Cardno Forbes Rigby

Shaping the Future

Dendrobium Area 3
Landscape Impact Assessment and Monitoring Report

October 2007

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ILLAWARRA COAL

Cardno Forbes Rigby Reference 107055-02 Report 001 Rev 0

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Dendrobium Area 3
Landscape Impact Assessment and Monitoring Report

Report 001 Rev 0

Final Report
October 2007

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EXECUTIVE SUMMARY

BHP Billiton Illawarra Coal (IC) seeks to apply to DoP in order to modify the approval for Dendrobium Area 3, (in terms of the Area 3 footprint) pursuant to section 75W of the *Environmental Planning and Assessment Act 1979*.

IC is also submitting a Subsidence Management Plan application to DPI in order to obtain mining approval for part of the new proposed Area 3, referred to as Area 3A.

IC has commissioned a Landscape Impact Assessment and Monitoring Report for the proposed mining in Dendrobium Area 3A (for which a mining layout is defined) and Areas 3B & 3C (for which a mining layout is not yet defined due to uncertainty regarding the area's geology).

The objective of the study is to:

- Identify significant landscape features that are at greatest risk of experiencing adverse impacts such as rockfalls, erosion and sedimentation.
- Assess the likely predicted impact that proposed mining may have.
- Identify suggested monitoring points in areas shown by the analysis to be at greatest potential risk.
- Outline a monitoring program with appropriate trigger levels for corrective management actions.

The study seeks to analyse sensitive landscape features with the greatest potential to experience mine subsidence induced impacts such as:

- Rock falls from cliffs and overhangs.
- Soil slippage, cracking or slumping.
- Increased/decreased gradients in watercourses and swamps that could lead to increased velocities and erosion, sedimentation or pooling.
- Increased/decreased gradients and surface cracking on fire trails or other disturbed areas that may modify flow paths and expose soil to erosion.
- Changes in sub-catchment areas associated with sensitive features (e.g. swamps).

Based on the subsidence predictions, the location of landscape features and the impacts monitored at Dendrobium Areas 1 and 2, the features at greatest risk of subsidence impacts within Area 3 are assessed as:

- Cliffs DA3-CF7 and DA3-CF8 in Area 3A.
- Cliffs DA3-CF17 and DA3-CF18, immediately adjacent Longwall 10 in Area 3A.
- Cliffs located within *goaf areas in future Areas 3B & 3C*.
- The Rock outcrops occurring on steep slopes *within goaf areas*.
- The Steep slopes above 30 degrees and the adjacent upland areas within goaf areas with risk increasing with slope gradient.
- Fire roads over goaf areas

For all of these features, those located at the margins of the subsidence trough in positions of maximum compressive and tensile strain would generally be at greater risk of impact.

Detailed location plans and indicative pre and post mining cross sections have been presented for cliffs and steep slopes. Indicative pre and post mining long sections have been presented for fire roads, swamps and minor watercourses.

The risk factors considered and analysed with respect to ***swamps*** and ***watercourses*** include:

- Catchment area change
- Slope gradient change
- Vegetation cover
- Soil landscape type
- Slope length
- Swamps oriented perpendicular to longwalls
- Location of swamp within the catchment
- Fire history & climatic events
- Existing disturbance and land use
- Hydrology changes
- Surface disturbance such as cracking of the soil profile and fracturing of rock

The characteristics of each swamp in Area 3 was reviewed and documented from several previous reports and inspections.

The analysis of mining induced subsidence on swamps and minor watercourses determined:

- Swamps in Area 3 are currently in a stable condition and have not shown any obvious surface disturbance over at least the last four decades.

- Analysis of predicted pre and post-mining contours in Area 3A showed no detectable difference in sub-catchment sizes as a result of the mine subsidence.
- Any catchment area changes identified as a result of the mining are likely to be minor in nature, and not represent a significant impact to the swamps.
- To ensure the impact assessment is conservative, this study assumed that the swamps and minor watercourses in Areas 3B & 3C *will lie across* longwalls (as occurs in area 3A). Due to this likely orientation across subsidence troughs, we conclude that these swamps and watercourses will be likely to undergo the landscape impact of minor gradient changes as a result of mine subsidence.
- Although there may be a *higher potential* for scour where gradient increases occur, these changes are unlikely to result in increased scour events due to the minimal increases on shear strengths over different flow events, the occurrence of bedrock as a control in some cases, and the lack of defined concentrated flow paths in other cases.
- Any mining induced gradient change will be less than the average grade of the swamp/watercourse and is insignificant in comparison to the natural grade variations observed in these swamps.
- In many cases, slope does not have a significant effect on sub-catchment surface flow velocities. Catchment area and surface roughness are the significant factors.
- Where minor gradient decreases occur, water has the potential to pool in the swamp/watercourse and no incision is likely to occur. The impact of increased pooling is likely to be minor and is not expected to result in any significant flow-on impacts other than perhaps a redistribution of vegetation in the immediate area due to increased moisture.
- Swamps 2, 5, 7, 8 and 15a are assessed as the swamps at *most potential risk* of undergoing scour due to their downstream location on the drainage channel, large respective catchment areas, and therefore magnitude of flows that may be expected in large rain events.
- Previous investigations have attributed scouring events to climatic episodes of drying, burning of peat substrate during bushfires, and then heavy rainfall. It is unclear whether mining has contributed to the drying of undermined swamps.
- Monitoring by IC and EarthTech indicates the only swamps with any notable existing points of disturbance where scour may be expected to be initiated are two small sections of scoured channel within Swamp 5 and one lower section of scoured channel within Swamp 8.
- In Area 3A, Swamp 15a is considered the swamp *at most risk* of potential mine subsidence induced scour impacts. This is due to it's large catchment area, considerable length, orientation over the subsidence perimeter of Longwalls 9 & 10, in addition to it's relatively flat grades over significant sections. Due to the stability of the swamp it is considered such an impact is unlikely and if observed, would be minor in nature.

In summary, the landscape related impacts from the proposed mining are assessed as being minor and not significant. In addition to this assessment, other specialist studies have been undertaken in relation to the induced cracking of bedrock below and around swamps and any hydrologic, water quality, or ecological impacts that may occur due to these effects. The results of these assessments have been summarised in Section 4.3.1, are available in (references) and have been taken into account in the landscape assessment provided here in.

Proposed landscape monitoring locations have been identified based on areas of greatest potential risk.

Based on the MSEC subsidence predictions, the location of landscape features and monitoring of impacts from Dendrobium Area 1 and 2, we predict that it is unlikely that there will be significant landscape related impacts on cliffs, slopes, fire roads, swamps and watercourses within Dendrobium Area 3.

Landscape impacts in Areas 3B and 3C will be assessed in further detail as part of the DPI's SMP assessment and approval process for each area, when the longwall layout is finalