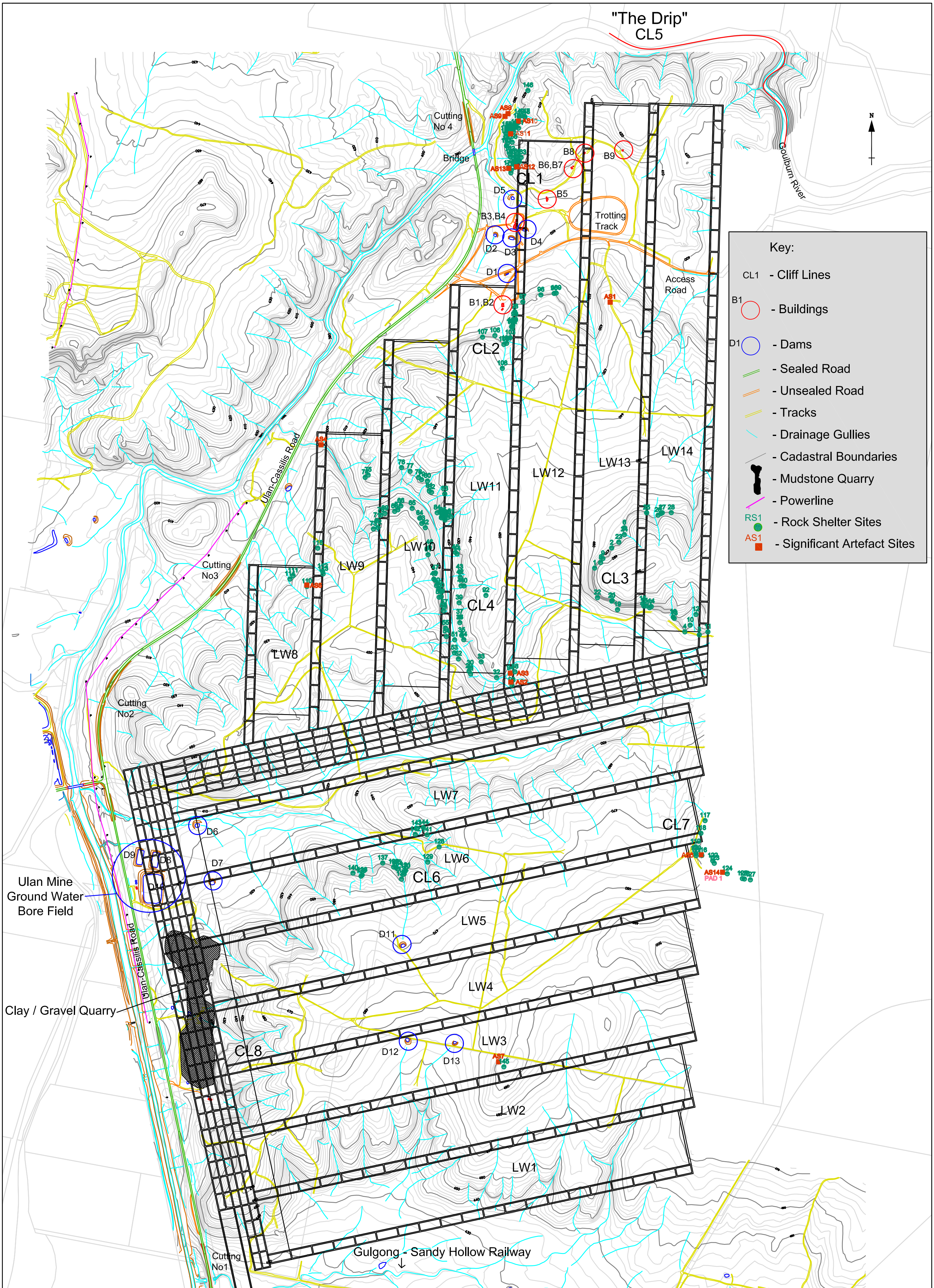
Engineer:	Jin Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	Jin Jiang			
Date:	25.01.06	TITLE:	Interpreted Unit 2 Sandstone Distance Above the Proposed LWs 1-14 Contours (m)	FIGURE 5.8
Scale:	1:2,000			



Engineer:	Jin Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	Jin Jiang			
Date:	25.01.06	TITLE:	Interpreted Unit 3 Sandstone Thickness Contours (m)	FIGURE 5.9
Scale:	1:2,000			

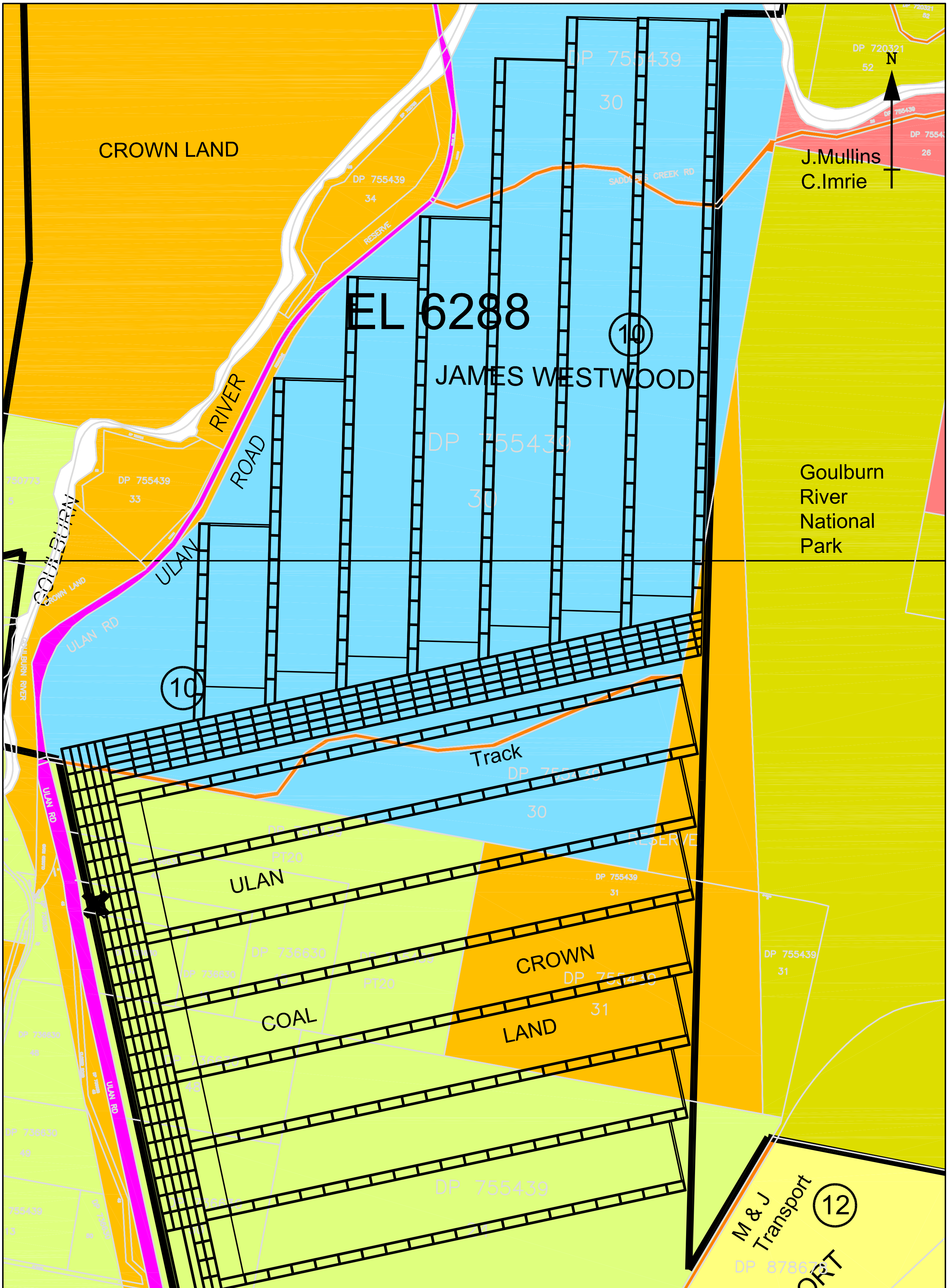


Engineer:	Jin Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	Jin Jiang			
Date:	25.01.06	TITLE:	Interpreted Unit 3 Sandstone Distance Above the Proposed LWs 1-14 Contours (m)	FIGURE 5.10
Scale:	1:2,000			



M:\Figures\Moolarben\R04-001(WHT)-1

Engineer:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited 04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S.Ditton			
Date:	13.01.06	TITLE:	Surface Level Contours and Features above the Proposed Moolarben UG4 LWs 1-14	FIGURE 5.11
Scale:	1:15,000			



Engineer:	S.Ditton	CLIENT:	Moolarben Coal Mine	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S.Ditton		04-001-WHT/1	
Date:	21/12/05	TITLE:	Land Ownership Details for No.4 UG Area	FIGURE 5.12
Scale:	1:20,000			

M:\Figures\Moolarben\Drawings\Subsidence

Looking North

Looking East

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	J.Jiang		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.02.06	TITLE:	Photographs of Cliff Line CL1, Above the	FIGURE
SCALE:	NTS		Proposed LW 12 and 13	5.13

Looking East

Looking South East

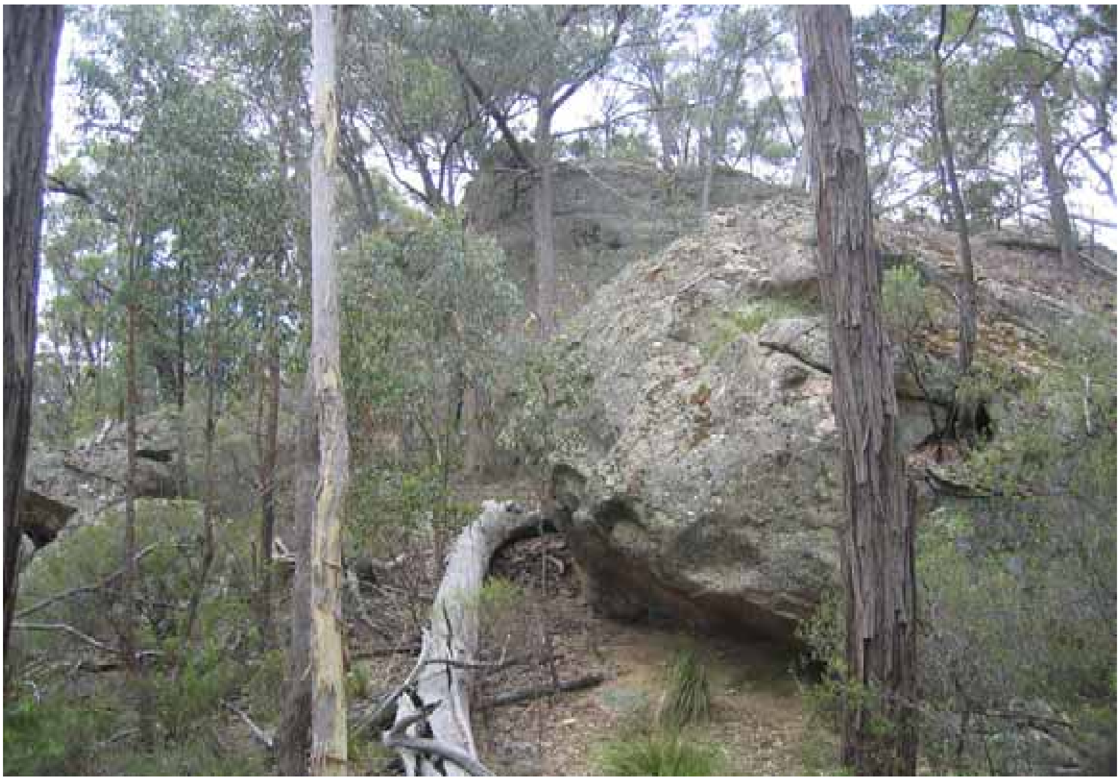
ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	J.Jiang		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.02.06	TITLE:	Photographs of Cliff Line CL2, Above the	FIGURE
SCALE:	NTS		Proposed LW 11	5.14

Looking north east

Looking east

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**	
DRAWN:	J.Jiang		R04-001-WHT/1	**(Australia) Pty Ltd**	
DATE:	07.02.06	TITLE:	Photographs of Cliff Line CL3, Above the		FIGURE
SCALE:	NTS		Proposed LWs 13 and 14		5.15

Looking east



Looking north

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**	
DRAWN:	J.Jiang		R04-001-WHT/1	**(Australia) Pty Ltd**	
DATE:	07.02.06	TITLE:	Photographs of Cliff Line CL4, above the		FIGURE
SCALE:	NTS		Proposed LWs 10 and 11		5.16

Looking west at northern cliff face

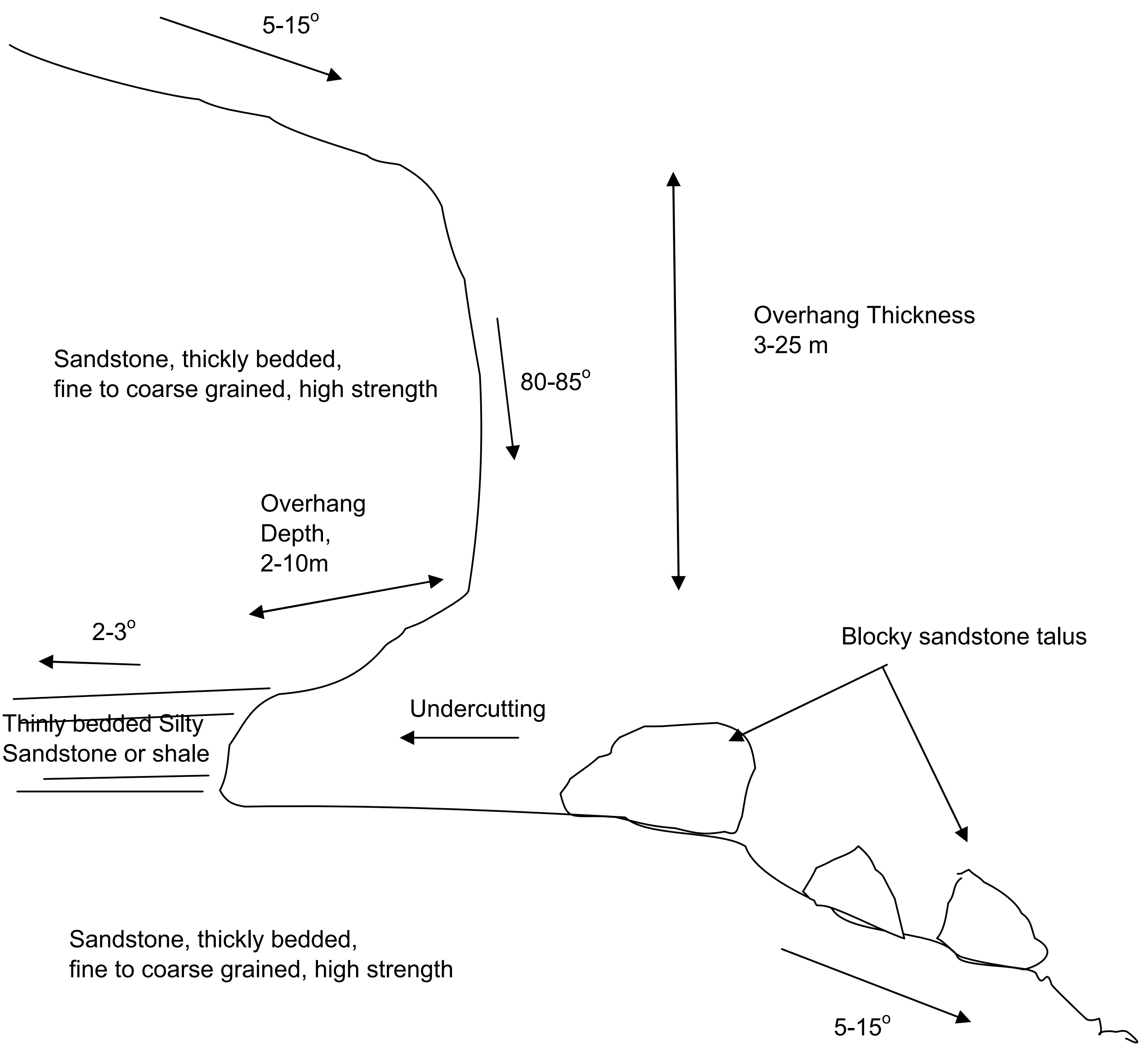
Looking north at 'bread knife' above northern cliff face

ENGINEER:	J. Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang			
DATE:	07.02.06	TITLE:	Photograph of Northern Cliff lines along The Drip (CL5)	FIGURE 5.17
SCALE:	NTS			

Looking east

Looking south

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	J.Jiang		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.02.06	TITLE:	Photographs of Cliff Line CL5, Above the	FIGURE
SCALE:	NTS		Proposed LW 6	5.18



Note: The cliff/overhang length is measured along the cliff face.

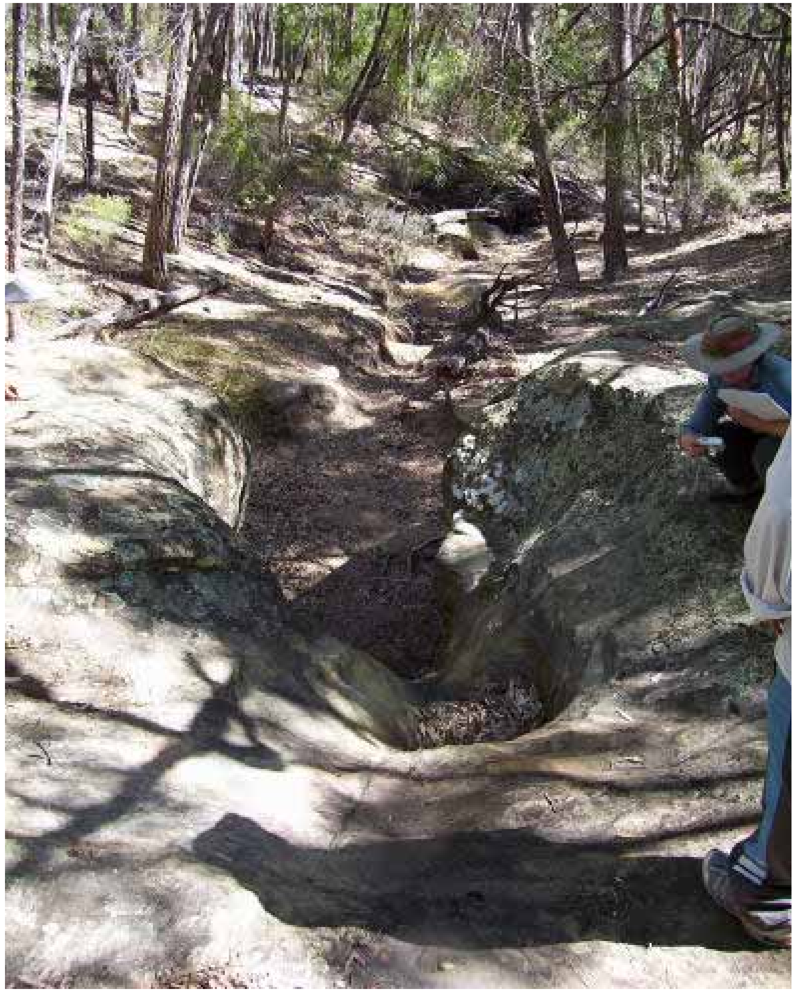
Key:

5 → Slope Angle (degrees)

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	11.02.06	TITLE:	Schematic Section of Typical Cliff Line Profiles	FIGURE
SCALE:	NTS		in No. 4 Underground Area	5.19

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Site	FIGURE
SCALE:	NTS		AS 1 (Refer to Figure 5.11 for Location)	5.20

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**	
DRAWN:	S.Ditton		R04-001-WHT/1		
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Site AS 2 (Refer to Figure 5.11 for Location)		FIGURE 5.21
SCALE:	NTS				



ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Site AS 4 (Refer to Figure 5.11 for Location)	FIGURE 5.22
SCALE:	NTS			

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Site	FIGURE
SCALE:	NTS		AS 5 (Refer to Figure 5.11 for Location)	5.23

Rock Shelter AS 6

Rock Shelter AS 14

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Sites	FIGURE
SCALE:	NTS		AS 6, 14 (Refer to Figure 5.11 for Location)	5.24

Axe Grinding Grooves

Looking south

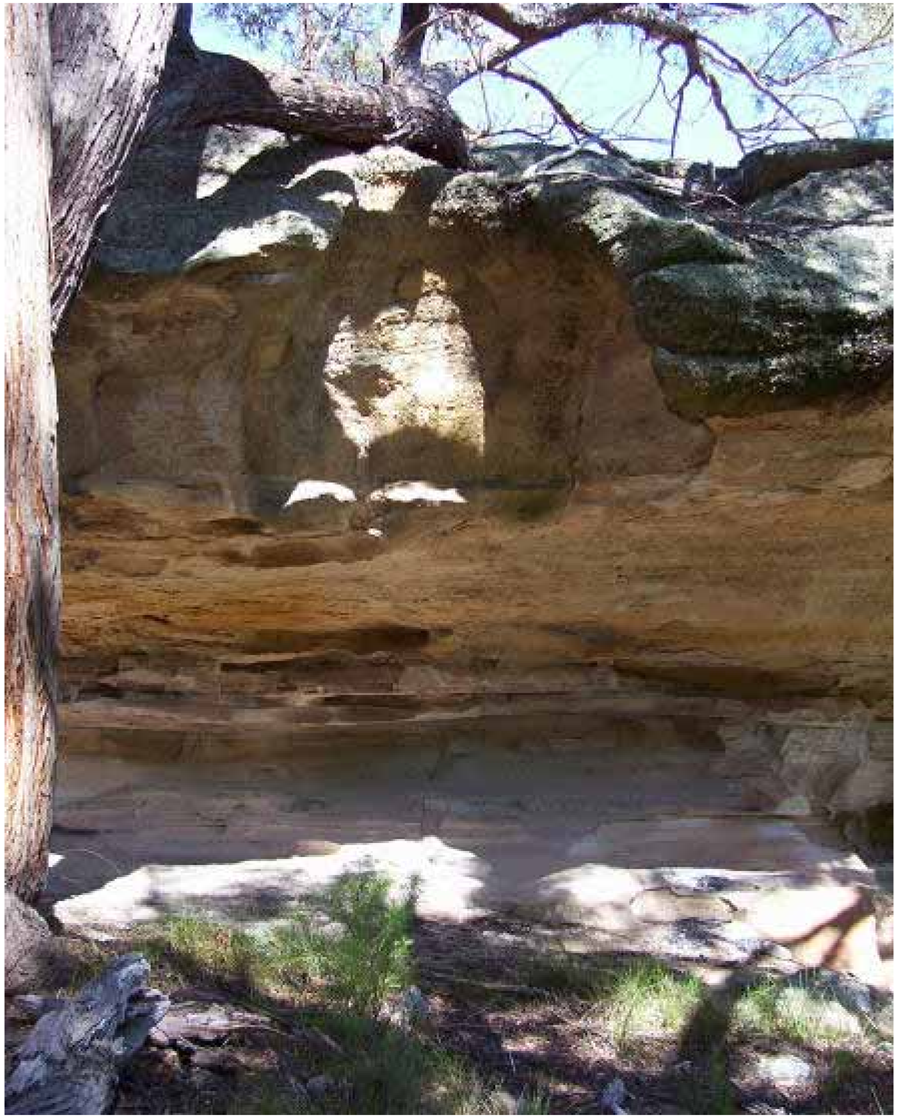
ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Site	FIGURE
SCALE:	NTS		AS 7 (Refer to Figure 5.11 for Location)	5.25

Hands on Rock (collapsed over hang)

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Site	FIGURE
SCALE:	NTS		AS 11 (Refer to Figure 5.11 for Location)	5.26

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Site AS 12 (Refer to Figure 5.11 for Location)	FIGURE 5.27
SCALE:	NTS			

Looking South-East



ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	07.04.06	TITLE:	Photograph of Significant Aboriginal Archaeological Site	FIGURE
SCALE:	NTS		AS 13 (Refer to Figure 5.11 for Location)	5.28

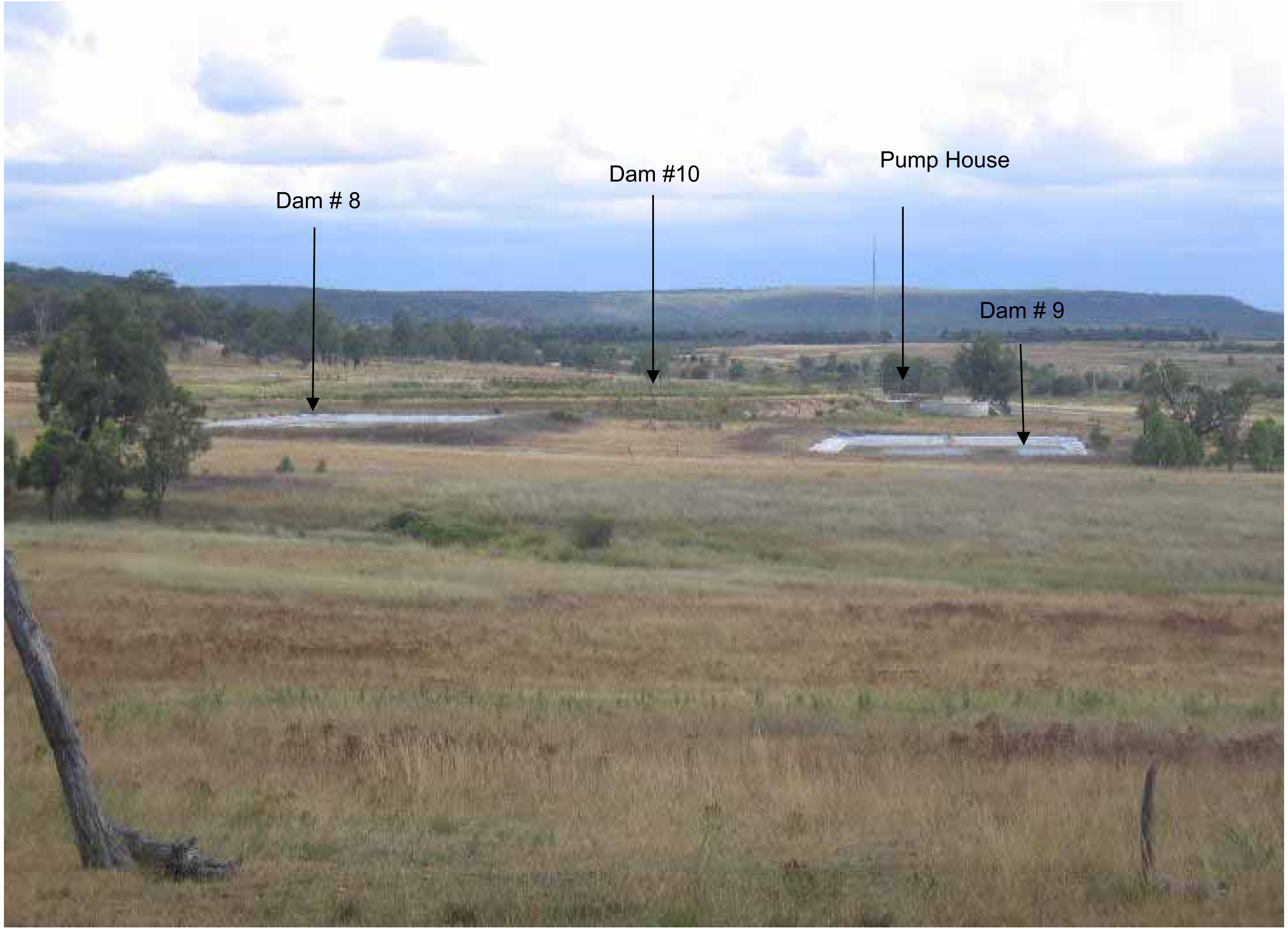
ENGINEER:	J. Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Photograph of Jim Westwood's House	FIGURE 5.29
SCALE:	NTS			

ENGINEER:	J. Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**	
DRAWN:	J.Jiang		R04-001-WHT/1		
DATE:	07.02.06	TITLE:	Photograph of Tony's House on Westwood's Land		FIGURE 5.30
SCALE:	NTS				

Hut No. B6

Hut No. B9

ENGINEER:	J. Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	J.Jiang		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.02.06	TITLE:	Photographs of Existing Westwood Huts (Building No.s 6,9)	FIGURE
SCALE:	NTS		(Building No.s 6, 9) Above the Proposed LWs 12 and 13	5.31



Looking South

ENGINEER:	J. Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang			
DATE:	07.02.06	TITLE:	Photographs of Existing Water Borefield Dams and Pump House (Dam No.s 8-10) West of the Proposed LWs 6 and 7	FIGURE 5.32
SCALE:	NTS			

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	07.04.06	TITLE:	Photograph of Dronvisa Gravel/Clay Quarry - Northern Pit	FIGURE
SCALE:	NTS		(Refer to Figure 5.11 for Location)	5.33

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	07.04.06	TITLE:	Photograph of Dronvisa Gravel/Clay Quarry - Southern Pit (Refer to Figure 5.11 for Location)	FIGURE 5.34
SCALE:	NTS			

Triassic Sandstone/Conglomerate and Lithic Sandstone and Mudstone at base of batter

Mine Site Buildings

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	07.04.06	TITLE:	Photograph of Dronvisa Gravel/Clay Quarry - Geology and Man-Made Structures &(Refer to Figure 5.11 for Location)	FIGURE 5.35
SCALE:	NTS			

Looking North West

Looking South East at Cutting No. 4

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton			
DATE:	07.04.06	TITLE:	Photograph of Goulburn River Bridge and Cutting No.4 (Refer to Figure 5.11 for Location)	FIGURE 5.36
SCALE:	NTS			

Cutting No.1, Looking South (West of LW1)

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.04.06	TITLE:	Photograph of Ulan Road and Cutting No.1	FIGURE
SCALE:	NTS		(Refer to Figure 5.11 for Location)	5.37

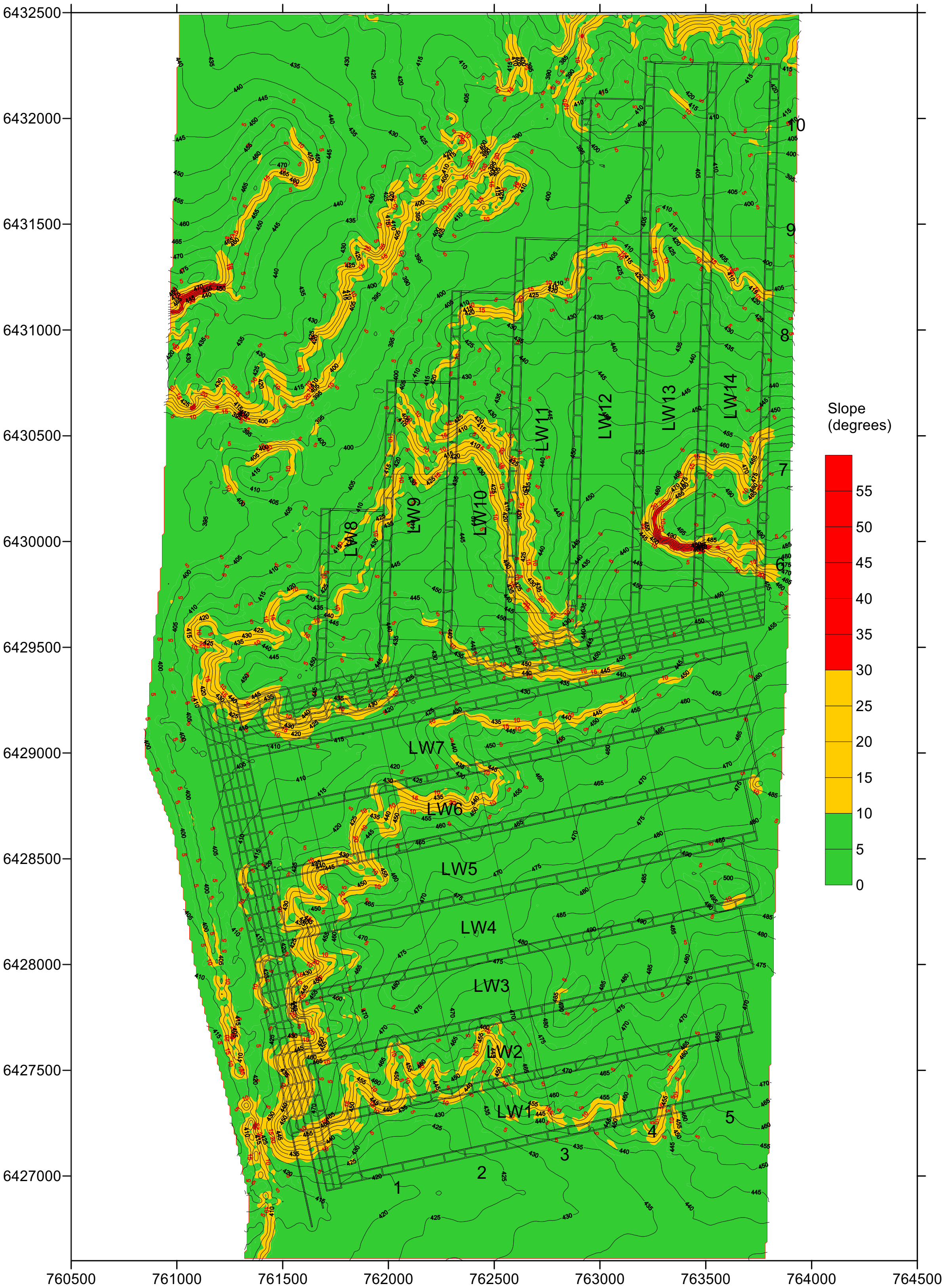
Cutting No.3, Looking North (West of LW8)

Cutting No.2 Looking North (West of LW8)

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.04.06	TITLE:	Photographs of Ulan Road Cutting No.s 2 and 3	FIGURE
SCALE:	NTS		(Refer to Figure 5.11 for Location)	5.38

Looking North East from Ulan - Cassilis Road

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	J.Jiang		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.02.06	TITLE:	Photographs of Southern Ridge and Alluvial Flats	FIGURE
SCALE:	NTS		Above the Proposed LWs 1 and 2	5.39

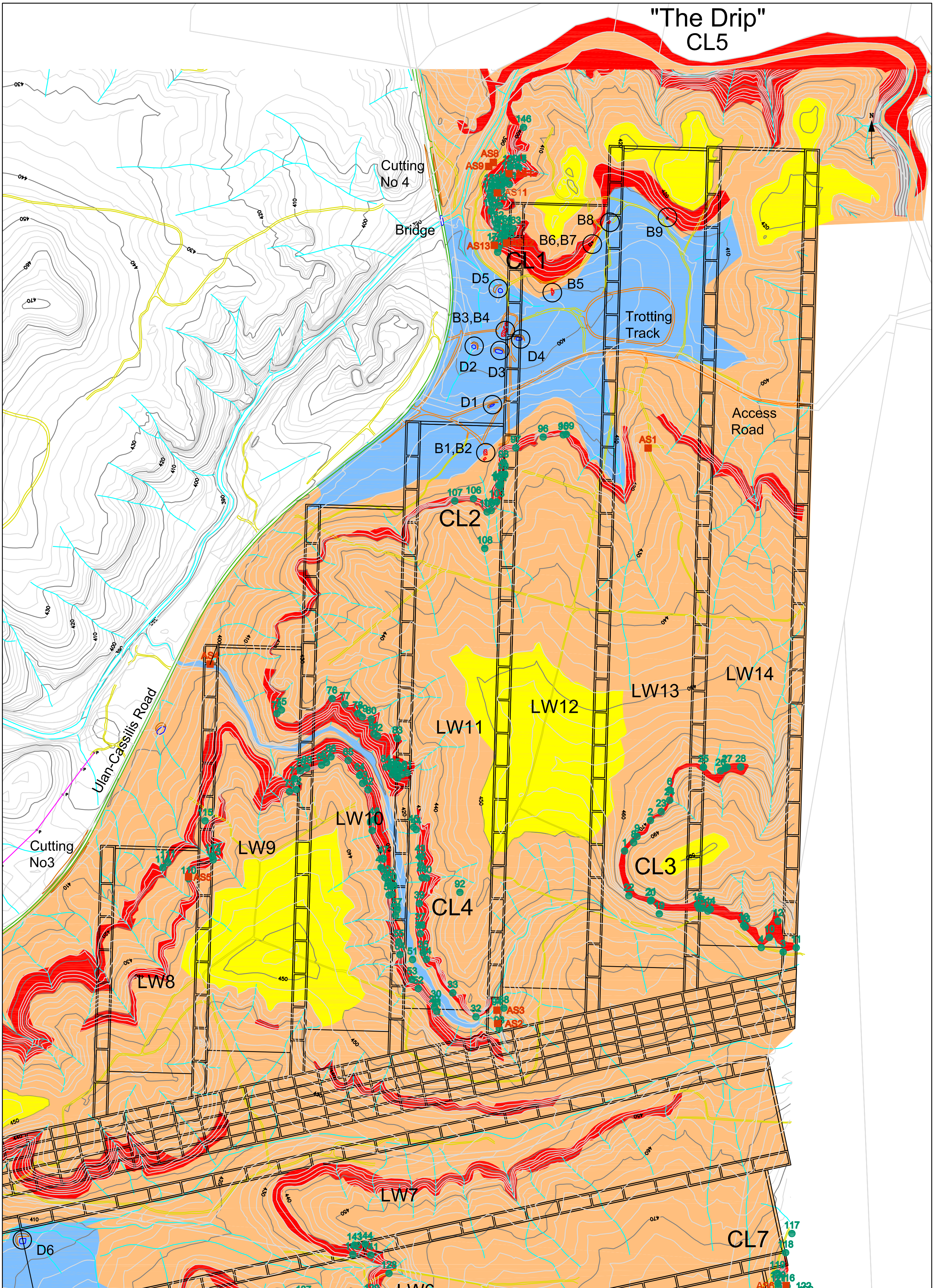


Key

435 Pre-mining Surface Levels

5 Ground Slope (degrees)

Engineer:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S. Ditton			
Date:	13.01.06	TITLE:	Pre-Mining Surface Level Contours and Ground Slopes above LWs1-14	FIGURE 5.40
Scale:	1:2,000			



Key: (refer text)

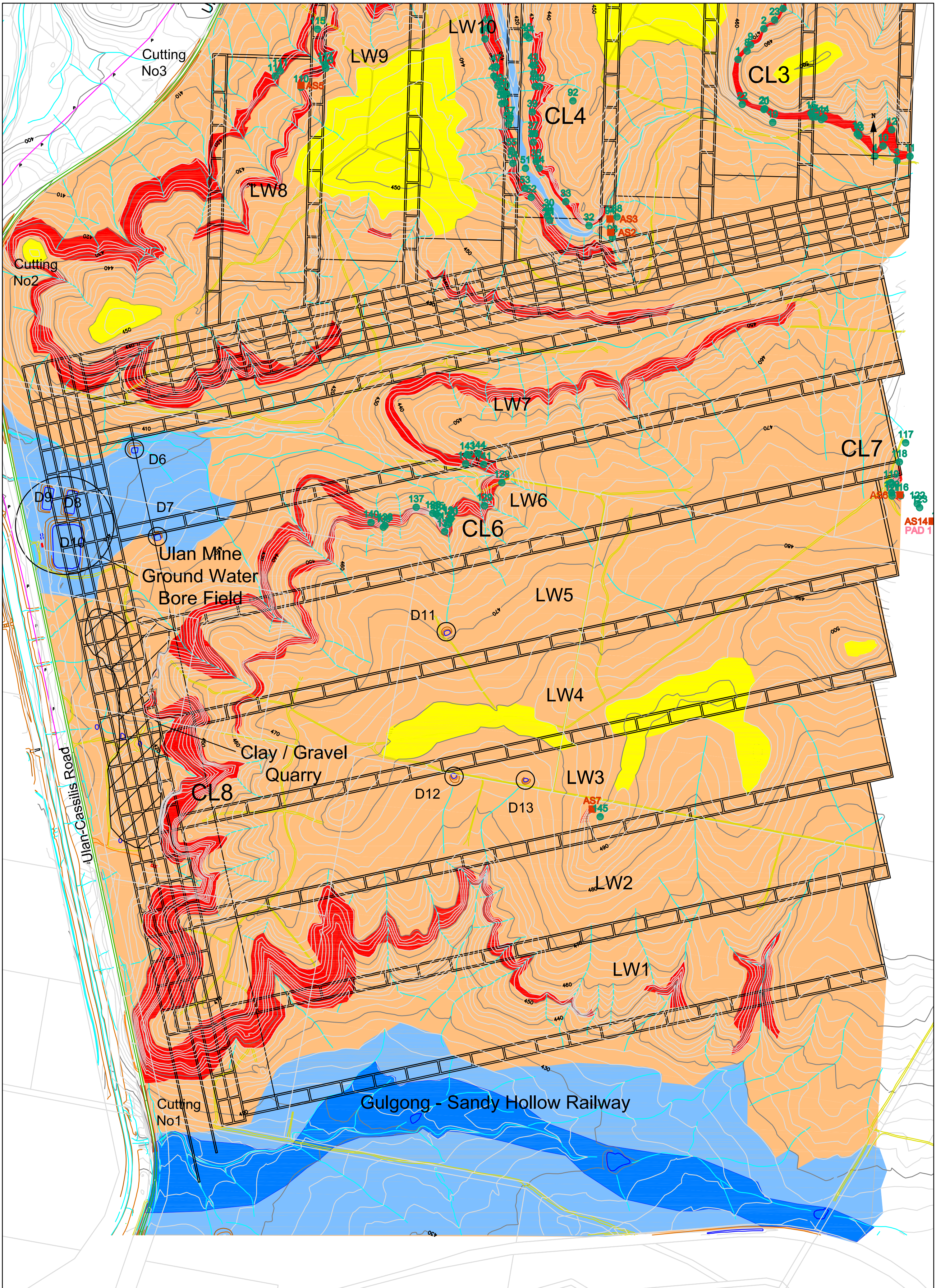
Residual Units:
- R1 - <5°
- R2 & R4 - 5-20°
- R3 - 20-80°

Alluvial Units:
- A1 - <3m

- CL1 - Cliff lines
- AS1 - Significant artifact sites
- 92 - Rock shelter
- Buildings and Dams

M:\Figures\Moolarben\R04-001(WHT)-1

Engineer:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited		STRATA ENGINEERING (Australia Pty Ltd)
Drawn:	K.Eagle		R04-001-WHT/1		
Date:	13/01/06	TITLE:	Interpreted Surface Terrain Units Above the		FIGURE
Scale:	1:10,000		Proposed Moolarben No. 4 UG LWs 8-14		5.41



Key: (refer text)

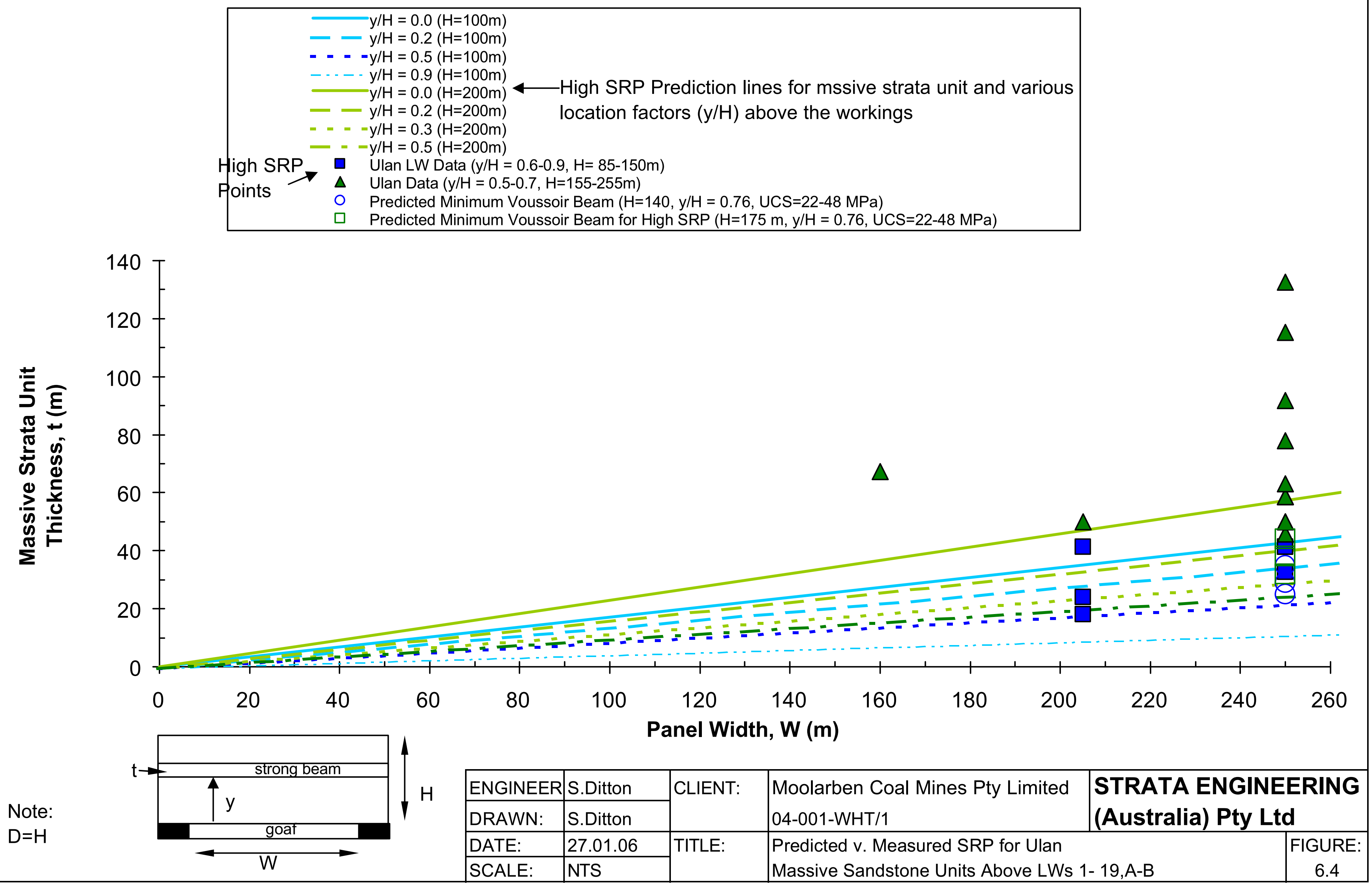
Residual Units:
- R1 - <5°
- R2 & R4 - 5-20°
- R3 - 20-80°

Alluvial Units:
- A1 - <3m
- A2 - 3-30m

CL1 - Cliff lines
AS1 - Significant artifact sites
92 - Rock shelter
○ - Buildings and Dams

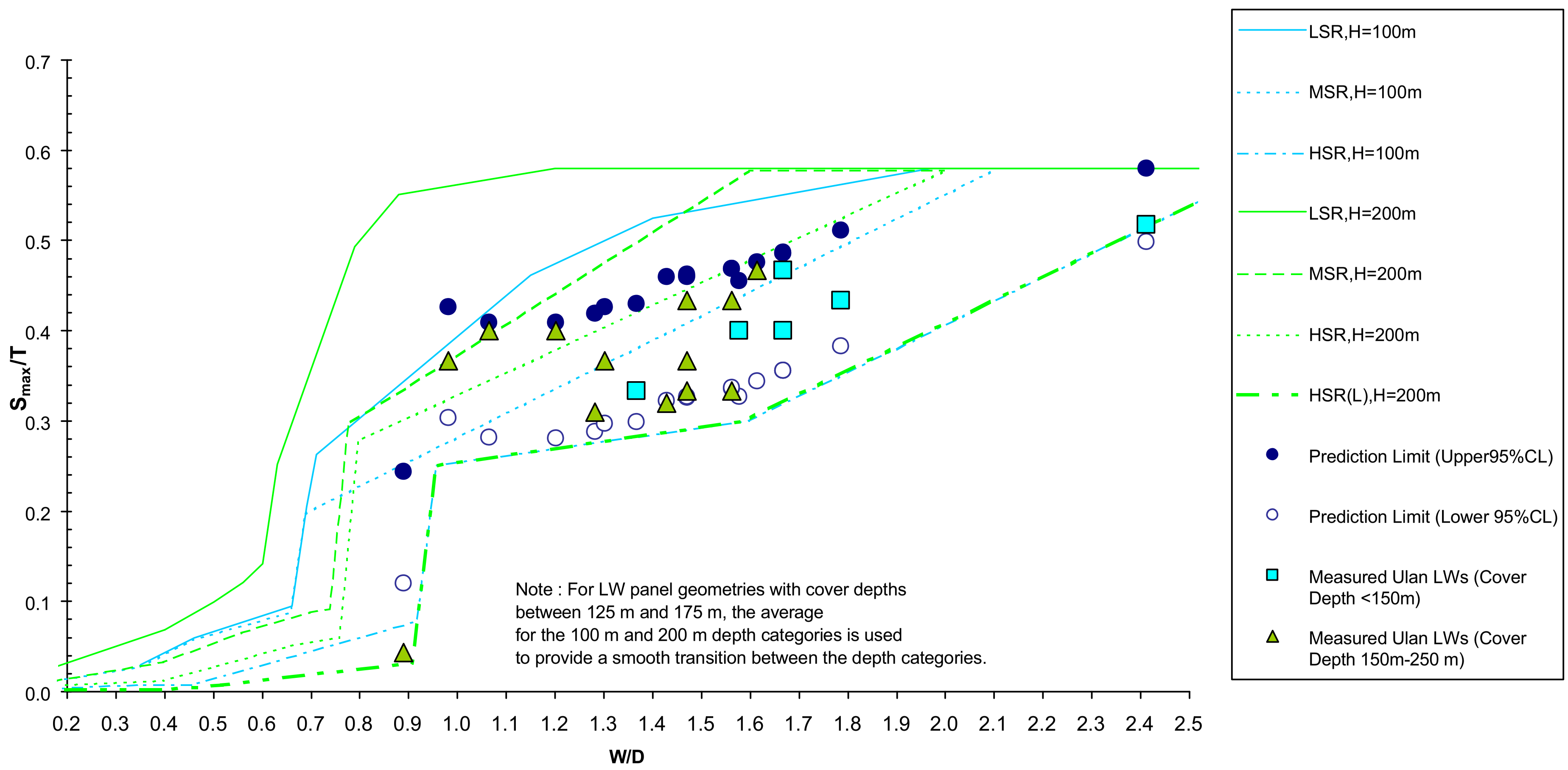
M:\Figures\Moolarben\R04-004(WHT)-1

Engineer:	S.Ditton	CLIENT:	White Mining Ltd 04-001-WHT/1	STRATA ENGINEERING (Australia Pty Ltd)
Drawn:	C. Wagner			
Date:	13/01/06	TITLE:	Interpreted Surface Terrain Units Above the Proposed Moolarben No. 4 UG LWs 1-7	FIGURE 5.42
Scale:	1:10,000			



Note:
D=H

ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	27.01.06	TITLE:	Predicted v. Measured SRP for Ulan	FIGURE:
SCALE:	NTS		Massive Sandstone Units Above LWs 1- 19,A-B	6.4



Key

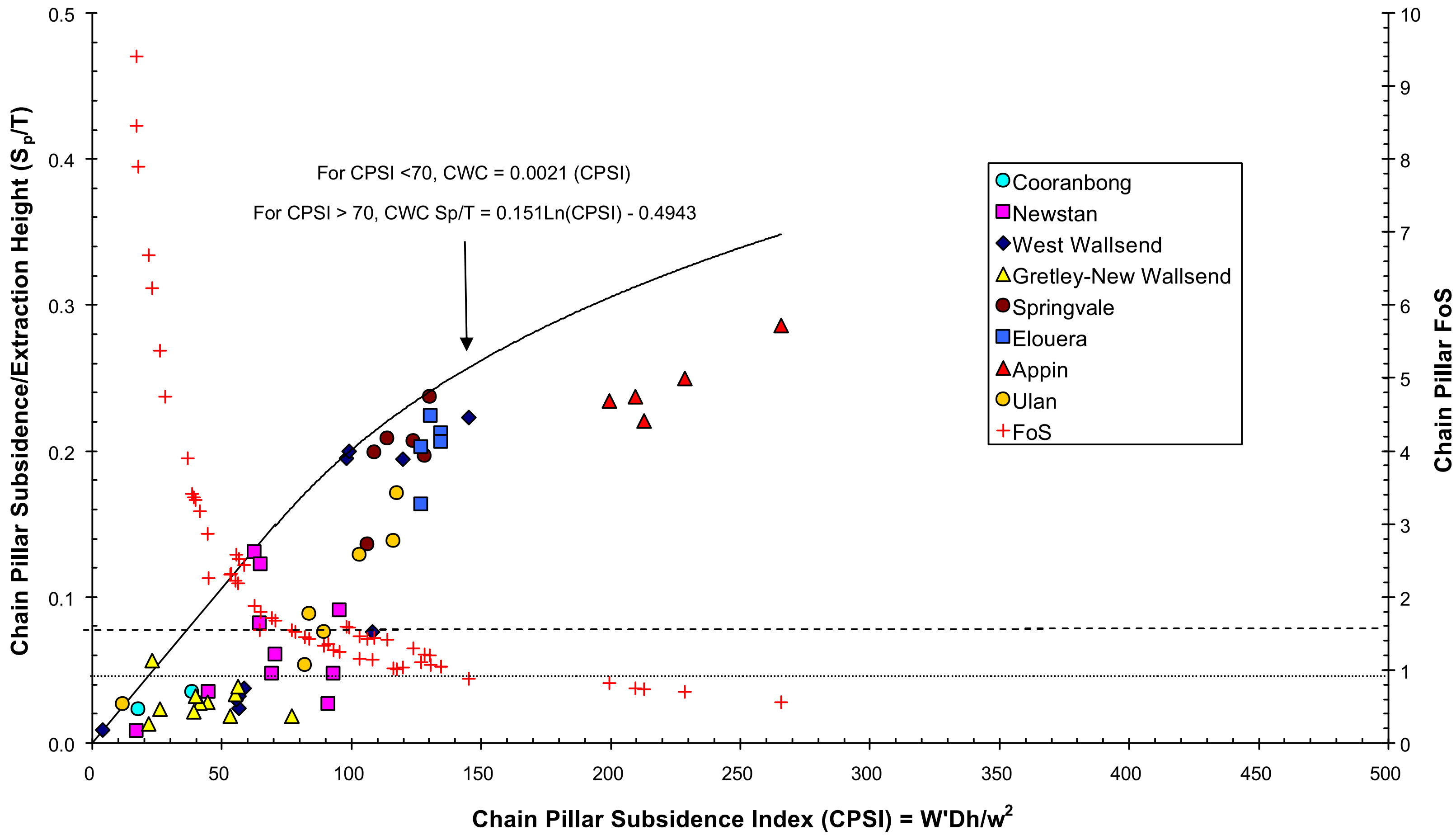
LSR = Low Subsidence Reduction Potential

MSR = Moderate Subsidence Reduction Potential

HSR = High Subsidence Reduction Potential

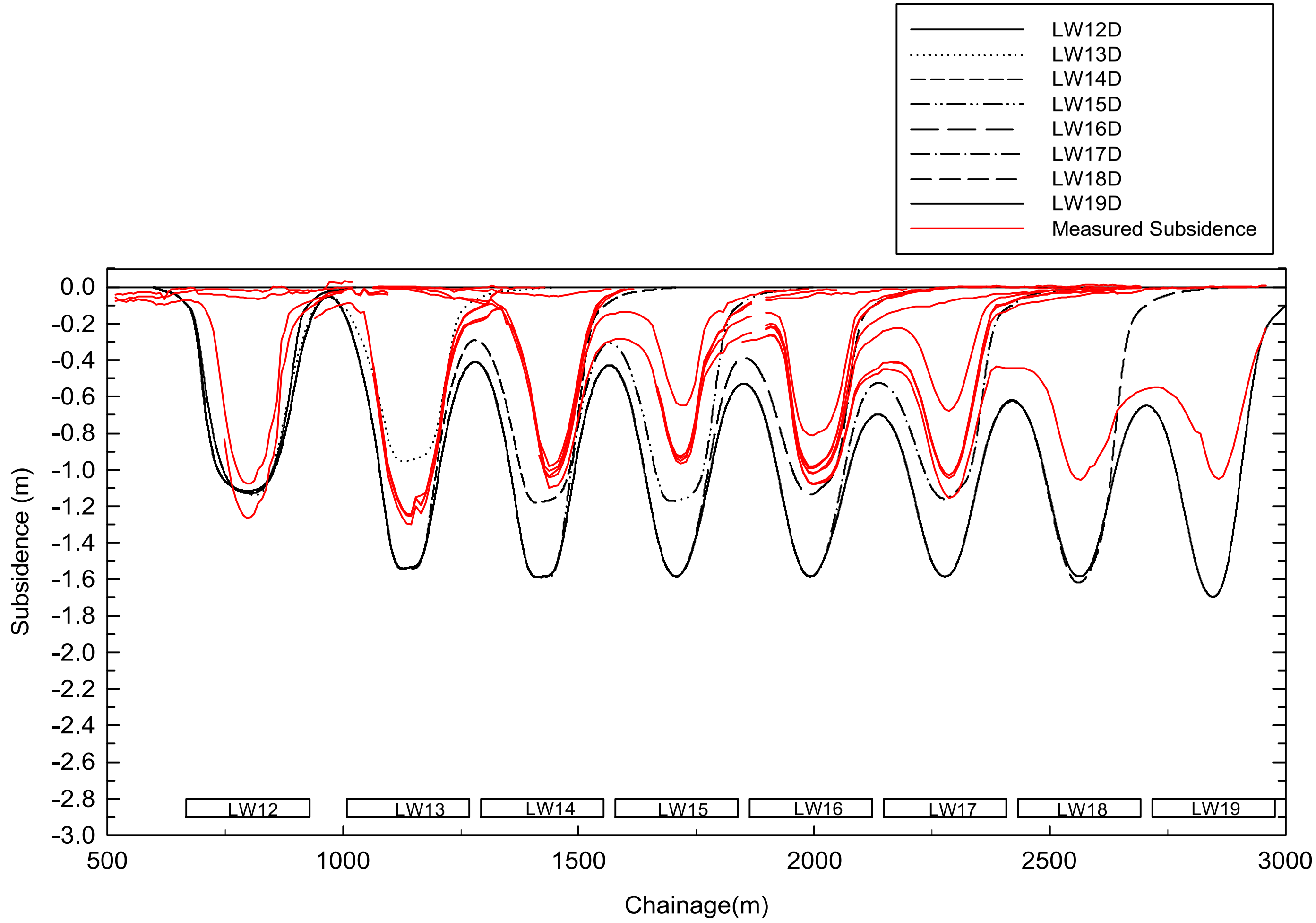
D=H=Cover Depth

ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	27.01.06	TITLE:	Predicted v. Measured First S_{max}/T for Ulan	FIGURE:
SCALE:	NTS		Massive Sandstone Units Above LWs 1- 19,A-B	6.2



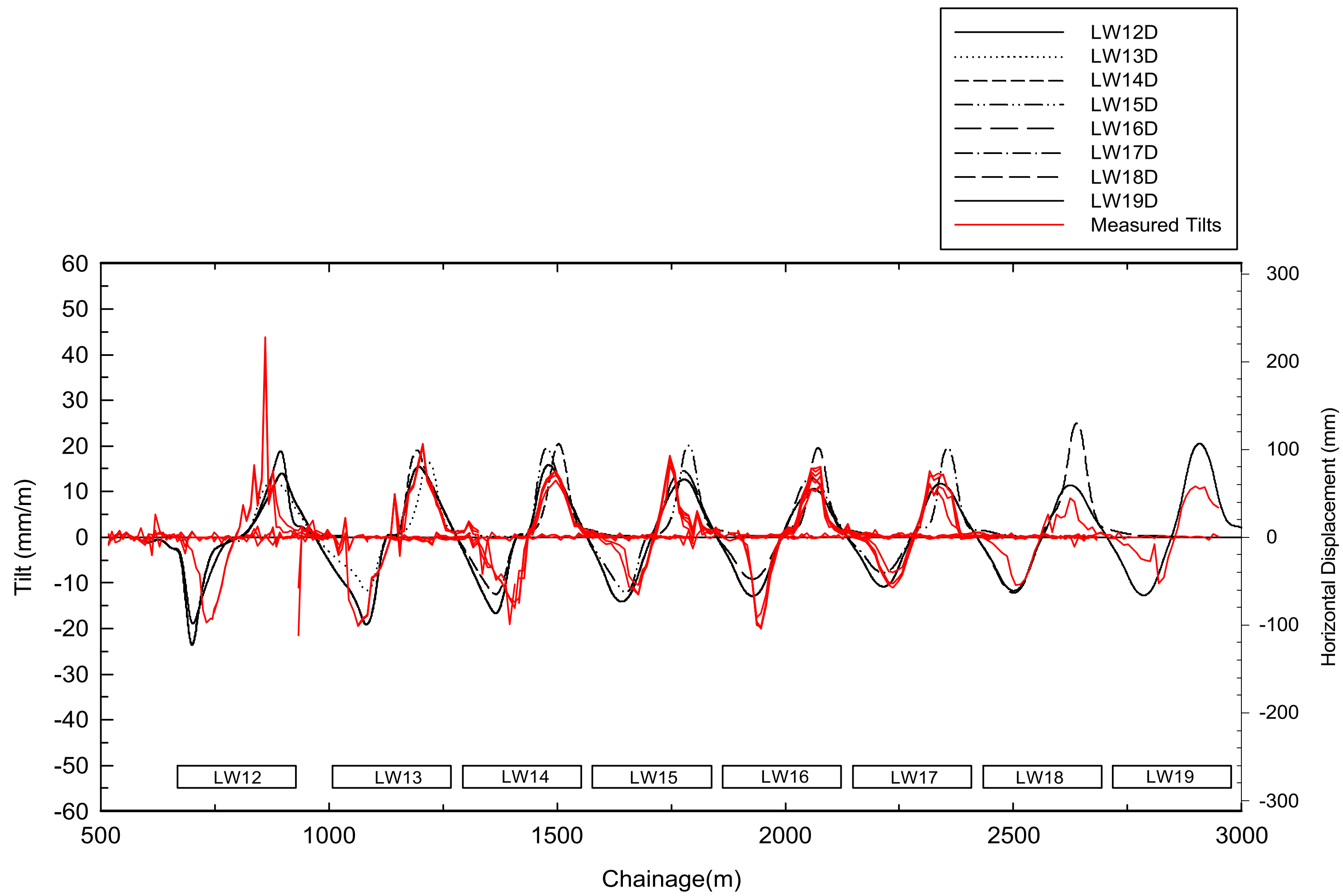
Note: W'H is the 2-D volume of rock above the chain pillar based on a caving angle of 21°.

ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	07.09.06	TITLE:	Measured Subsidence Over Ulan LWs 12 - 18 Chain Pillars Subject to Double Abutment Loading Conditions	FIGURE: 6.3
SCALE:	NTS			



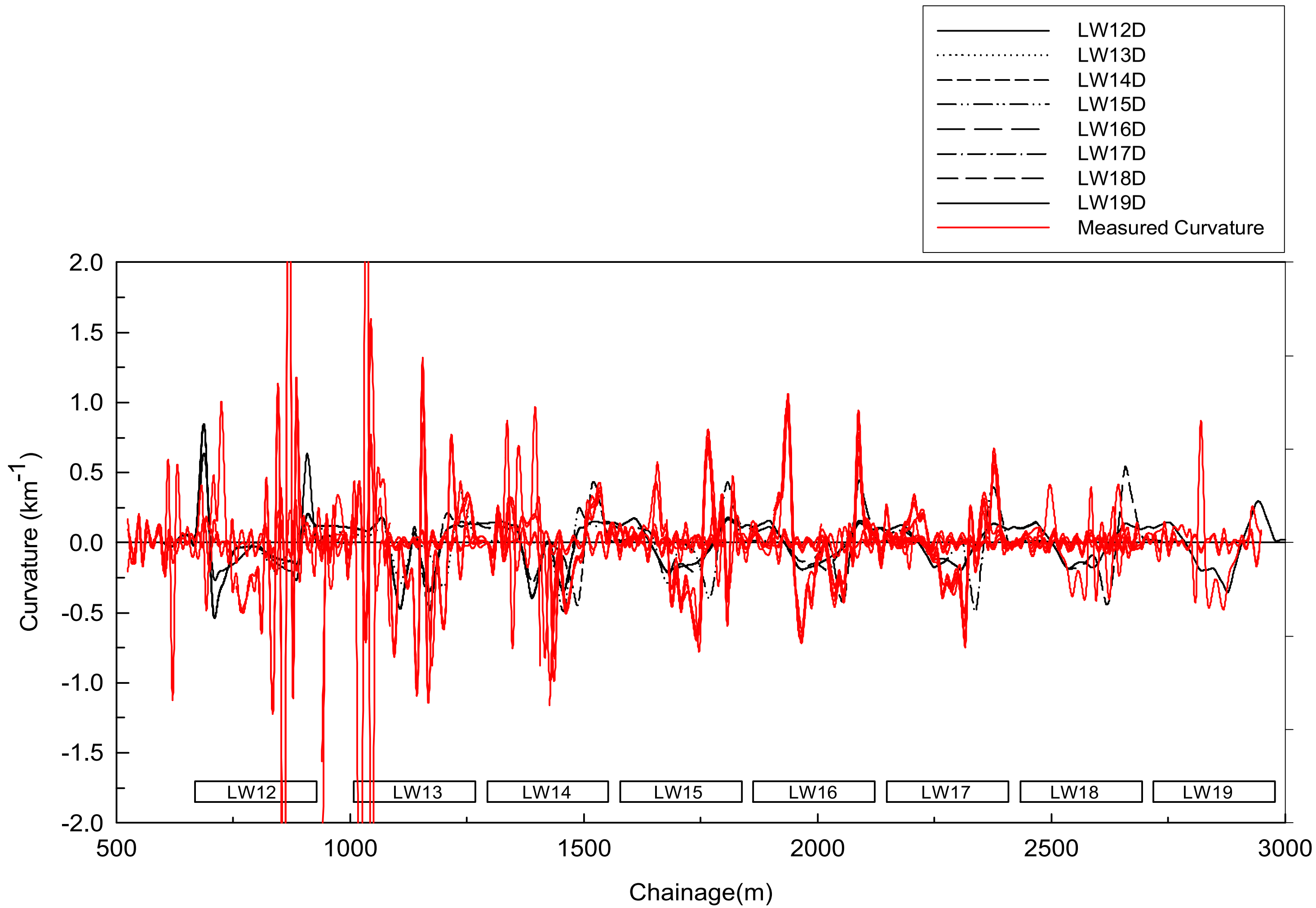
Note:
Predicted profiles are Lower 95% Confidence Profiles

ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	23.08.06	TITLE:	Predicted v. Measured Subsidence Profiles for Ulan	FIGURE:
SCALE:	NTS		LWs 12 - 19 (D Line)	6.4



Note:
Predicted profiles are derived from Lower
95% Confidence Limit subsidence profiles

ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	23.08.06	TITLE:	Predicted v. Measured Tilt Profiles for Ulan	FIGURE:
SCALE:	NTS		LWs 12 - 19 (D Line)	6.5

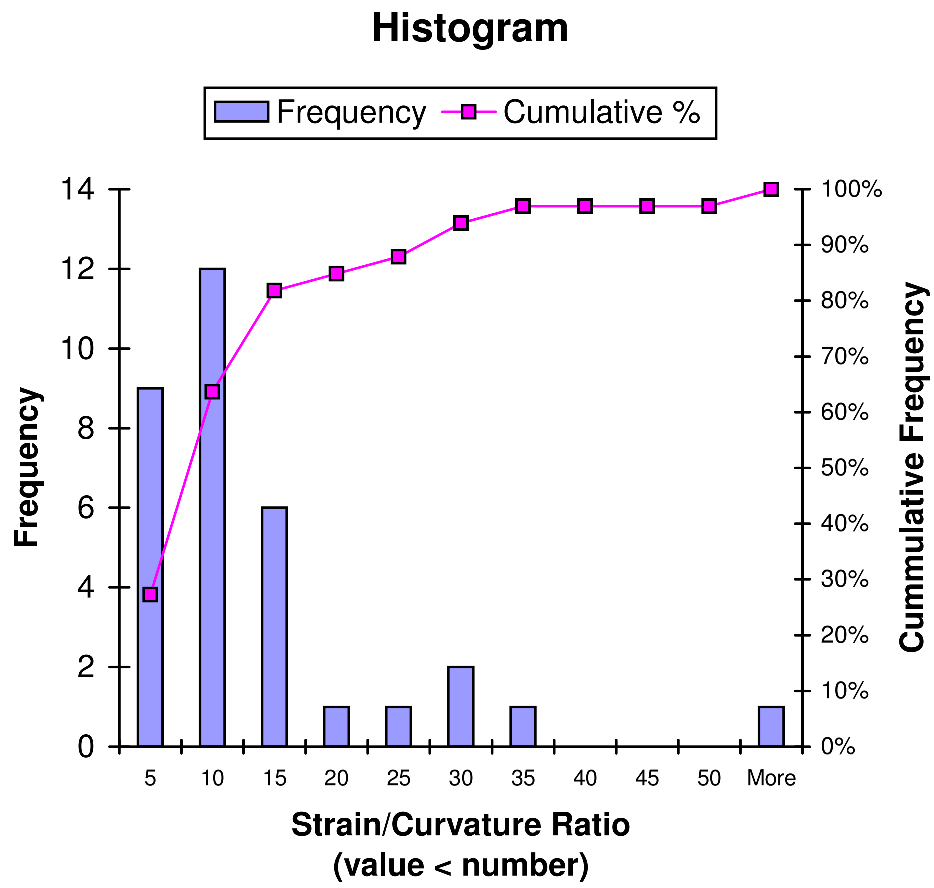


Note:
Predicted profiles are derived from Lower
95% Confidence Limit Subsidence Profiles

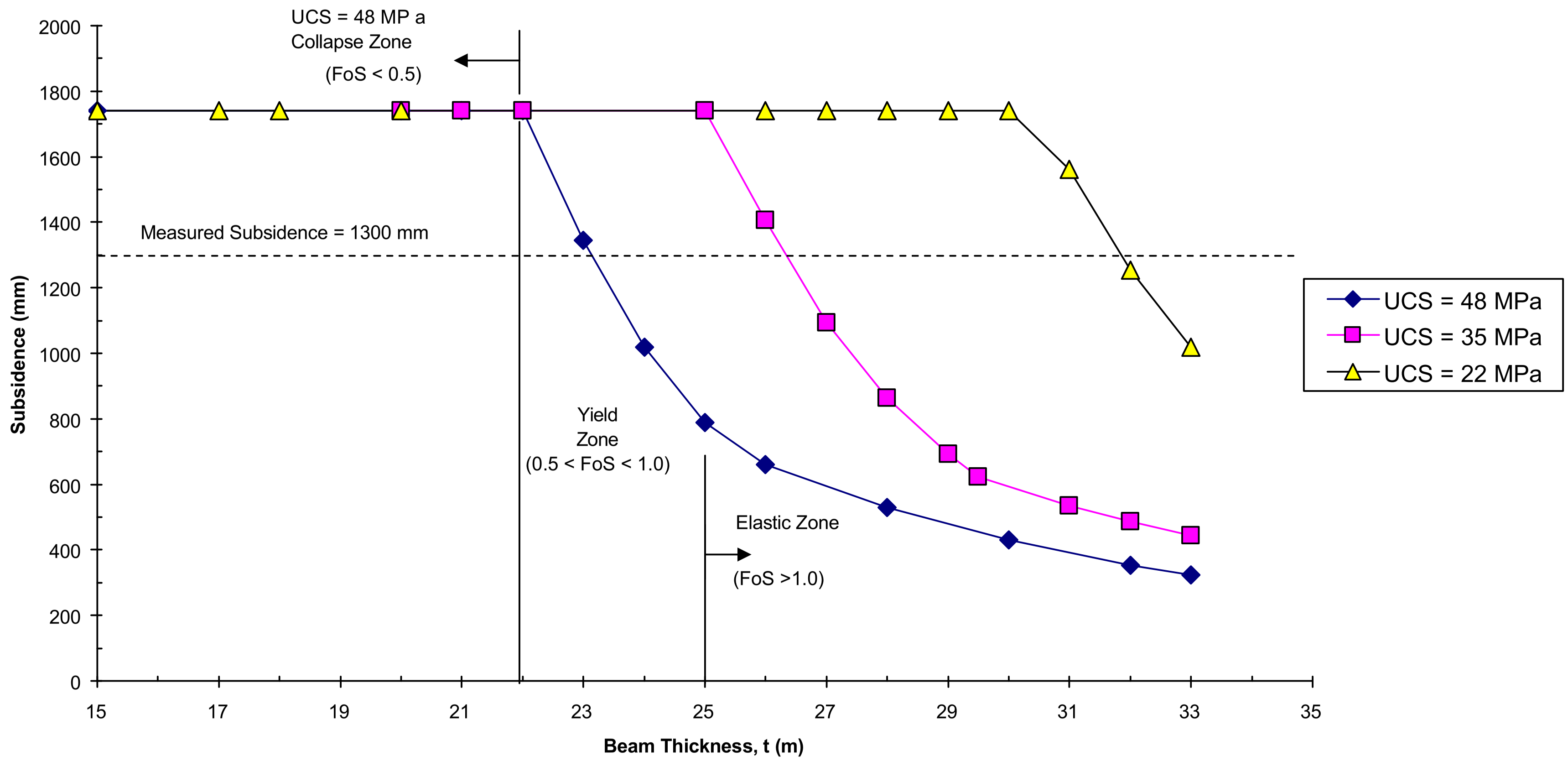
ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	23.08.06	TITLE:	Predicted v. Measured Curvature Profiles for Ulan	FIGURE:
SCALE:	NTS		LWs 12 - 19 (D Line)	6.6

Bin	*Frequency*	*Cumulative %*
5	9	27.27%
10	12	63.64%
15	6	81.82%
20	1	84.85%
25	1	87.88%
30	2	93.94%
35	1	96.97%
40	0	96.97%
45	0	96.97%
50	0	96.97%
More	1	100.00%

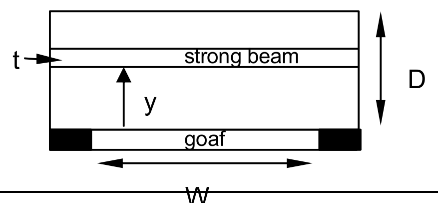
Statistics	
Mean	**11.2**
Standard E	1.8
Median	**9.1**
Standard D	10.5
Sample Va	110.1
Kurtosis	5.6
Skewness	2.2
Range	49.2
Minimum	1.5
Maximum	50.7
Sum	368.5
Count	33.0
u95%	28.48296
u95%/mea	2.550752



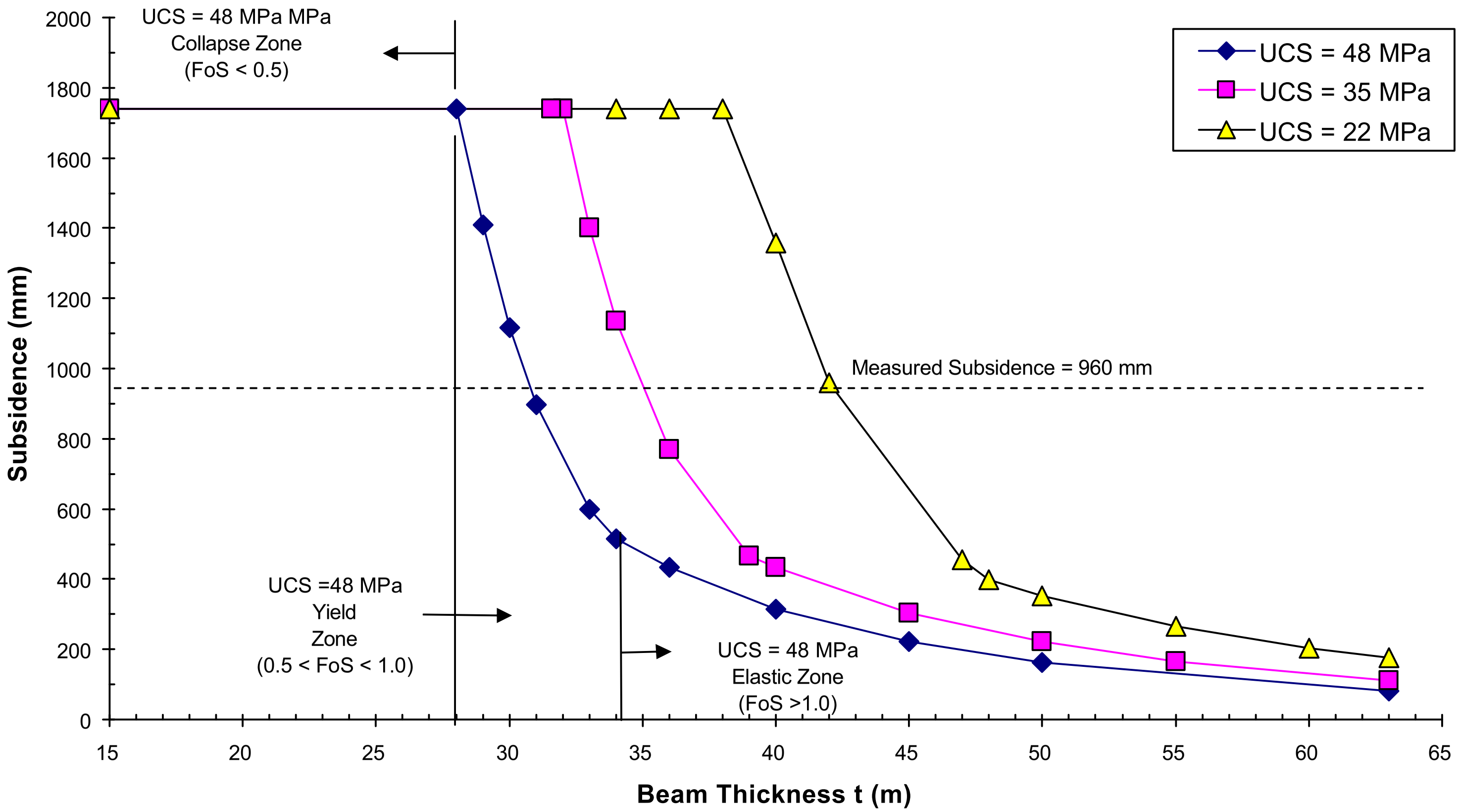
ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	23.08.06	TITLE:	Statistics of Measured Maximum Strains against Curvatures for Ulan Mines LWs 12 - 19 (D Line)	FIGURE: 6.7
SCALE:	NTS			



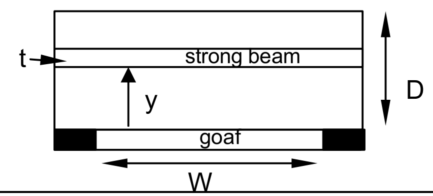
Note
W = 250 m
D = 140 m
y = 107 m



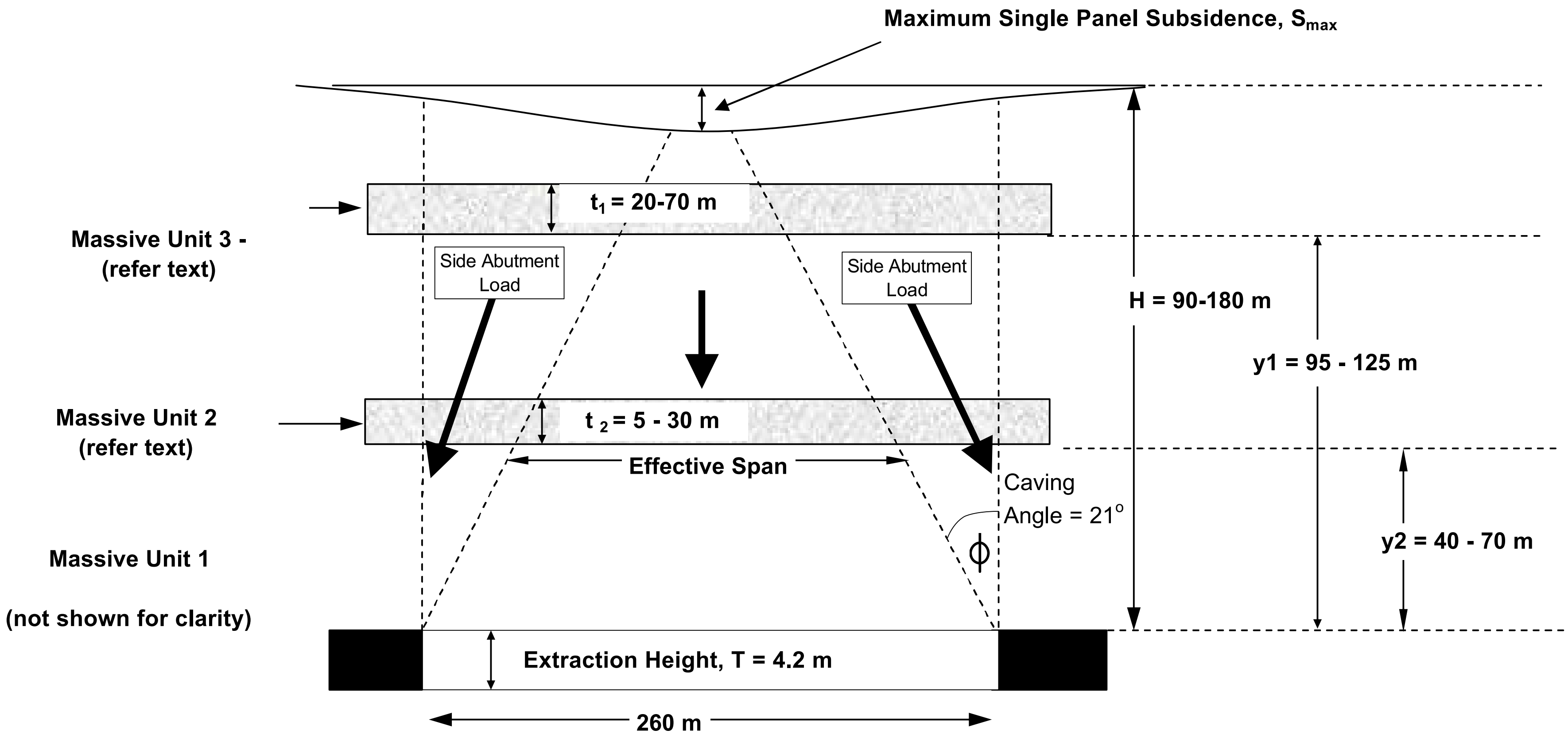
ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	27.01.06	TITLE:	Predicted Bridging Limits for Wollar Sandstone above Ulan LW10 using Voussoir Beam Theory	FIGURE: 6.8
SCALE:	NTS			



Note
W = 250 m
D = 175 m
y = 112 m



ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	27.01.06	TITLE:	Predicted Bridging Limits for Wollar Sandstone above Ulan LW15D Using Voussoir Beam Theory	FIGURE: 6.9
SCALE:	NTS			



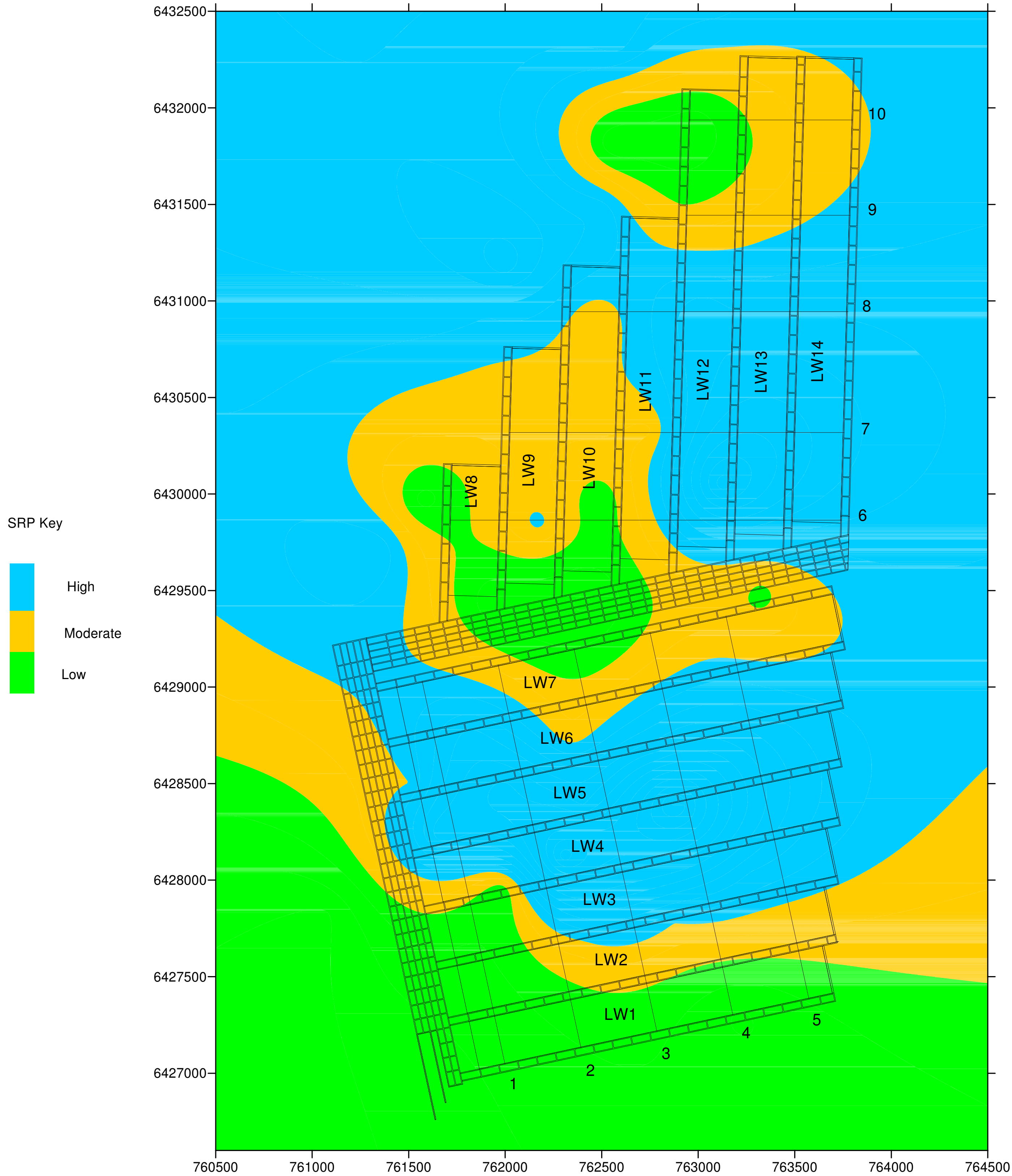
Legend

SRP Subsidence Reduction Potential

Low - Moderate SRP

High SRP when t3 > 25 m or t2 >35 m

ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	06.02.06	TITLE:	Conceptual Model of Overburden Above the Proposed LWs 1 to 14	FIGURE: 7.1
SCALE:	NTS			

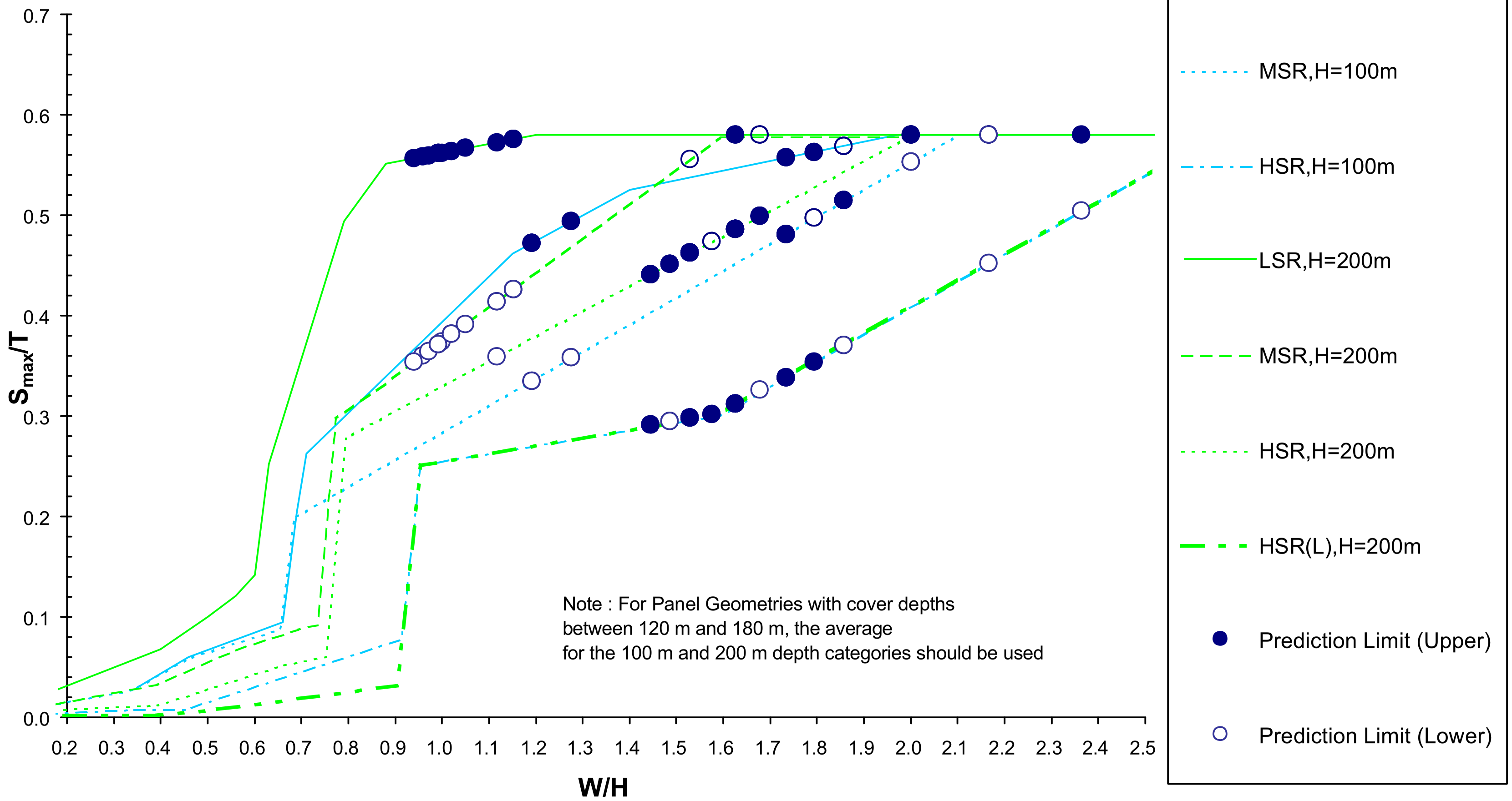


Note:

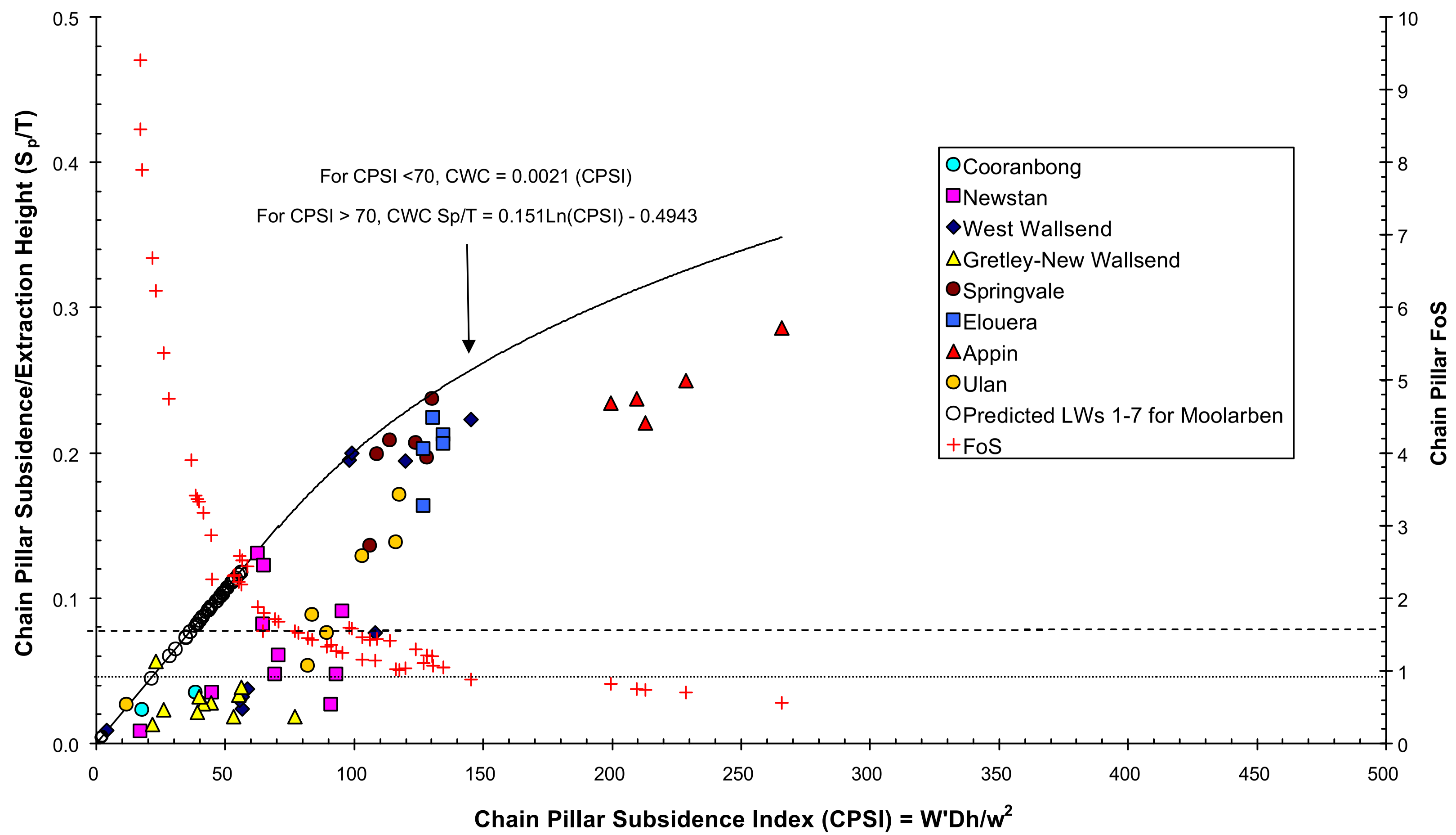
SRP = Subsidence Reduction Potential

(refer to text)

Engineer:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S.Ditton			
Date:	25.01.06	TITLE:	Interpreted Subsidence Reduction Potential Due to Sandstone Units in the Overburden	FIGURE 7.2
Scale:	1:2,000			

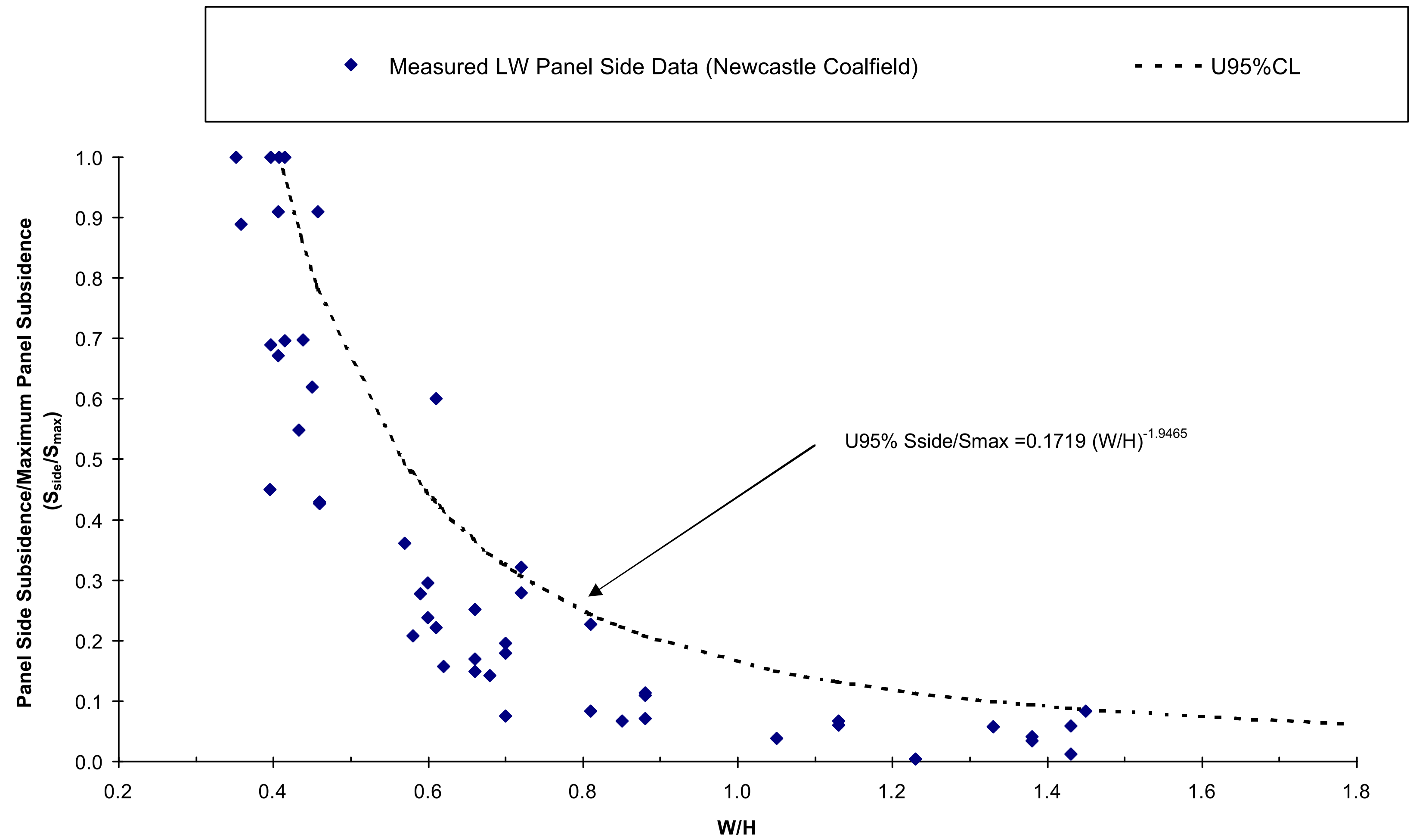


ENGINEER	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	STRATA ENGINEERING (Australia) Pty Ltd
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	25.01.06	TITLE:	Predicted Normalised Subsidence for Single LWs	FIGURE:
SCALE:	NTS		Proposed LW1-14 Predictions	7.3

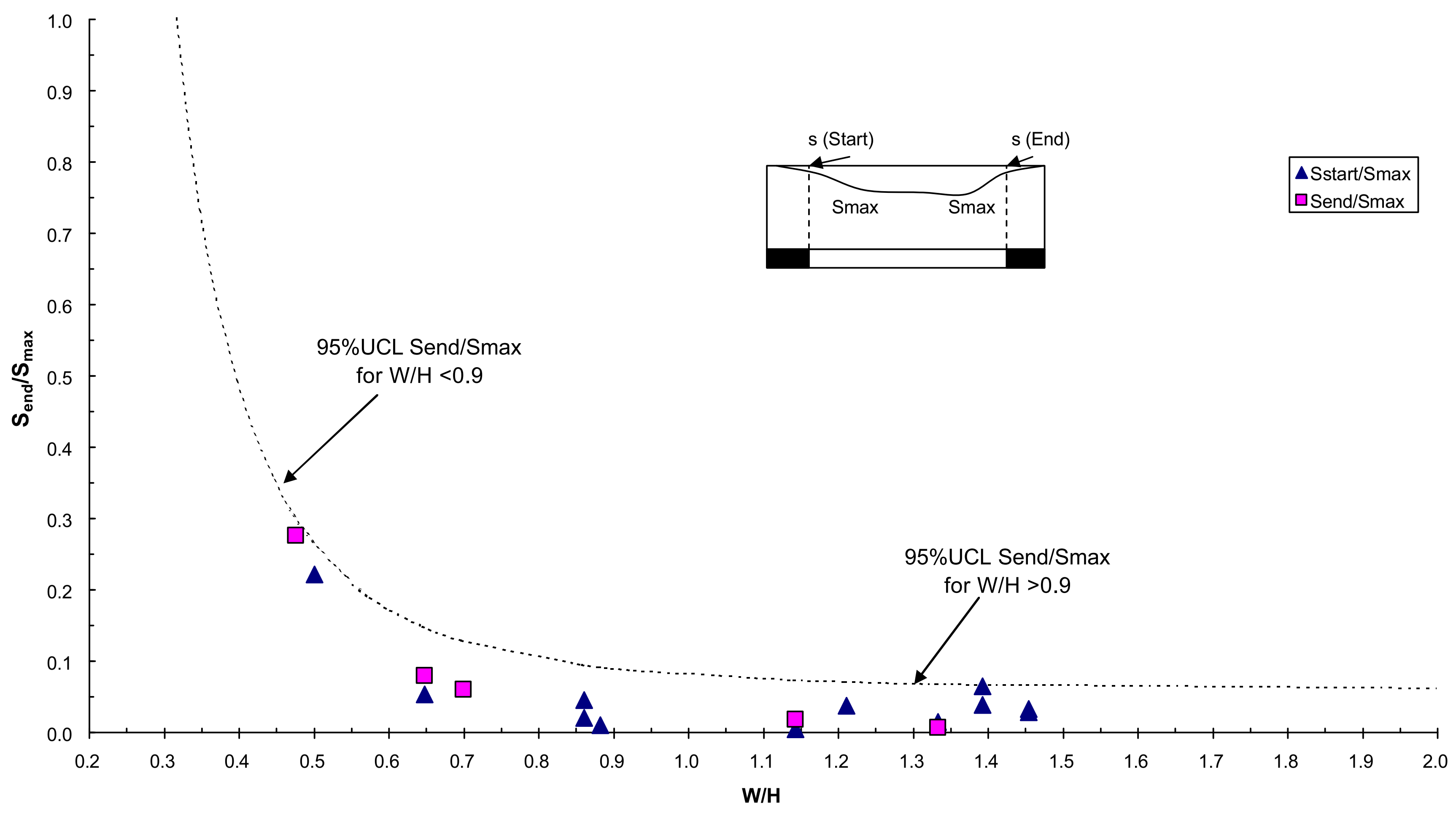


Note: W'H is the 2-D volume of rock above the chain pillar based on a caving angle of 21°.

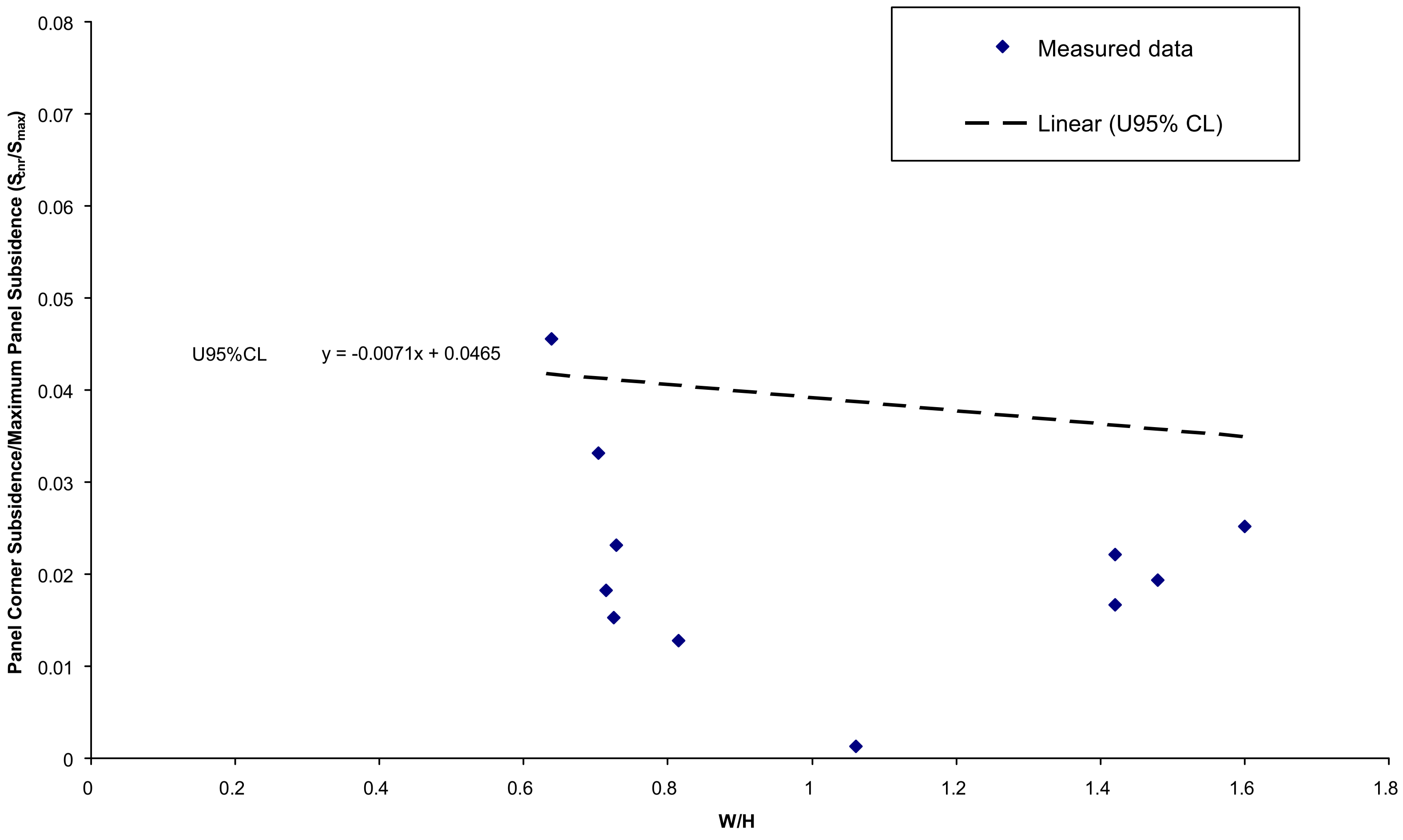
ENGINEER	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	07.09.06	TITLE:	Predicted Subsidence Over Chain Pillars Subject to Double Abutment Loading Conditions for LWs 1-14	FIGURE: 7.4
SCALE:	NTS			



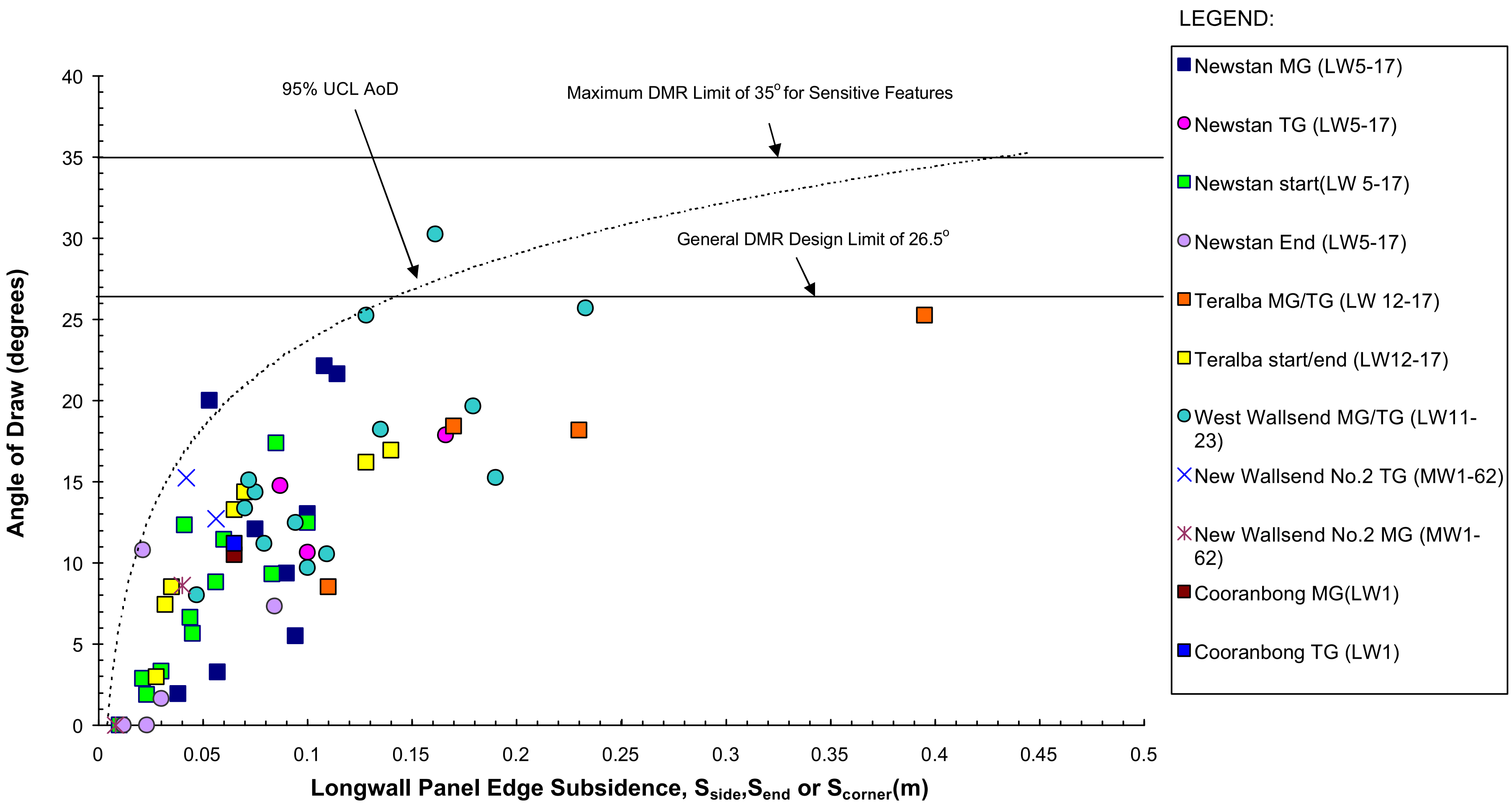
Engineer:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
Drawn:	S.Ditton		R04-001-WHT/1	
Date:	21/02/2006	TITLE:	Empirical Model for Goaf Edge Subsidence	FIGURE
Scale:	NTS		Prediction Above Panel Crossline	10.1



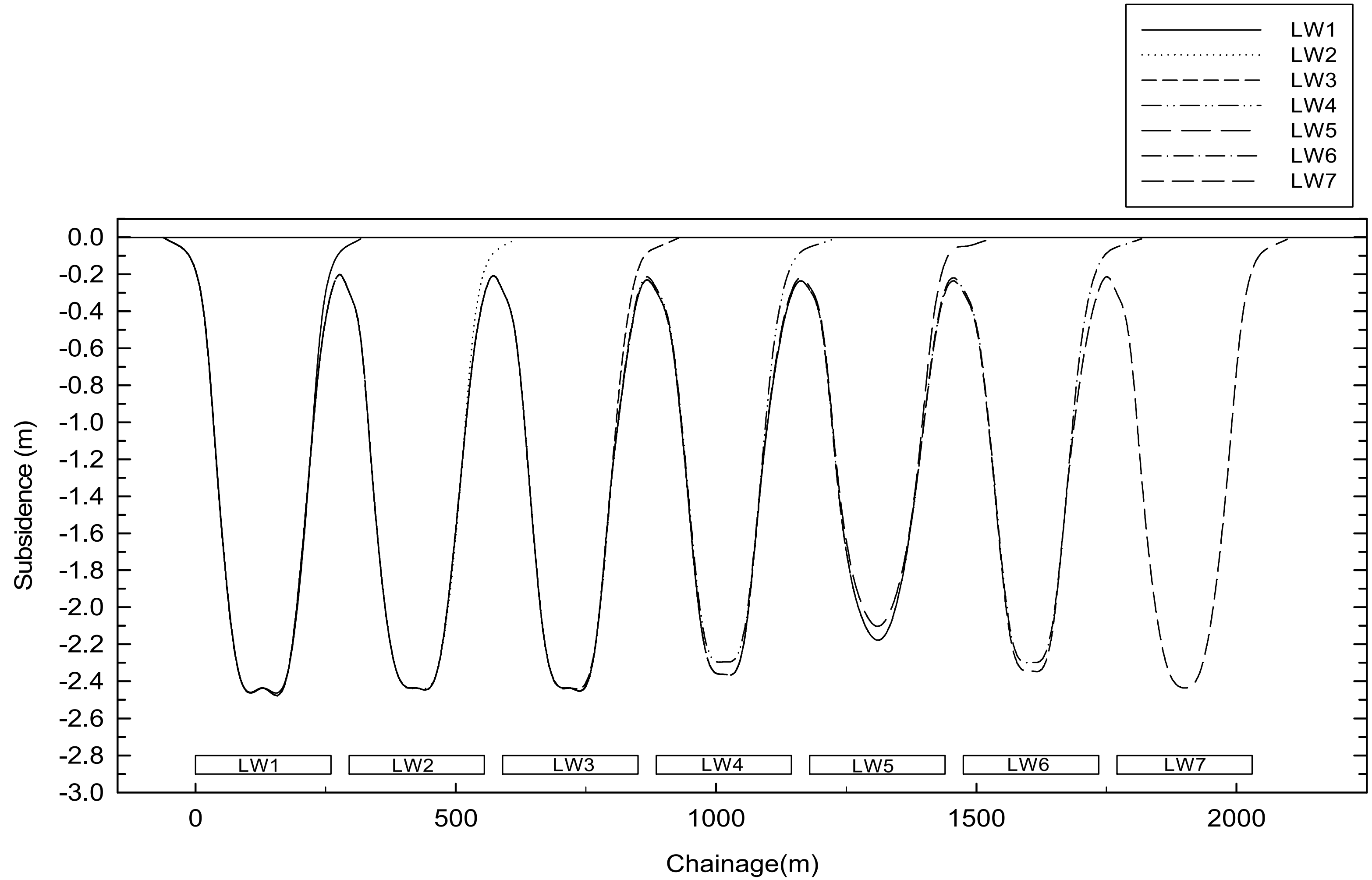
ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	7/02/2006	TITLE:	Empirical Model for Goaf Edge Subsidence Prediction Above Panel Centreline at End of LW	FIGURE: 10.2
SCALE:	NTS			



Engineer:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
Drawn:	S.Ditton		R04-001-WHT/1	
Date:	7/02/2006	TITLE:	Empirical Model for Goaf Edge Subsidence	FIGURE
Scale:	NTS		Prediction Above Panel Cornerline	10.3

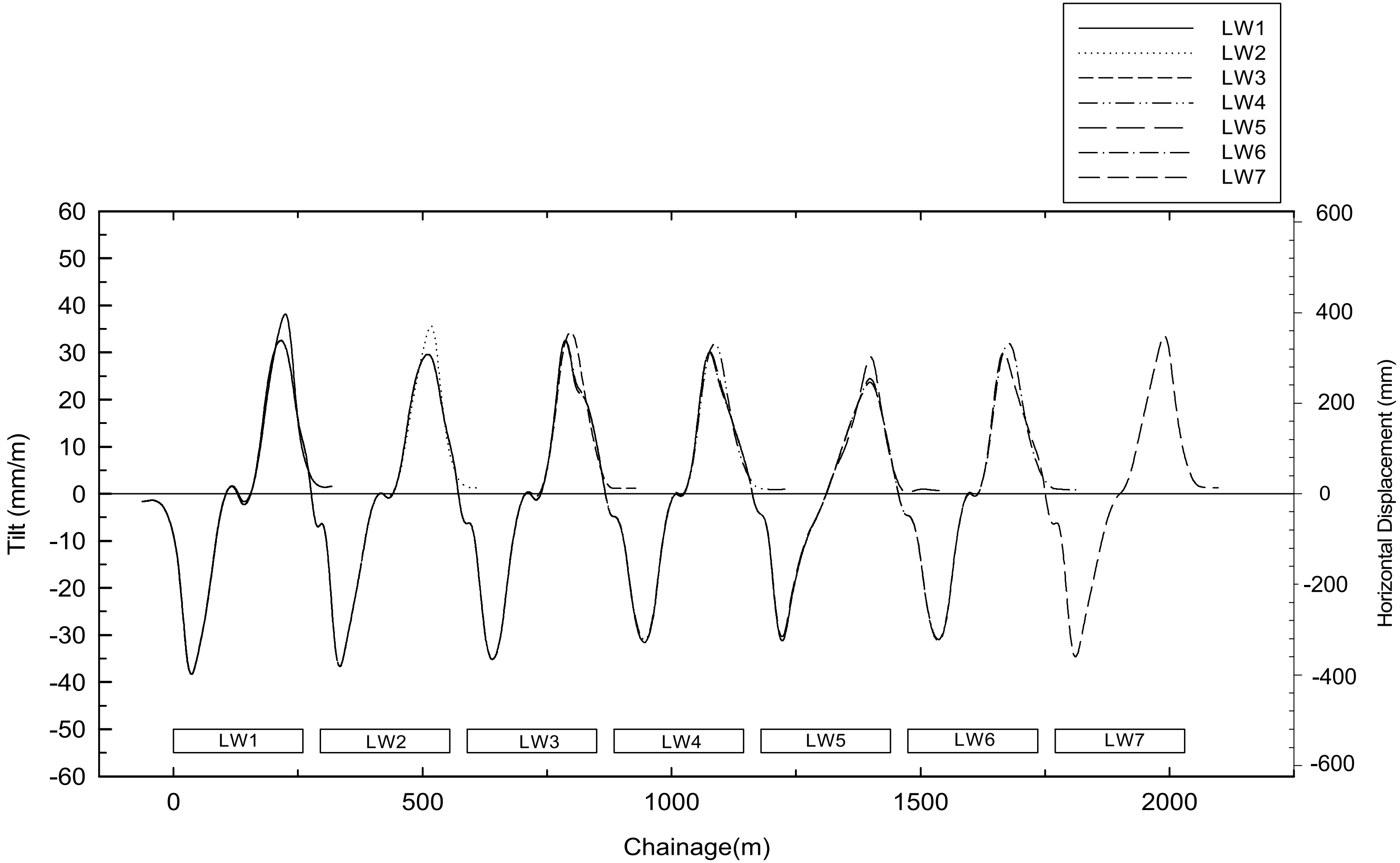


ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	12/12/2005	TITLE:	Empirical Prediction Model for Angle of Draw Outside Longwall Panel Sides, Ends and Corners	FIGURE: 10.4
SCALE:	NTS			



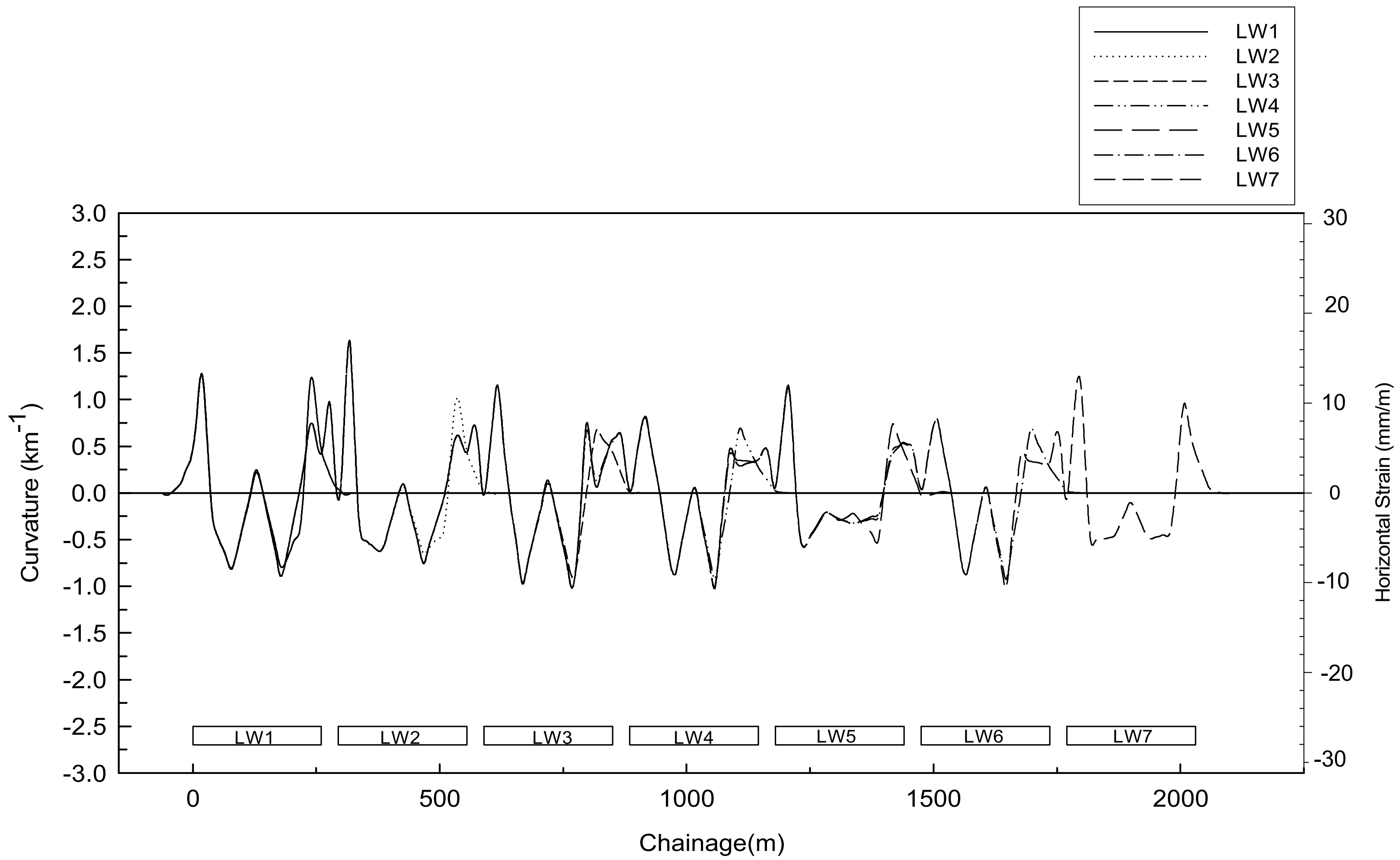
Note: The predicted profiles are for 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First and Final Subsidence Profiles (U95%) at XL1, LW1 to LW7	FIGURE: 11.1
SCALE:	As Shown			



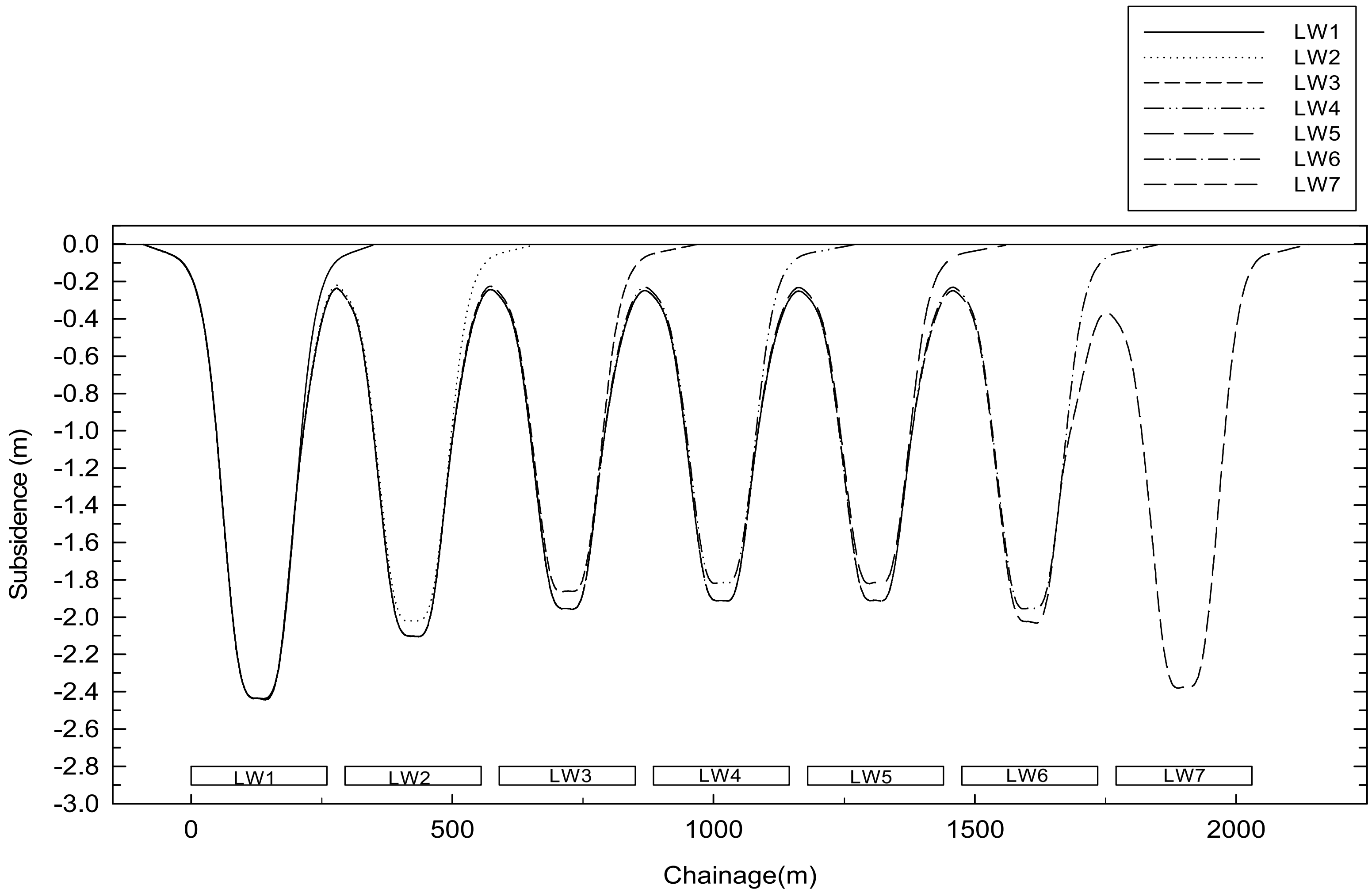
Note: The predicted profiles are for the CWC 'smooth' subsidence profiles (refer to text).

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First & Final Tilt & Horizontal Displacement Profiles at XL1 above LWs 1 to 7	FIGURE: 11.2
SCALE:	As Shown			



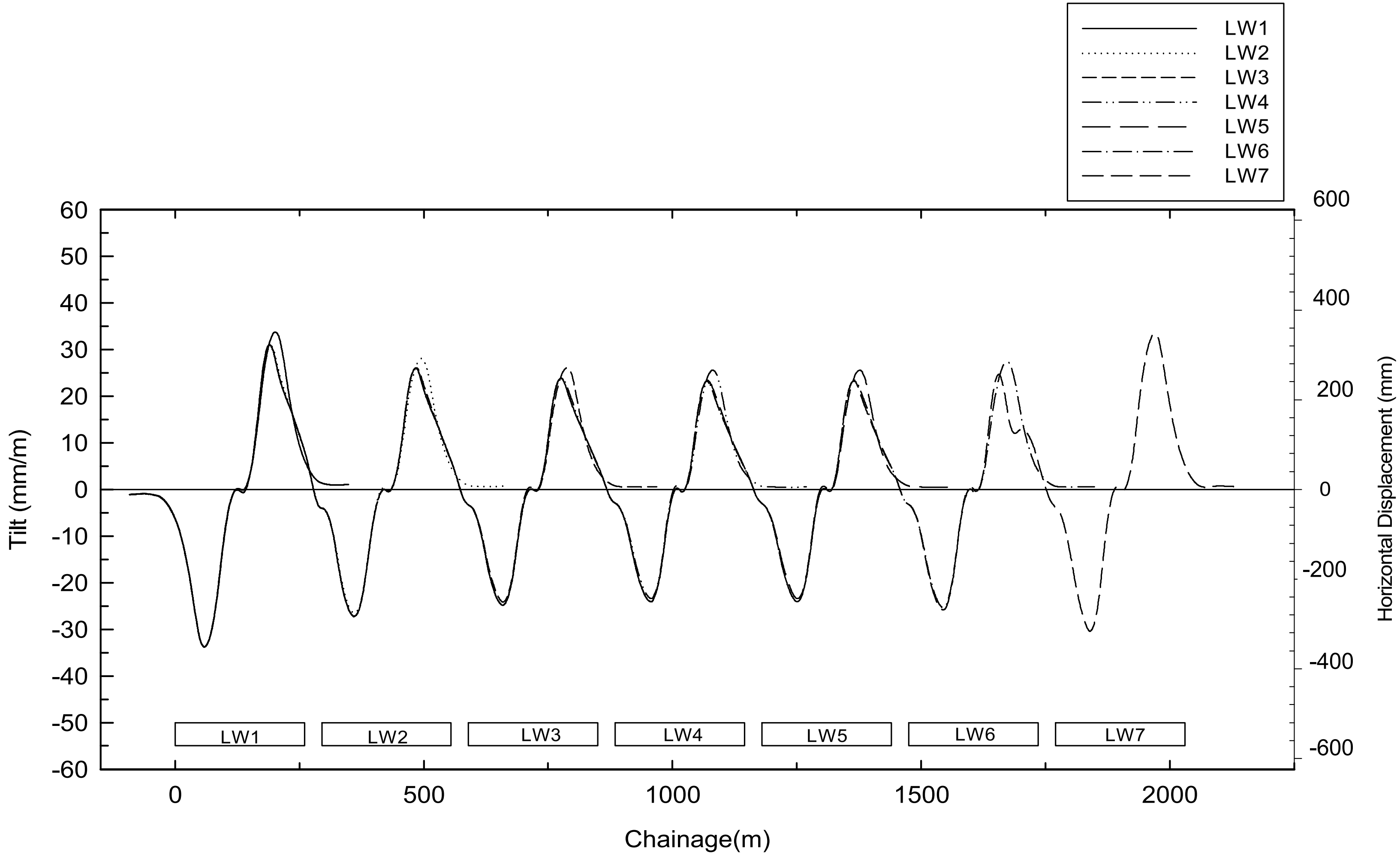
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	J.Jiang		R04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.02.06	TITLE:	Predicted First & Final Curvature & Strain	FIGURE
SCALE:	As Shown		Profiles at XL1 above LWs 1 to 7	11.3



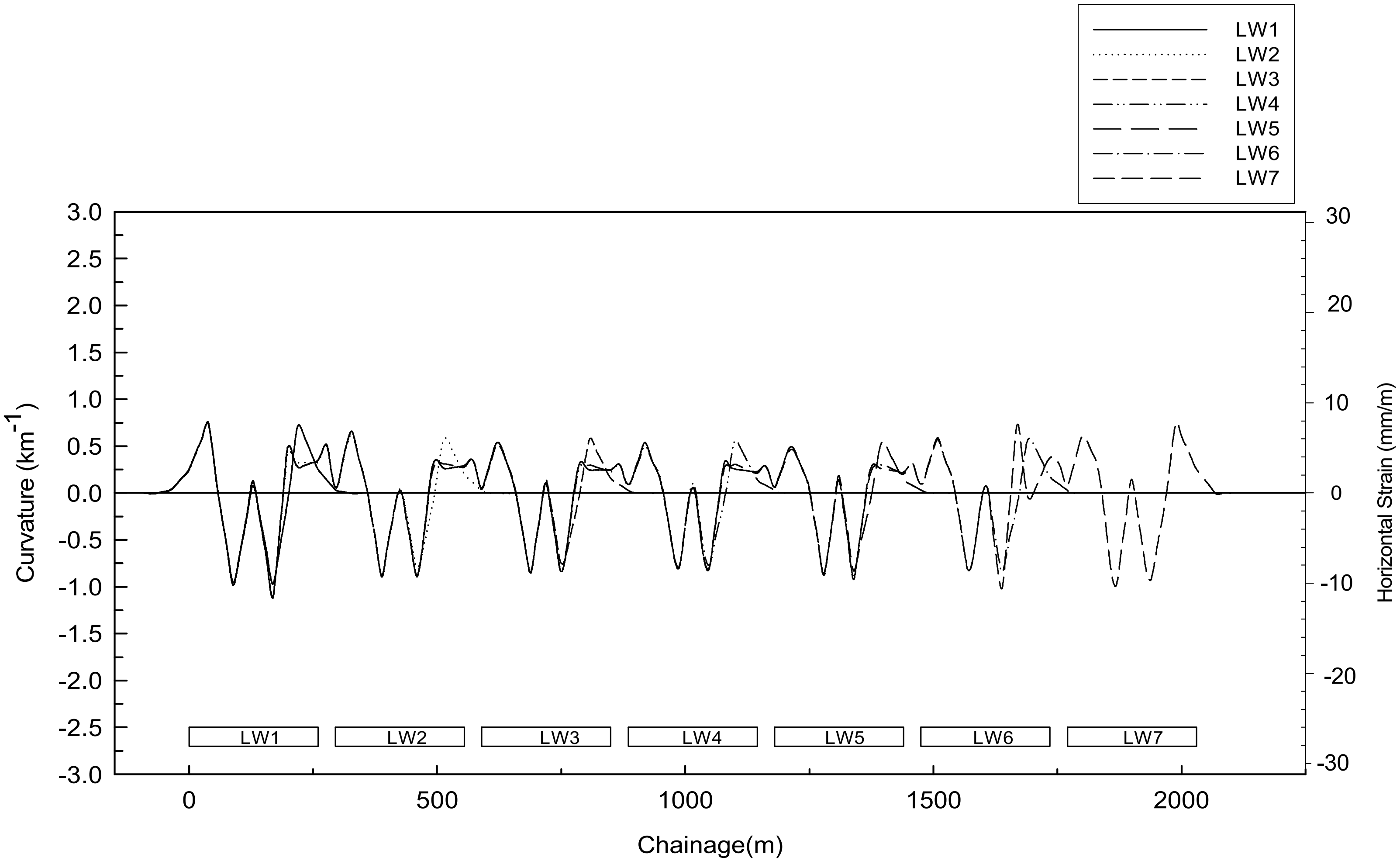
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First and Final Subsidence Profiles at XL4, LW1 to LW7	FIGURE 11.4
SCALE:	As Shown			



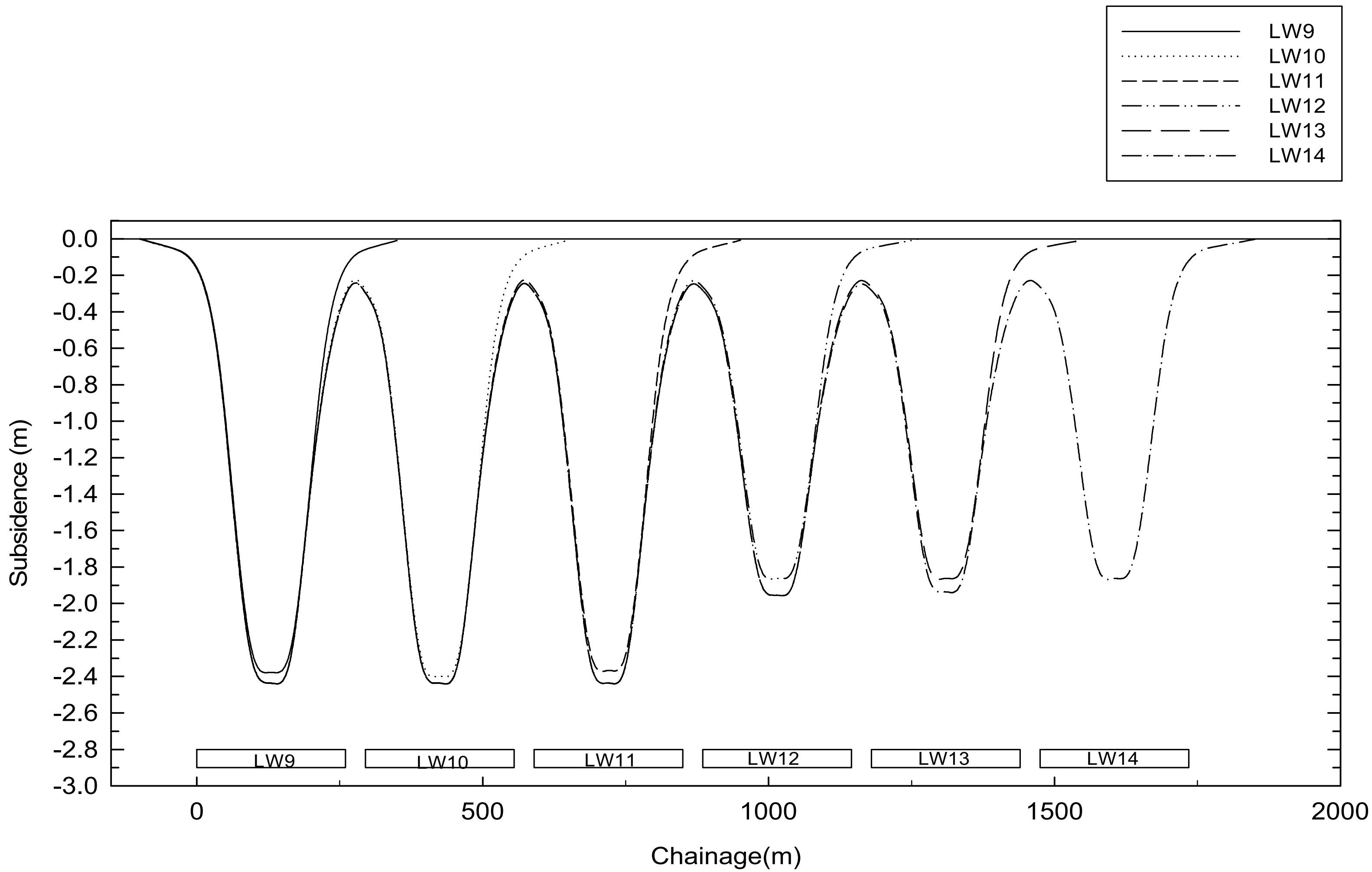
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First & Final Tilt & Horizontal Displacement Profiles at XL4, LW1 to LW7	FIGURE 11.5
SCALE:	As Shown			



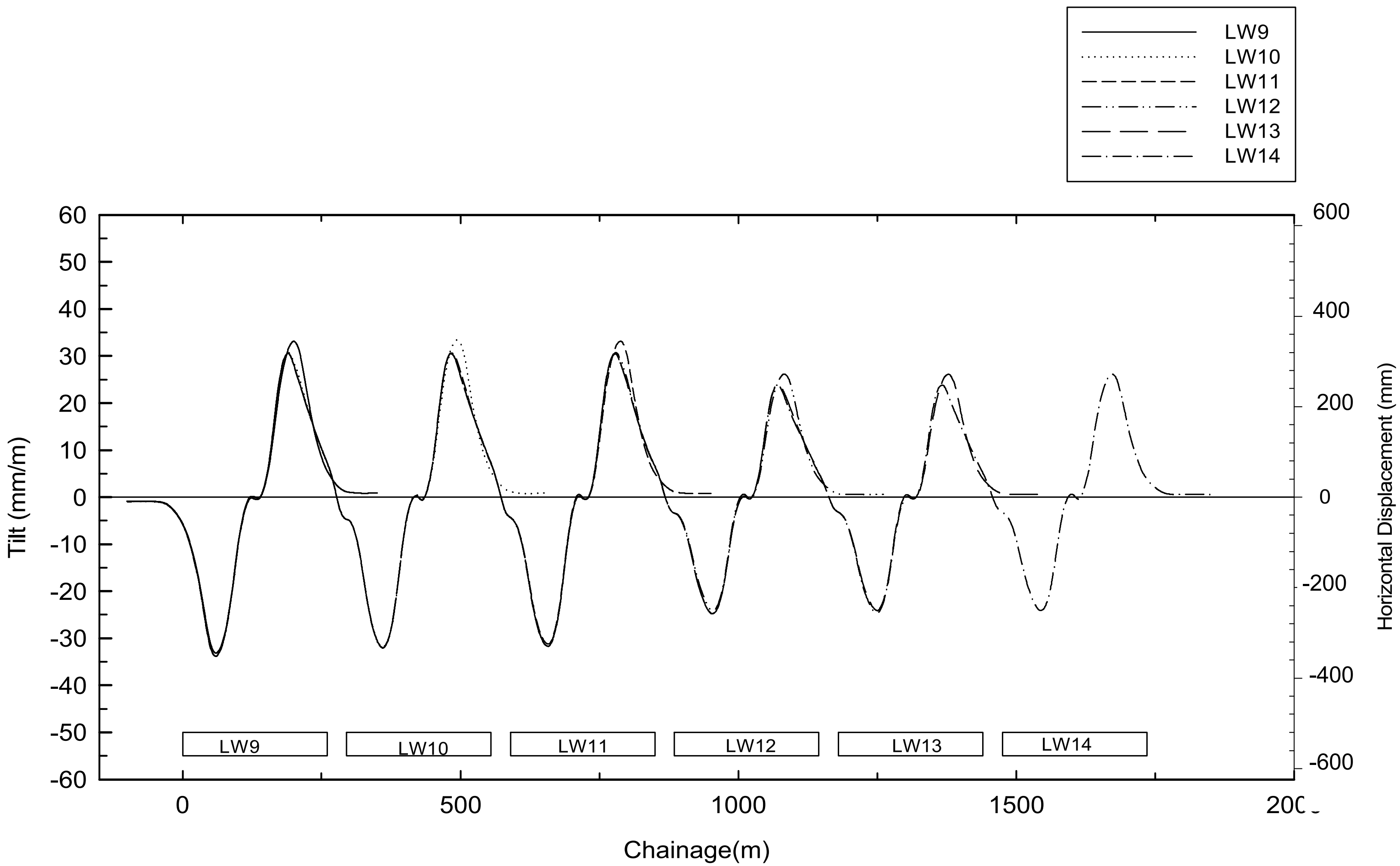
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First & Final Curvature & Strain	FIGURE
SCALE:	As Shown		Profiles at XL4, LW1 to LW7	11.6



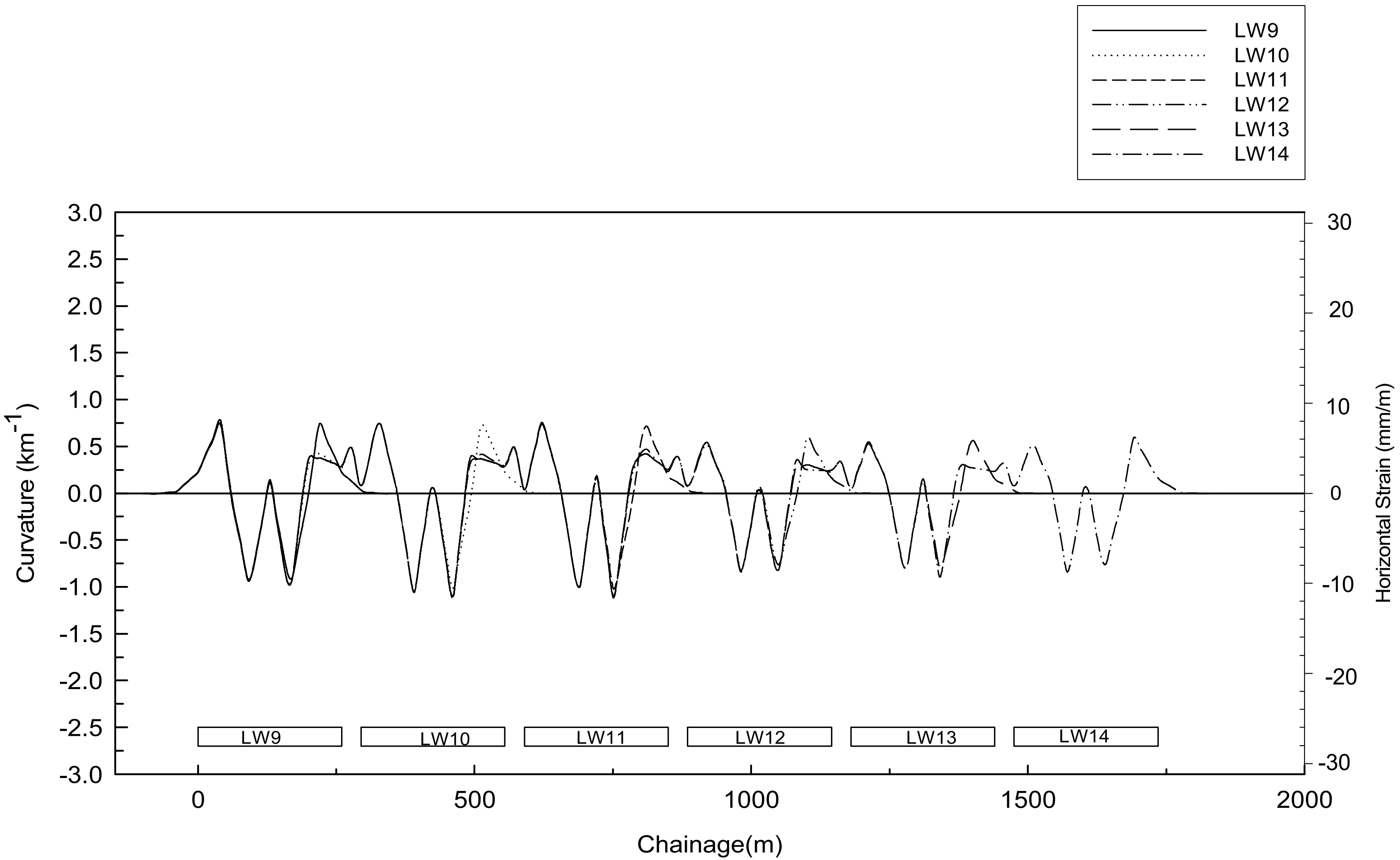
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First and Final Subsidence Profiles at XL7, LW9 to LW14	FIGURE:
SCALE:	As Shown			11.7



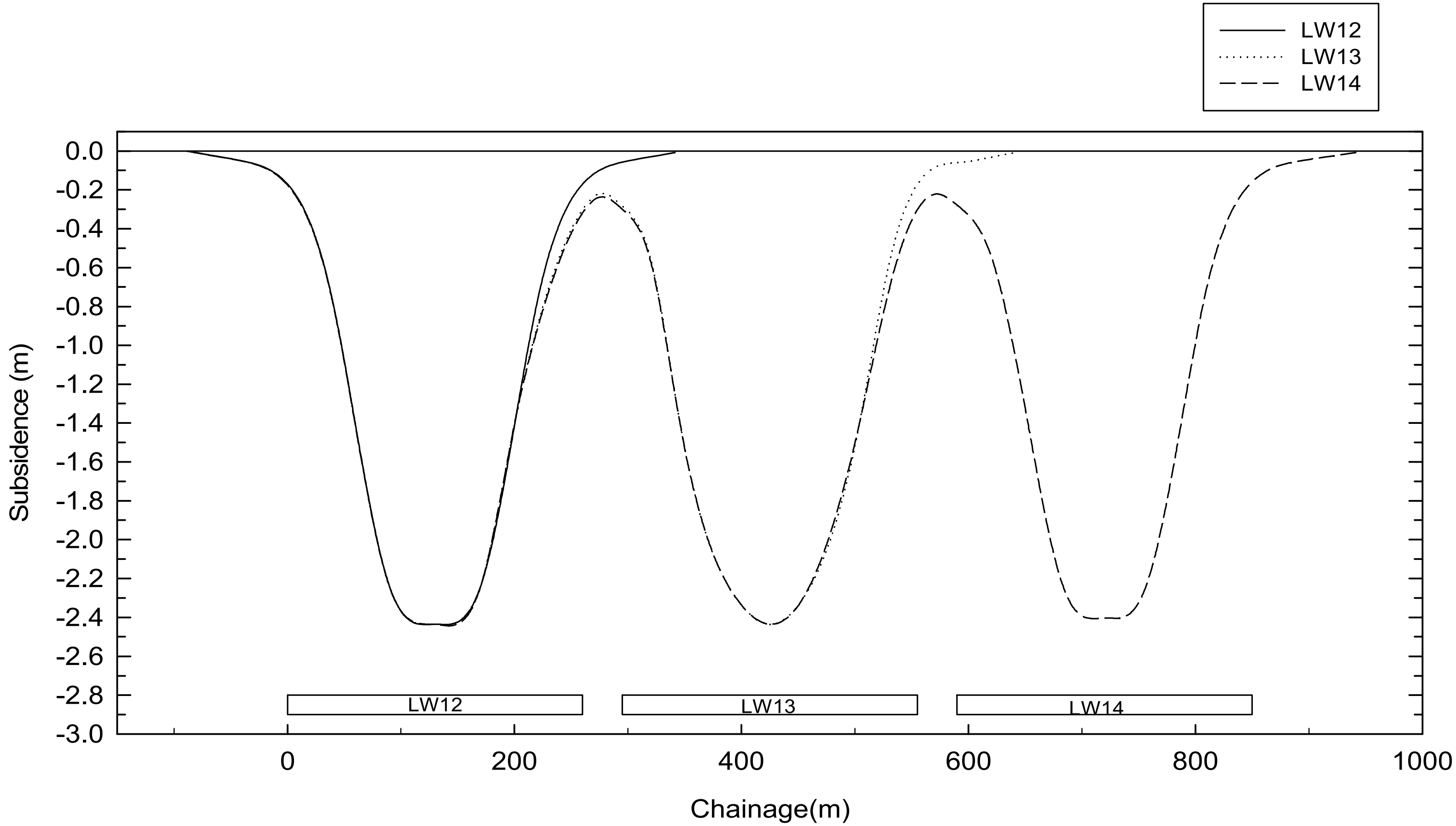
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**	
DRAWN:	J.Jiang		R04-001-WHT/1		
DATE:	07.02.06	TITLE:	Predicted First & Final Tilt & Horizontal Displacement Profiles at XL7, LW9 to LW14		FIGURE 11.8
SCALE:	As Shown				



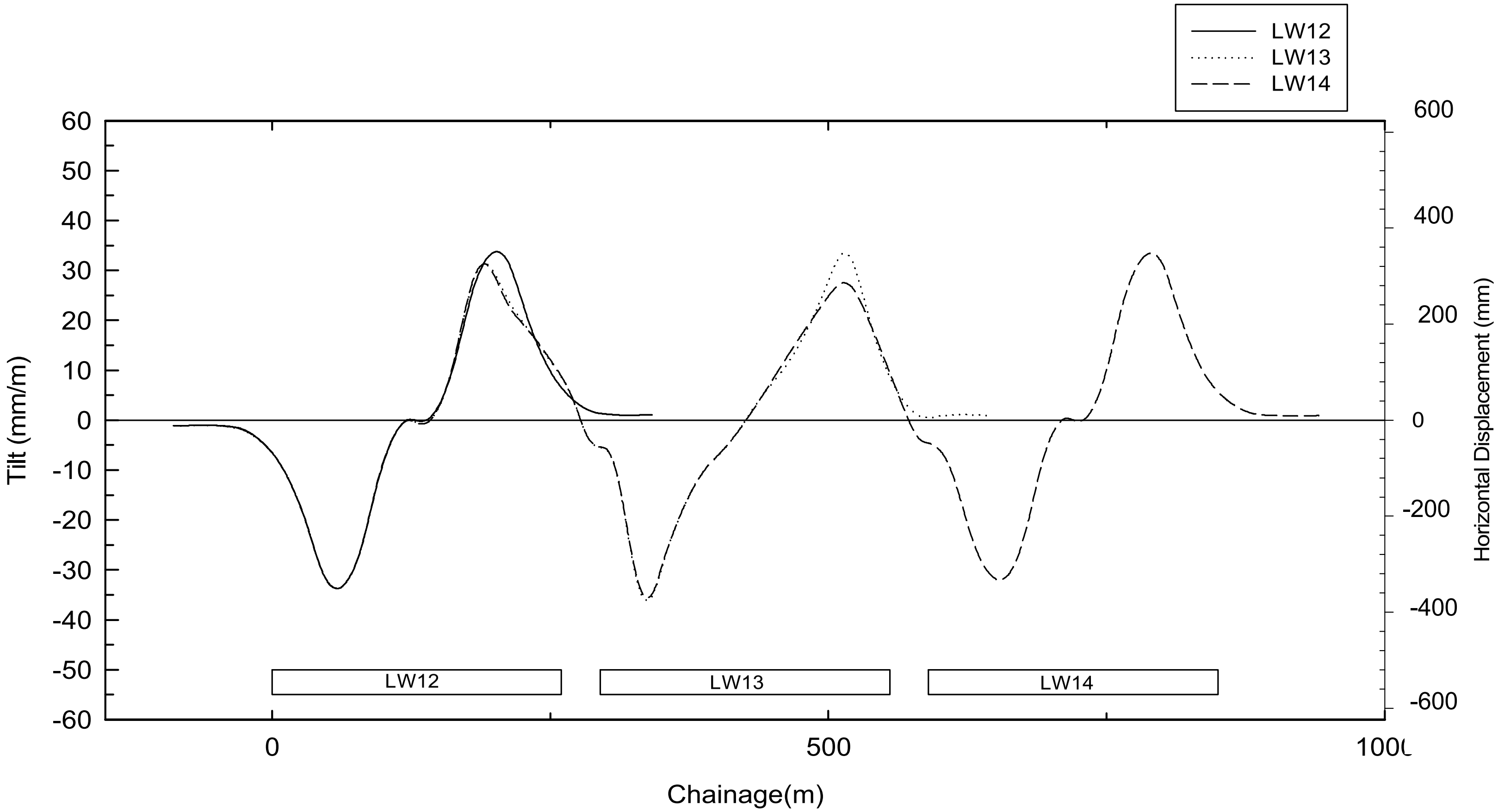
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First & Final Curvature & Strain	FIGURE
SCALE:	As Shown		Profiles at XL7, LW9 to LW14	11.9



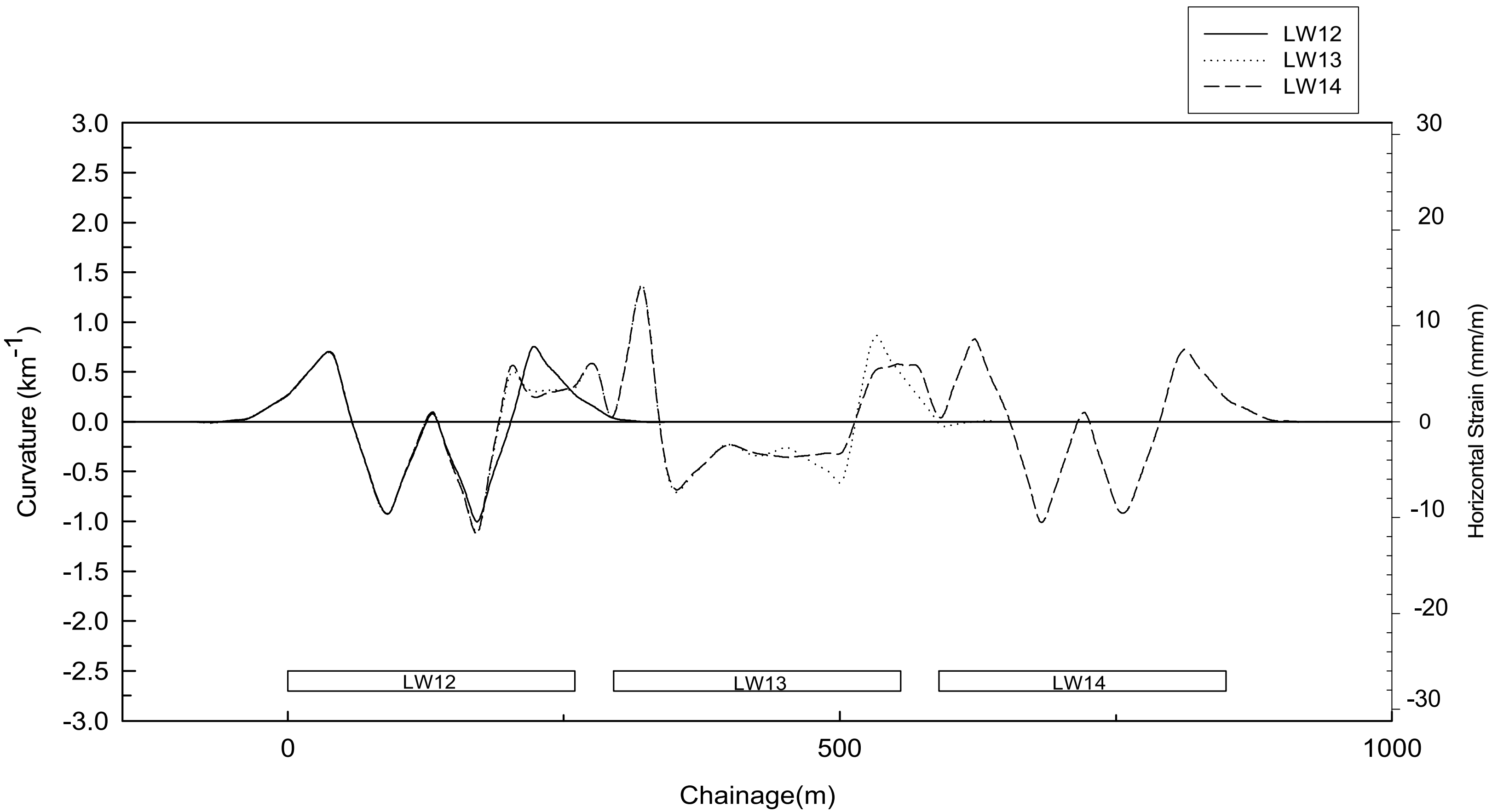
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First and Final Subsidence Profiles at XL10, LW12 to LW14	FIGURE: 11.10
SCALE:	As Shown			



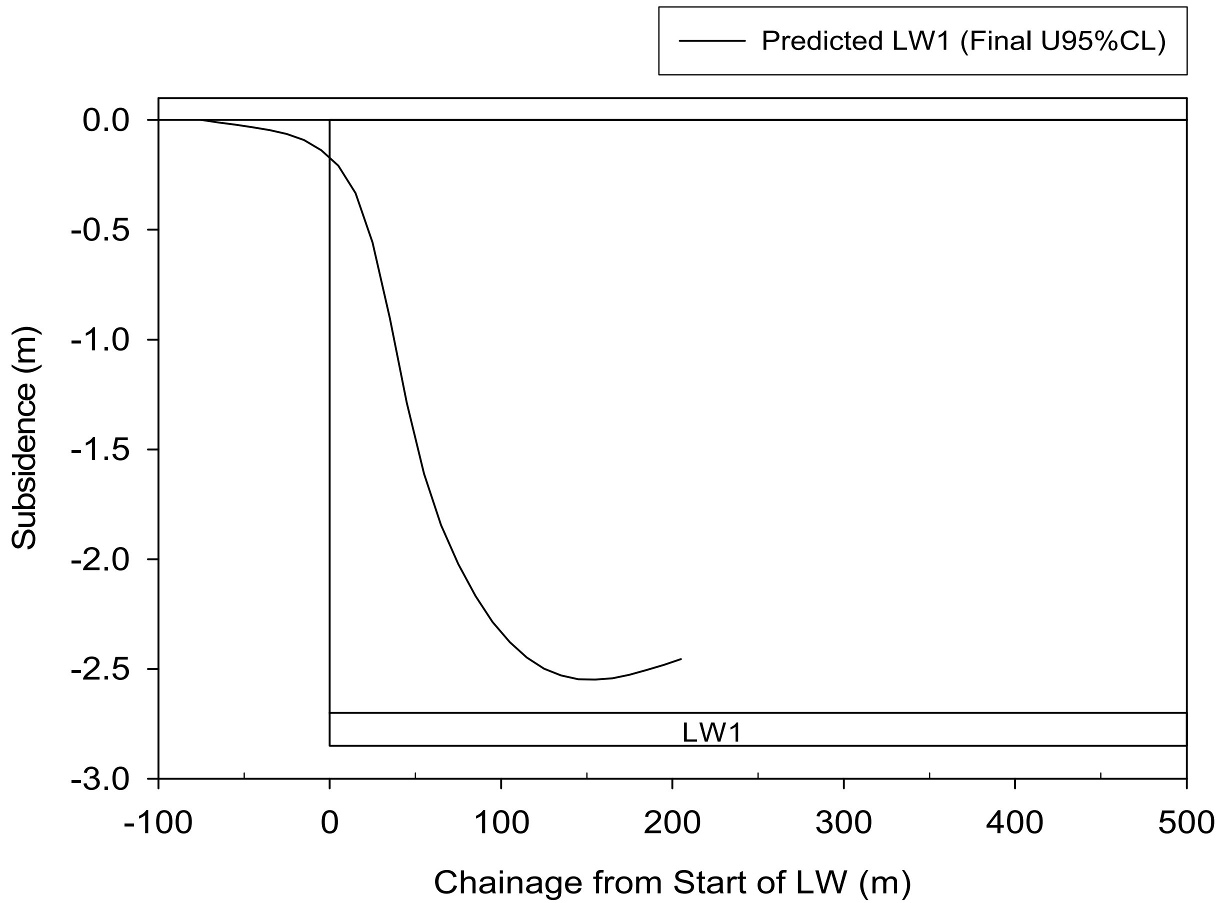
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**	
DRAWN:	J.Jiang		R04-001-WHT/1		
DATE:	07.02.06	TITLE:	Predicted First & Final Tilt & Horizontal Displacement Profiles at XL10, LW12 to LW14		FIGURE 11.11
SCALE:	As Shown				



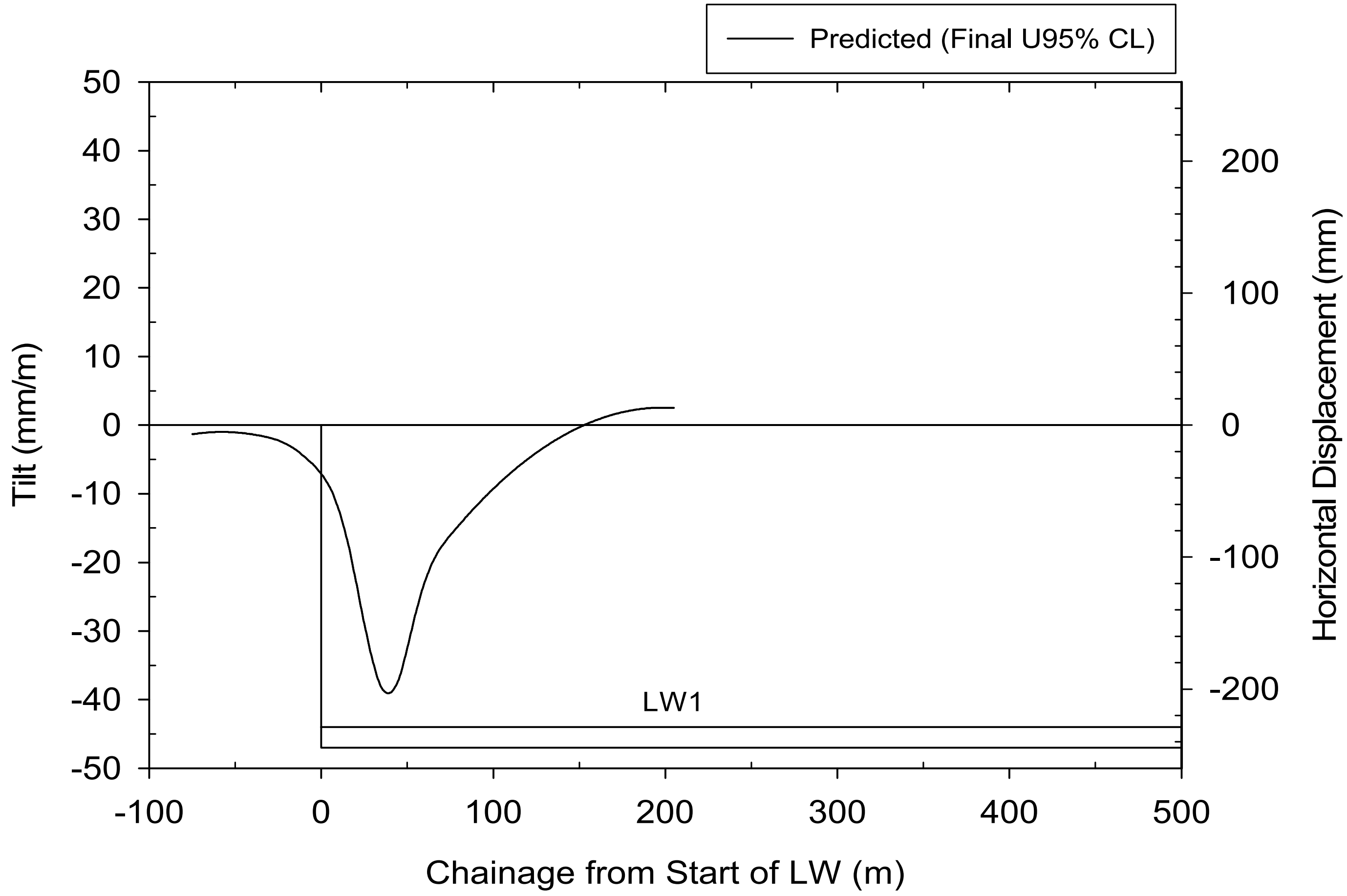
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	STRATA ENGINEERING (Australia) Pty Ltd
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted First & Final Curvature & Strain	FIGURE:
SCALE:	As Shown		Profiles at XL10, LW12 to LW14	11.12



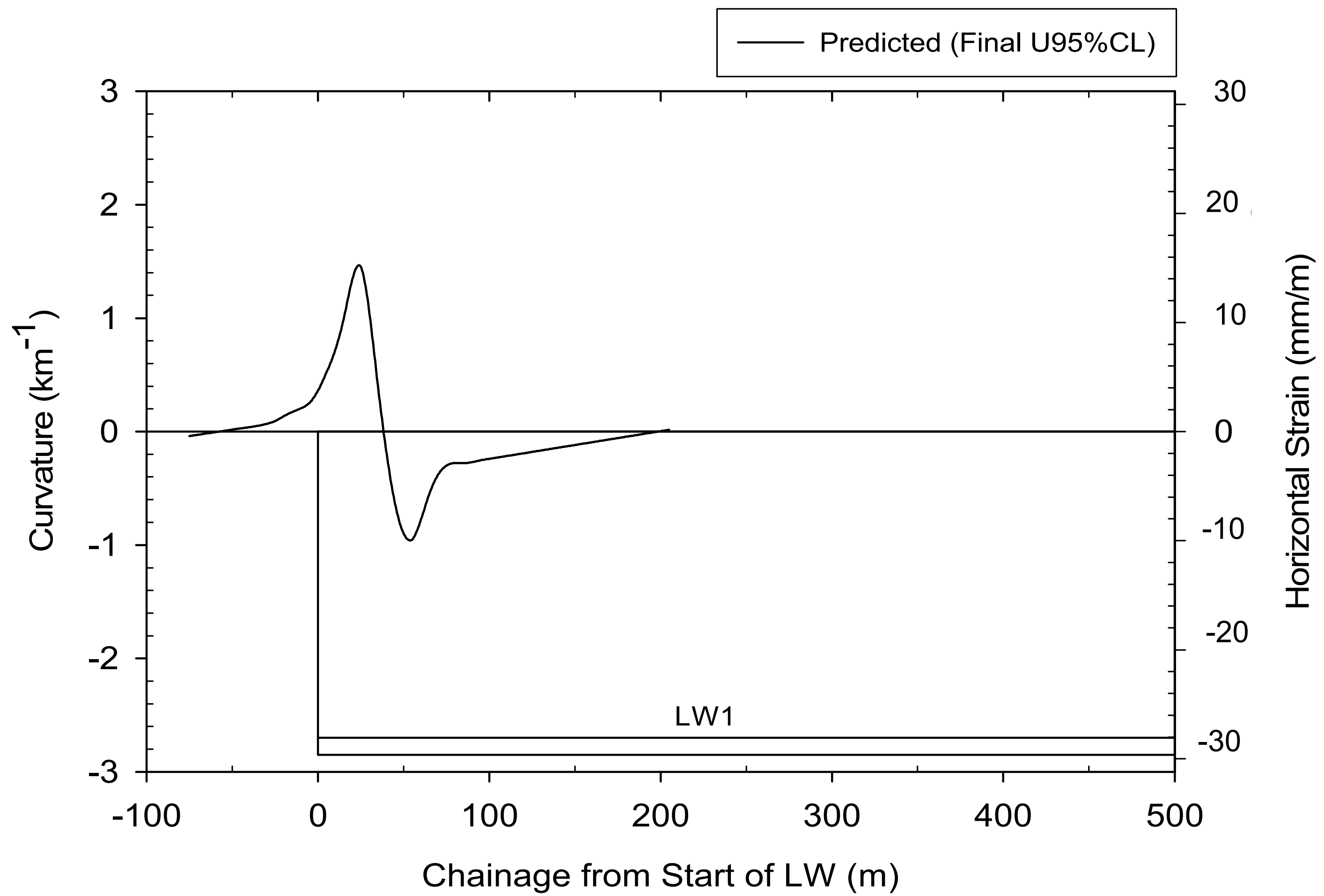
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	S,Ditton	CLIENT:	Moolarben Coal Mines Pty Ltd	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S,Ditton		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted Final Subsidence Profiles at Start of LW1	FIGURE 11.13
SCALE:	As Shown			



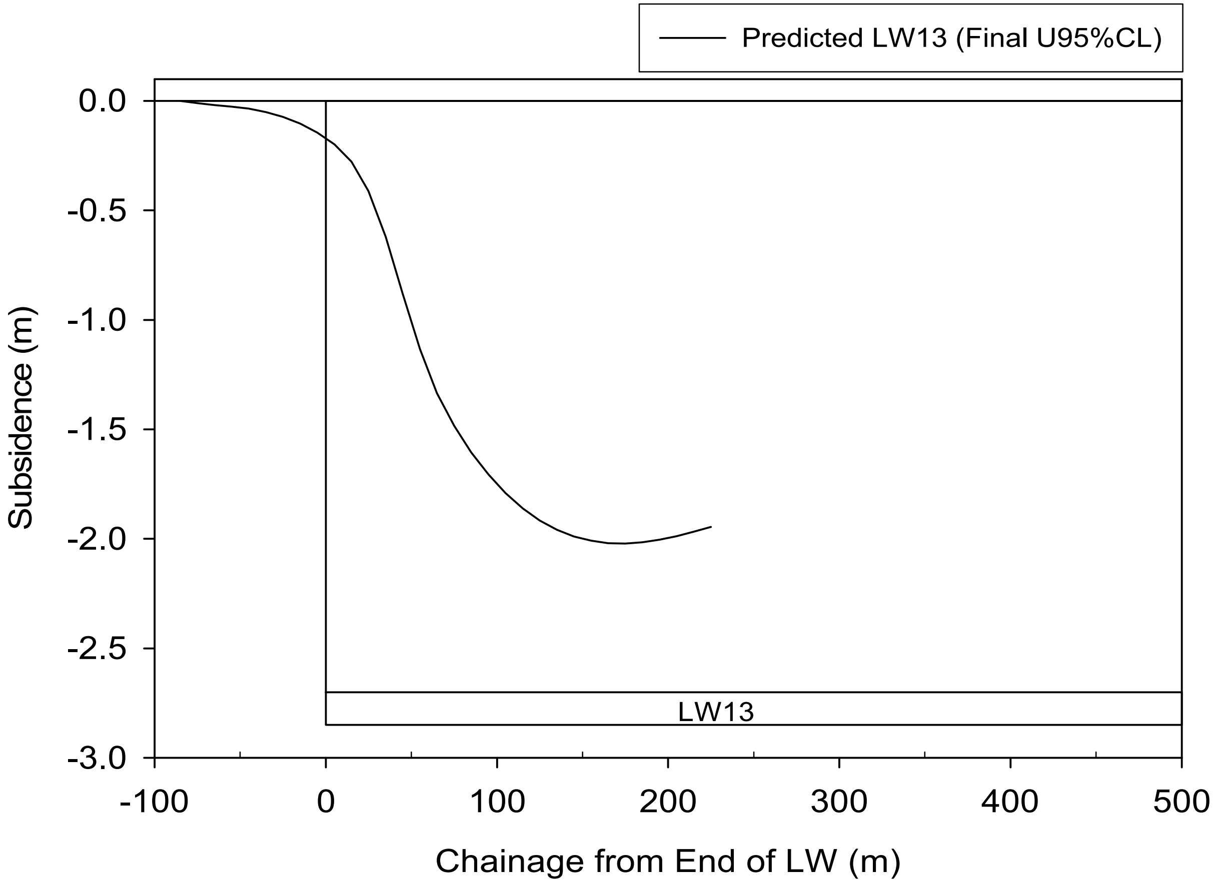
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	S,Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted Final Tilt and Horizontal Displacement Profiles at Start of LW1	FIGURE 11.14
SCALE:	As Shown			



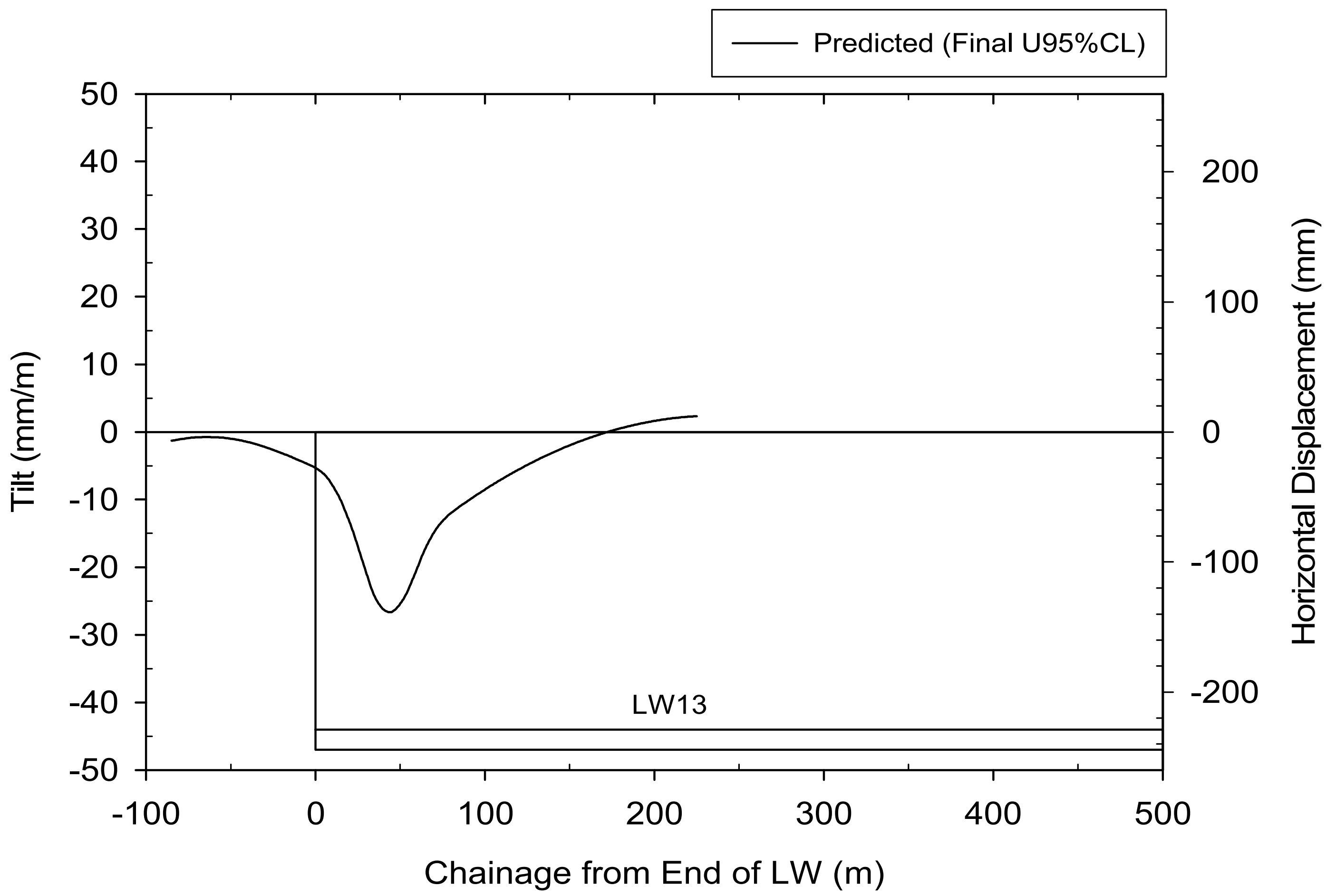
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	S,Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S,Ditton		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted Final Curvature and Horizontal Strain Profiles at Start of LW1	FIGURE 11.15
SCALE:	As Shown			



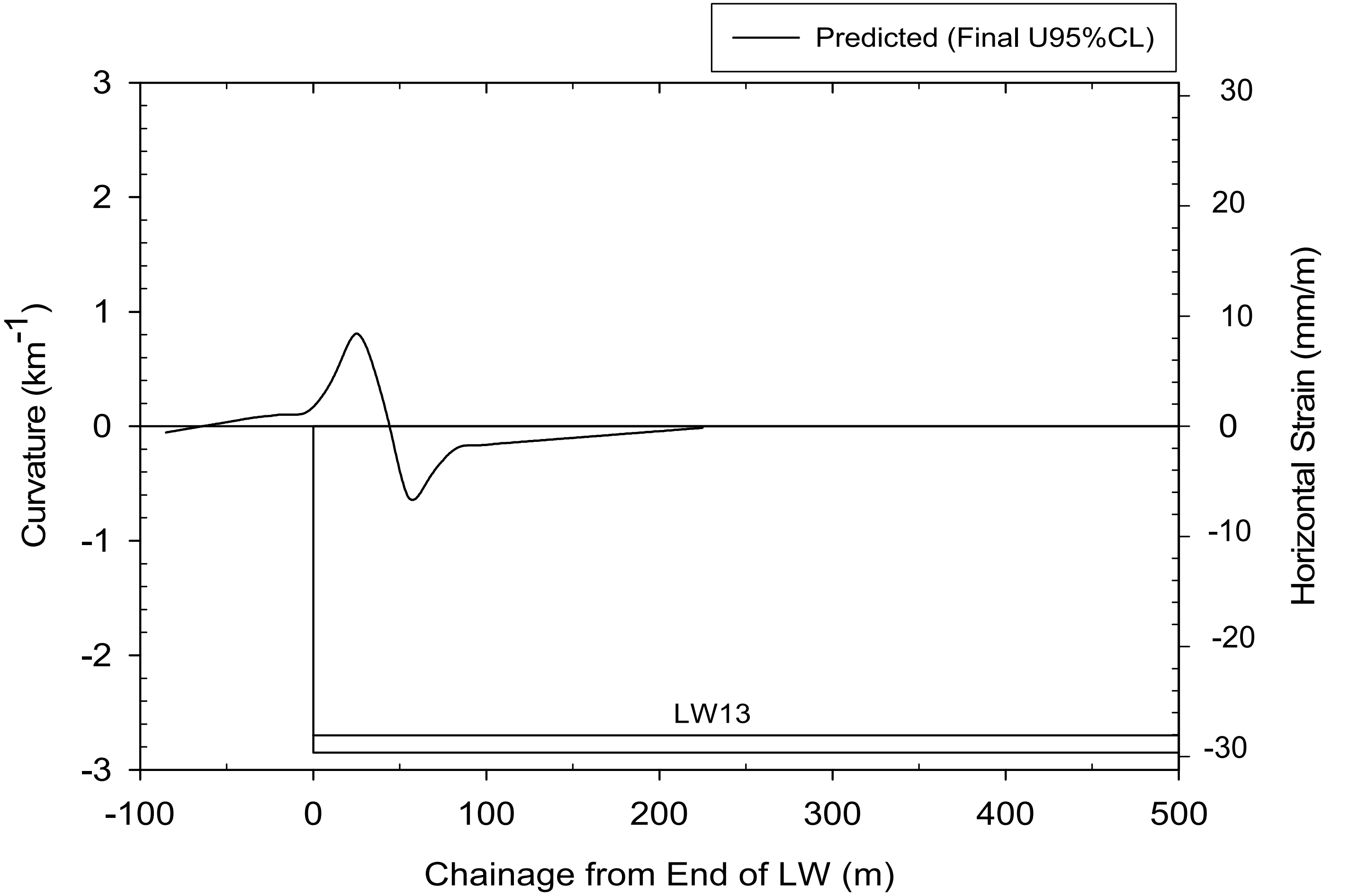
Note: The predicted profiles are for CWC 'smooth' subsidence profiles (refer to text)

ENGINEER:	S,Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S,Ditton		04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.02.06	TITLE:	Predicted Final Subsidence Profiles	FIGURE
SCALE:	As Shown		at Finish of LW13	11.16



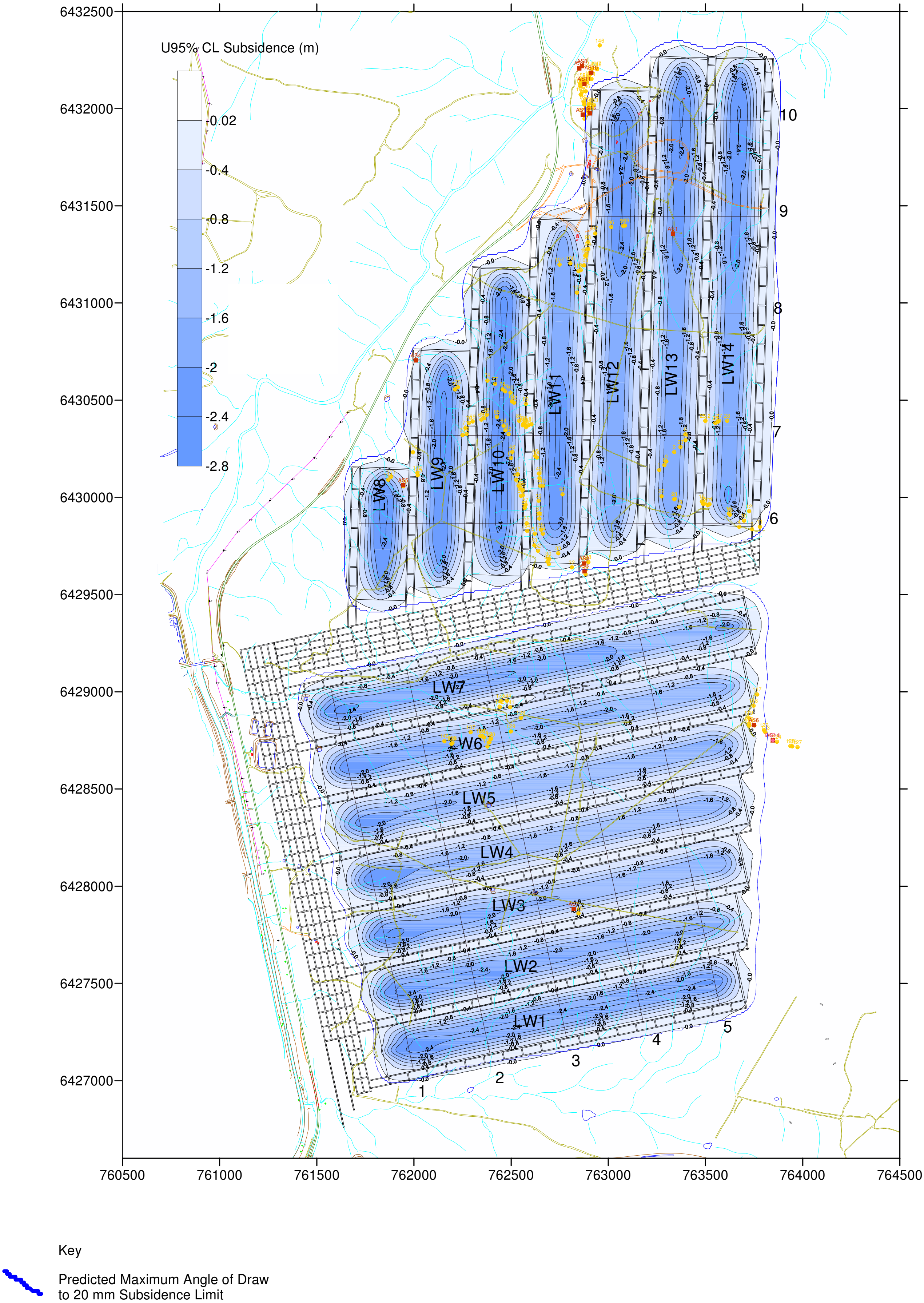
Note: The predicted profiles are for 'smooth' subsidence profiles (refer to text)

ENGINEER:	S,Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S,Ditton		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted Final Tilt and Horizontal Displacement Profiles (U95%) at XL6, LW13	FIGURE 11.17
SCALE:	As Shown			

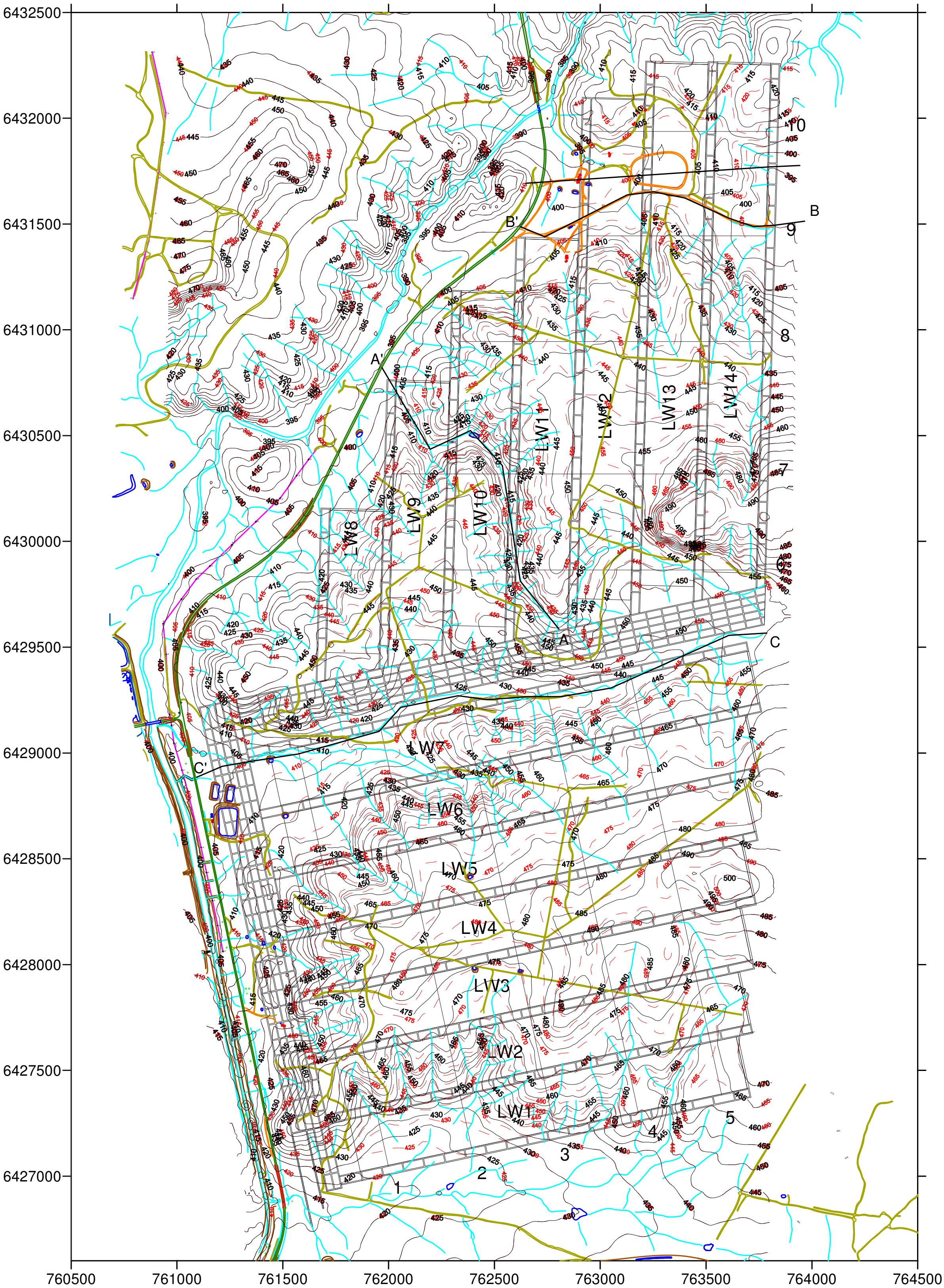


Note: The predicted profiles are for 'smooth' subsidence profiles (refer to text)

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	07.02.06	TITLE:	Predicted Final Curvature and Horizontal Strain Profiles at the Finish of LW13	FIGURE 11.18
SCALE:	As Shown			



Engineer:	Jin Jiang	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1		STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	Jin Jiang				
Date:	26.01.06	TITLE:	Predicted Upper 95% Confidence Limit Subsidence Contours for the Proposed Moolarben LWs 1-14		FIGURE 11.19
Scale:	1:2,000				



Key

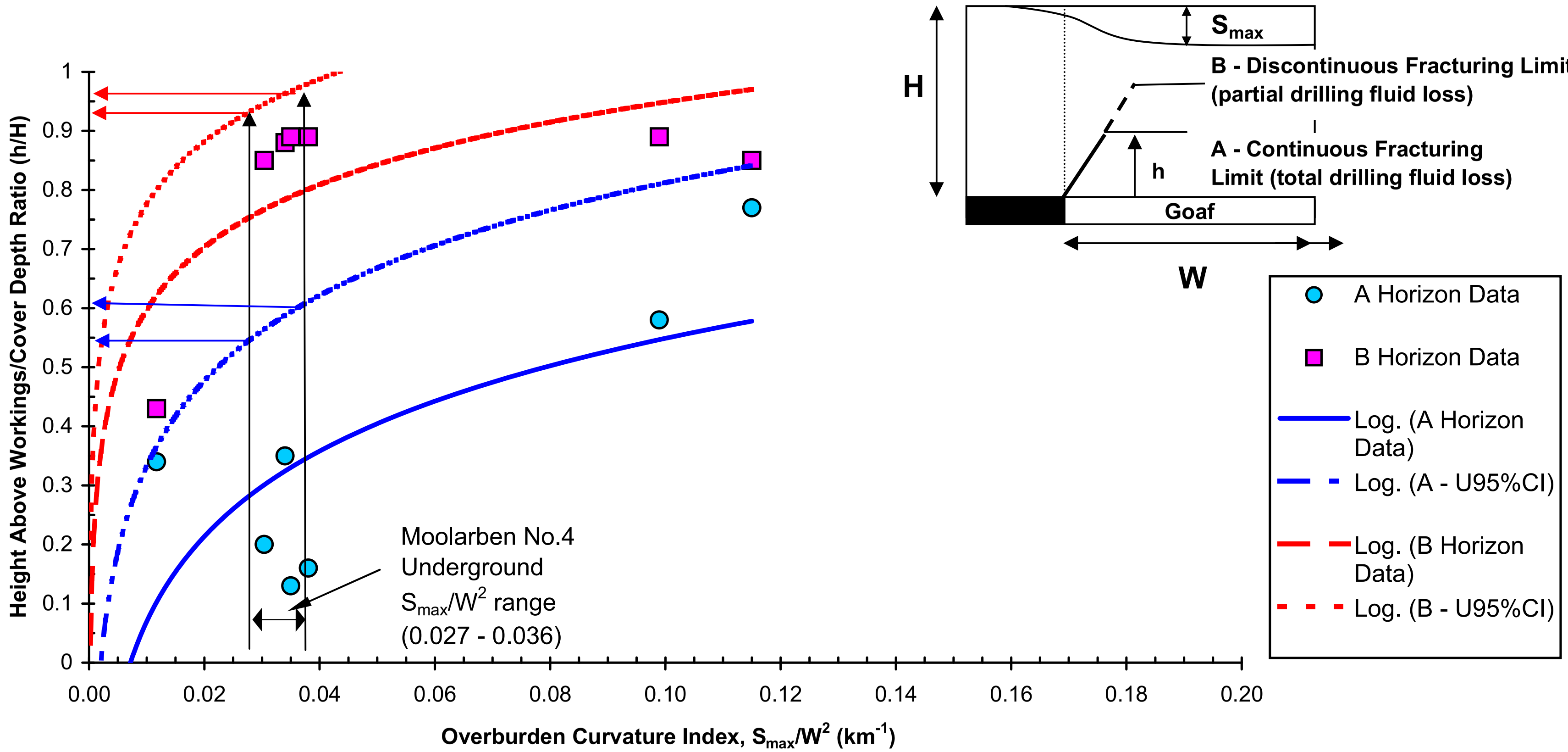
435 Pre-mining Surface Levels

435 Post-mining Surface Levels

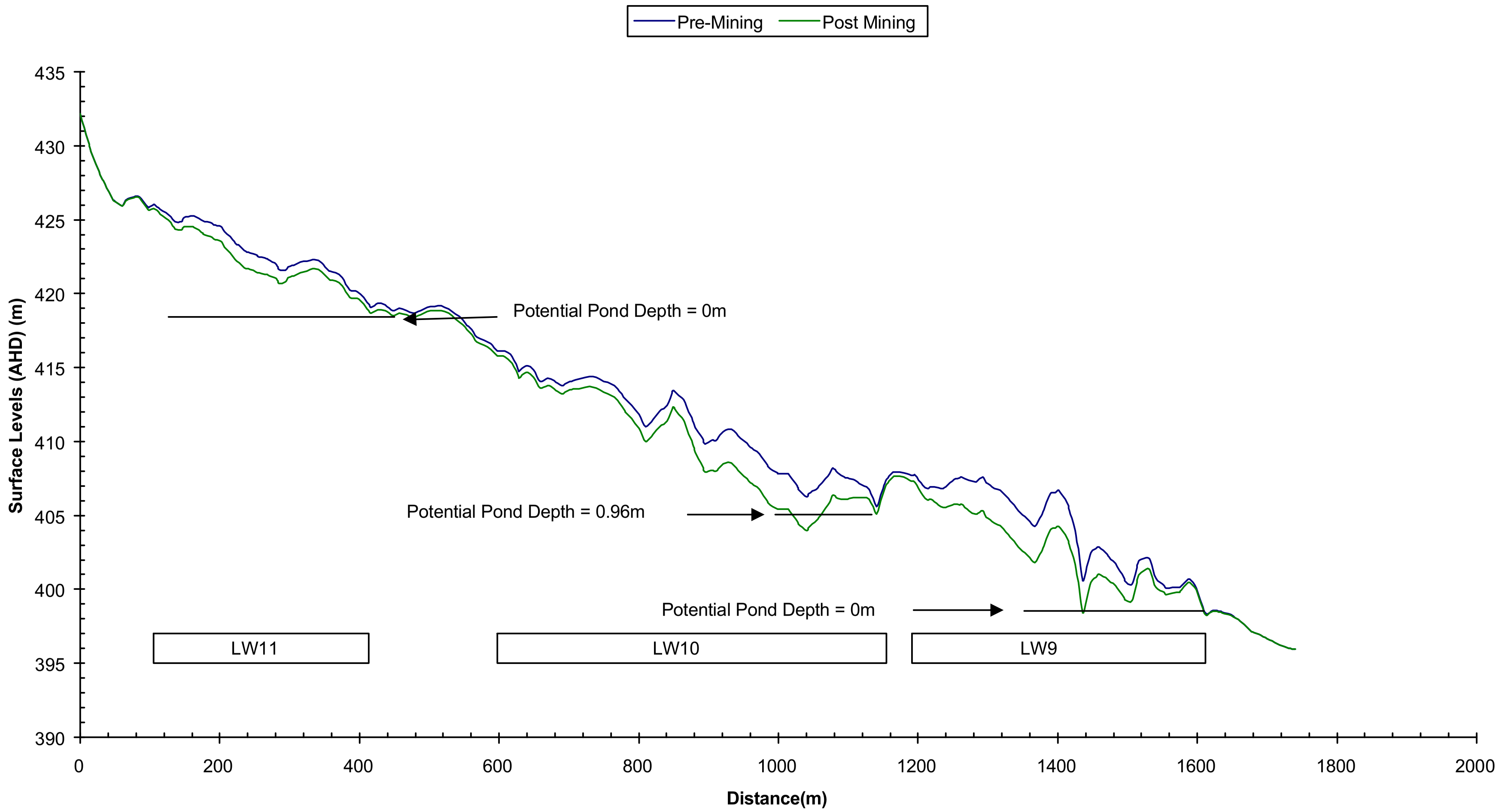
A' A Section

Potential Ponding Affected Area

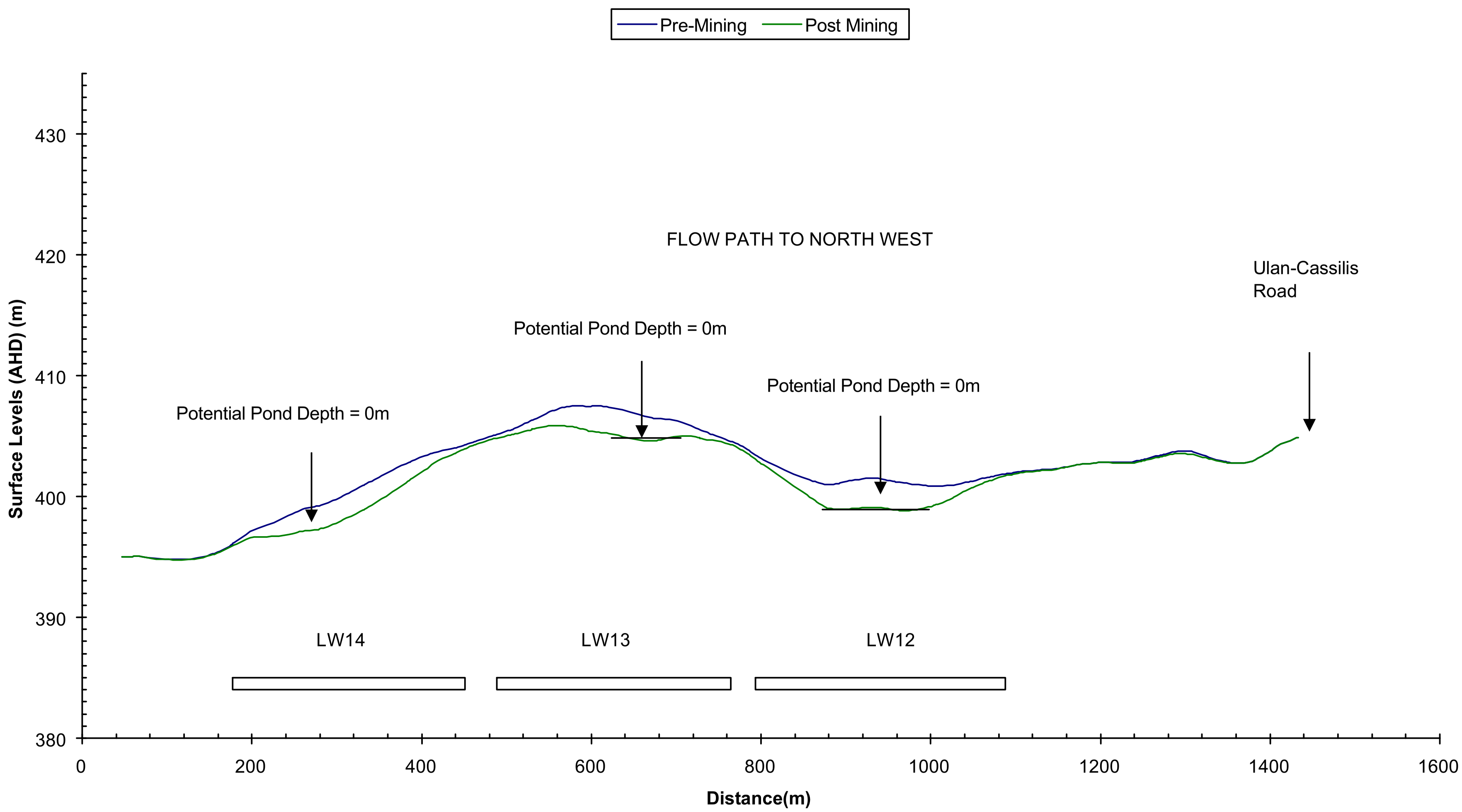
Engineer:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited R04-001-WHT/1	STRATA ENGINEERING (Australia) Pty Ltd
Drawn:	S. Ditton			
Date:	13.01.06	TITLE:	Pre-Mining and Predicted Post-Mining Surface Level Contours for No. 4 UG LWs1-14	FIGURE 11.20
Scale:	1:2,000			



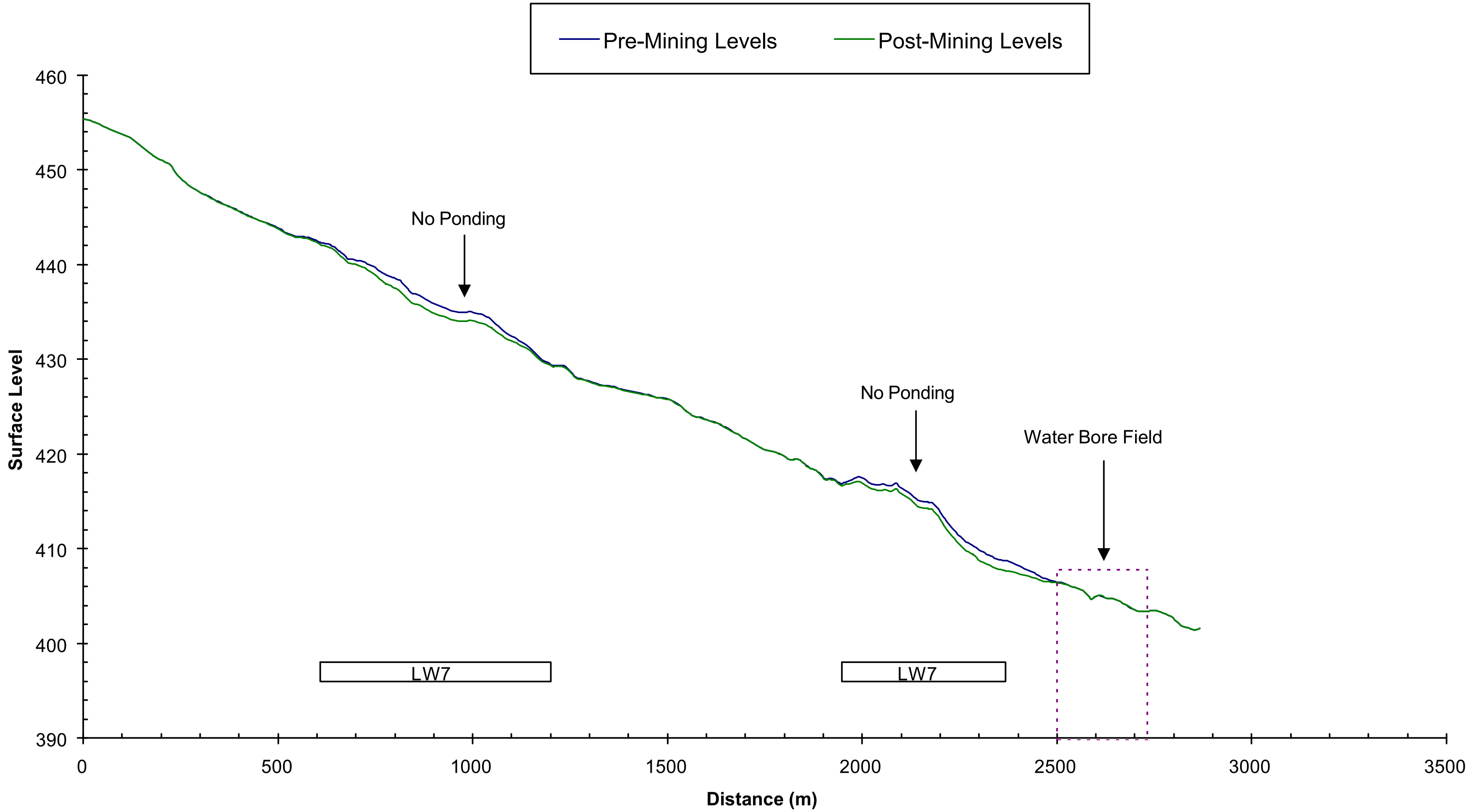
ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Empirical Subsurface Fracturing Prediction Model for NSW & QLD - Predictions for LWs 1 to14	FIGURE 12.1
SCALE:	NTS			



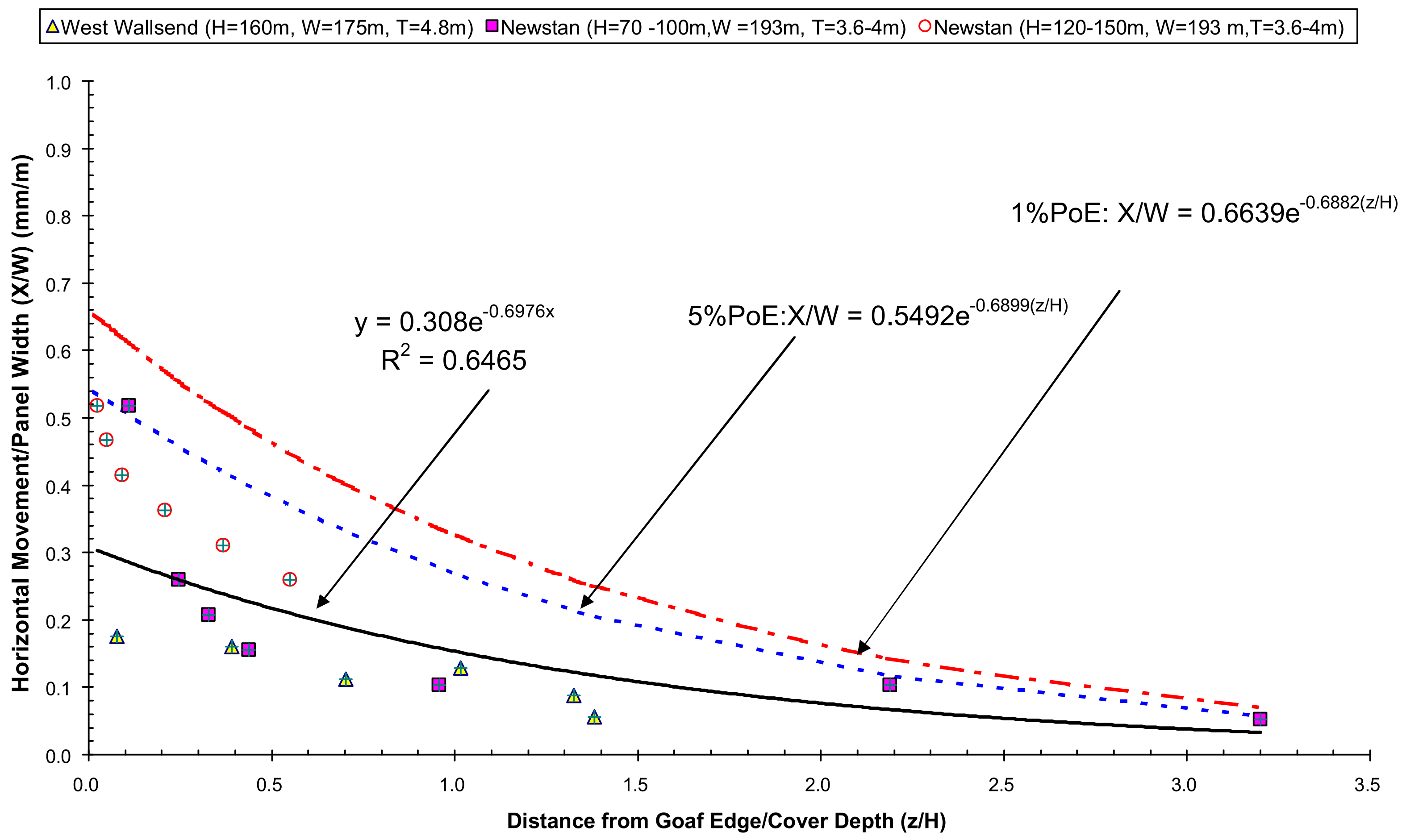
ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	STRATA ENGINEERING (Australia) Pty Ltd
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Pre and Post Mining Surface Levels along Section A-A' Northern Region Water Course (Refer Figure 11.20)	FIGURE 12.2
SCALE:	NTS			



ENGINEER:	J.Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Pre and Post Mining Surface Levels Along Section B-B'	FIGURE
SCALE:	NTS		Imrie-Mullins Access Road (Refer Figure 11.20)	12.3

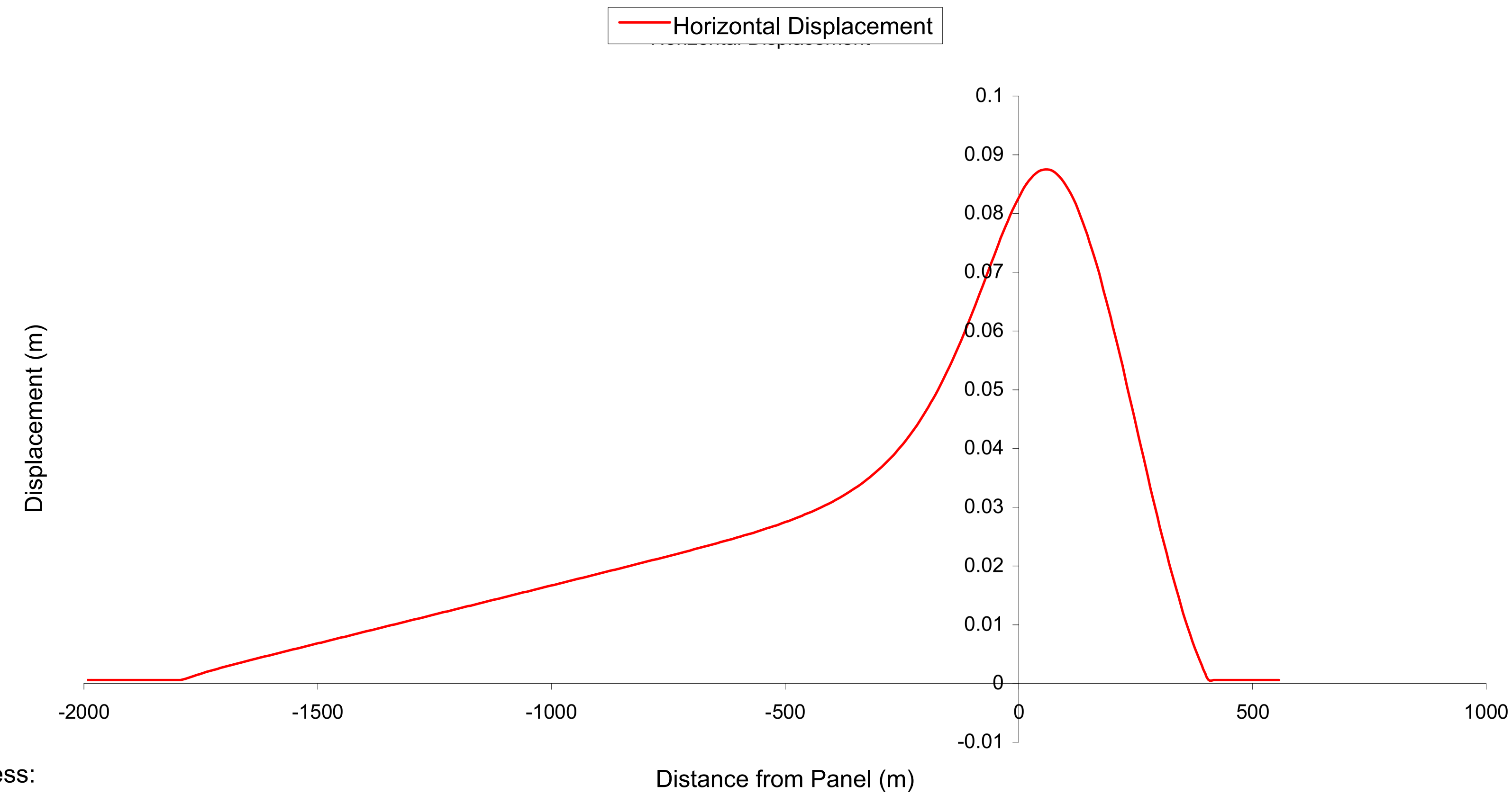


ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Pre and Post Mining Surface Levels along Section C-C' East-West Water Course (Refer Figure 11.20)	FIGURE 12.4
SCALE:	NTS			



Note: Model assumes movement in direction of extraction, however some out-of-plane movement may also occur due to regional stress field.

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		R04-001-WHT/1	
DATE:	25/01/2006	TITLE:	Measured Far-Field Horizontal Movement Data Outside LW Panel Ends (Normalised to Key Mining Geometry)	FIGURE: 12.5
SCALE:	NTS			



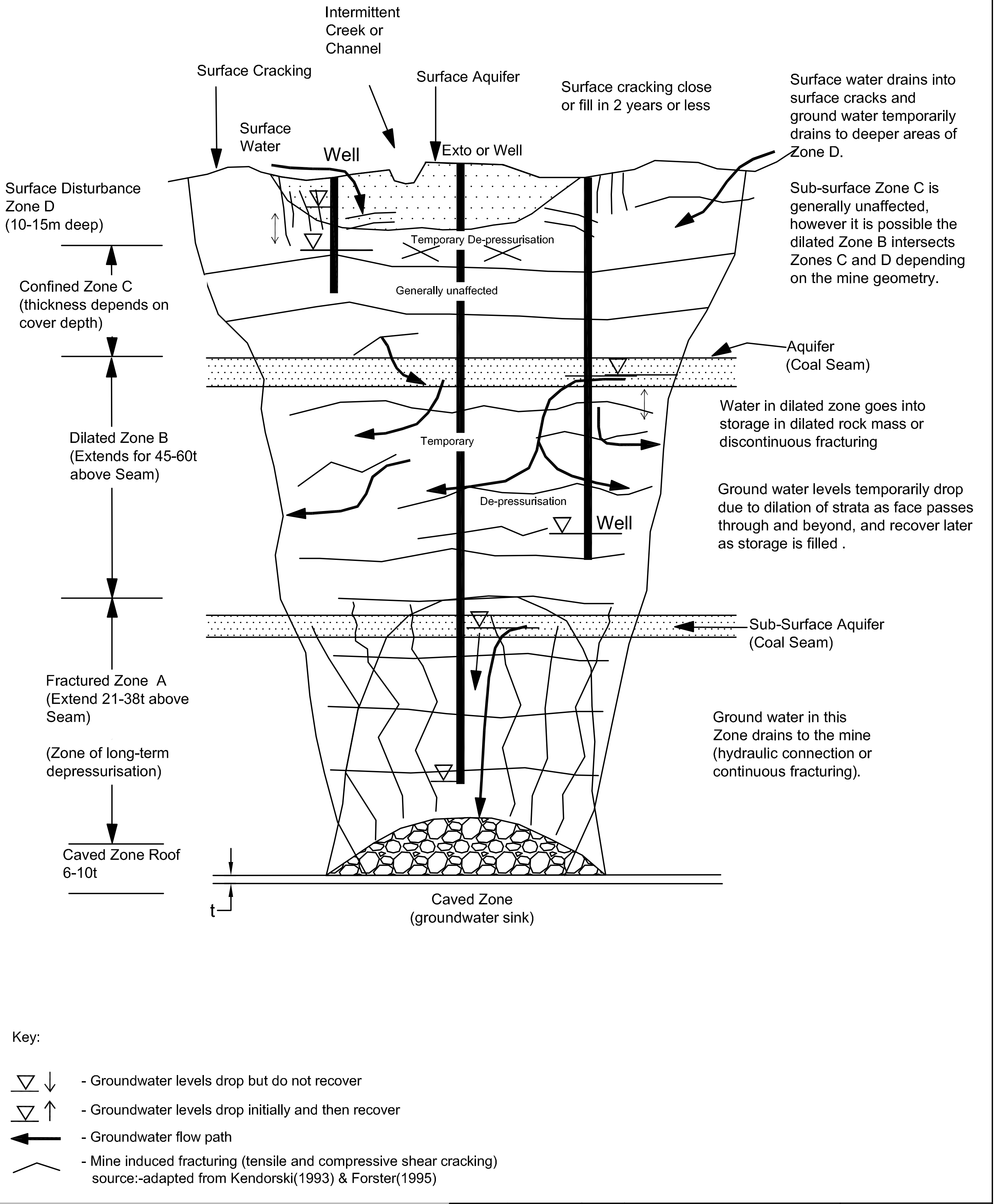
In-situ Stress:
Sigma 1 = 10 MPa,
Sigma 2 =6 MPa
Sigma 3 = 4 MPa

E sandstone = 10 GPa
E Mudstone = 5 GPa

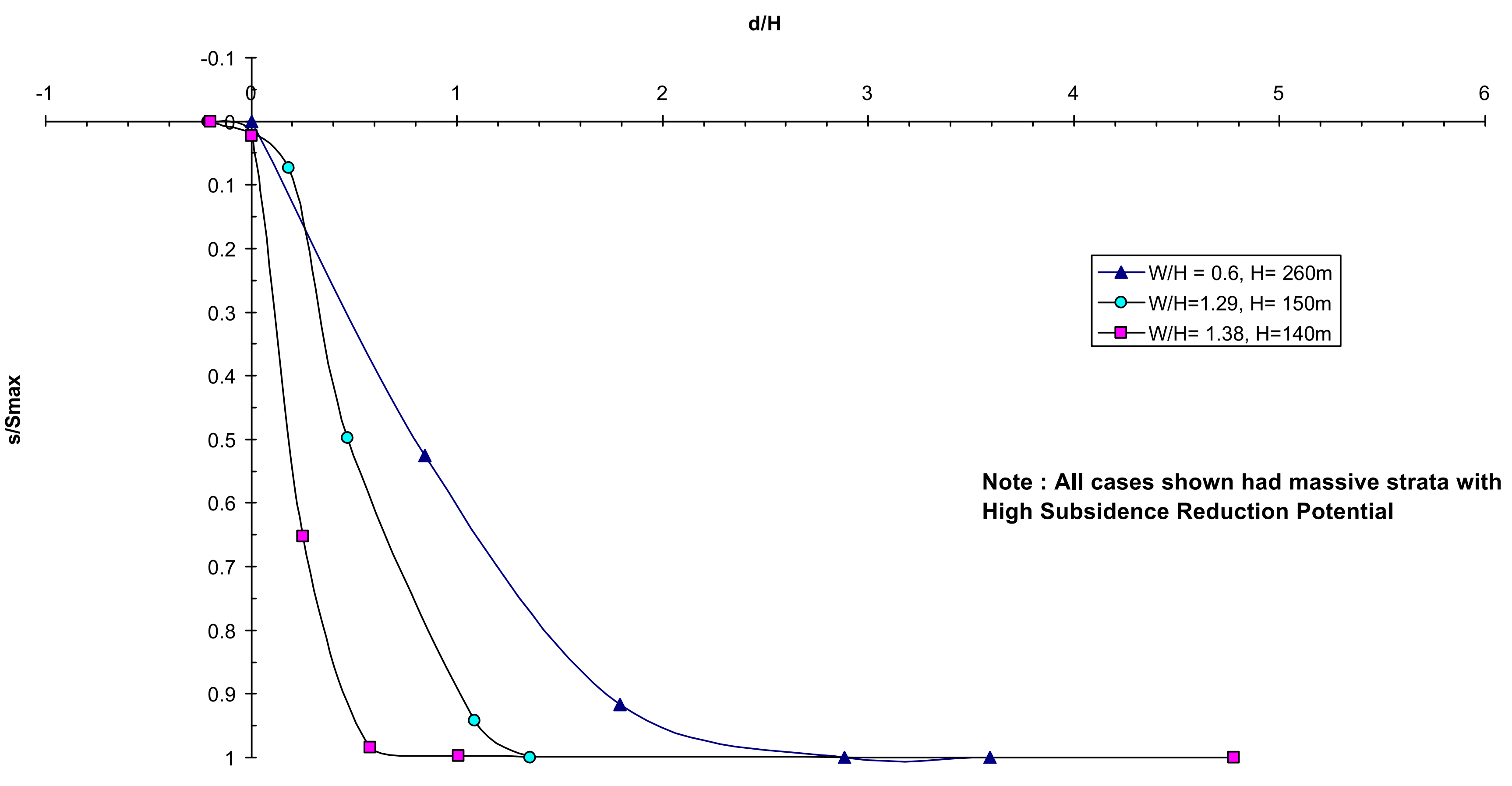
ENGINEER:	S,Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S,Ditton		04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	07.02.06	TITLE:	Far-field Horizotal Displacement Results Predicted by Numerical Modelling (Phase 2 FEM)	FIGURE 12.6
SCALE:	As Shown			

Looking South East

ENGINEER:	J. Jiang	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	J.Jiang		R04-001-WHT/1	
DATE:	07.02.06	TITLE:	Photographs of Large Wedge Failure from Southern Cliff Along 'The Drip' Outside of the Proposed LWs 12 and 13	FIGURE 12.7
SCALE:	NTS			



	Engineer:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Ltd	STRATA ENGINEERING (Australia Pty Ltd)	
	Drawn:	N.Paine		04-001-WHT/1		
	Date:	20.02.06	TITLE:	Conceptual Model of Longwall Impacts on Hydro-		FIGURE
M:\Figures\Moolarben\R04-001-WHT_1	Scale:	NTS		Geological Conditions in Overburden		13.1

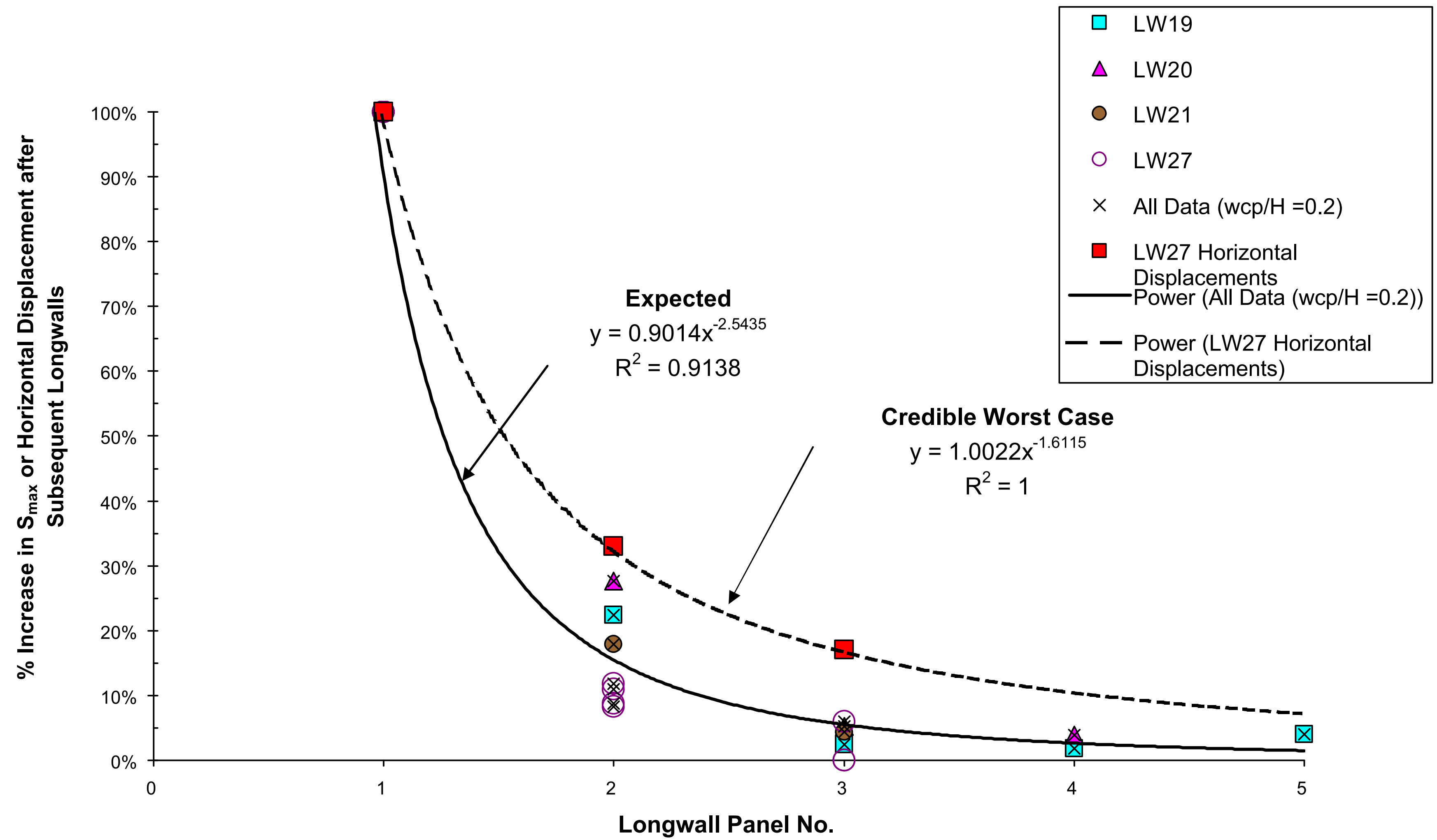


LEGEND

s/Smax = Subsidence/Smax

d/H = face distance/cover depth

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING**
DRAWN:	S.Ditton		04-001-WHT/1	**(Australia) Pty Ltd**
DATE:	4/02/2003	TITLE:	Empirical Model for Predicting	FIGURE:
SCALE:			Subsidence Development	13.2



Note: % increases between longwalls are proportional to subsidence after first longwall panel extracted

ENGINEER:	S.Ditton	CLIENT:	Moolarben Coal Mines Pty Limited	**STRATA ENGINEERING (Australia) Pty Ltd**
DRAWN:	S.Ditton		04-001-WHT/1	
DATE:	20/02/2006	TITLE:	Example of Maximum Subsidence and Horizontal Displacement Increases after More LWs Extracted	FIGURE: 13.3
SCALE:	NTS			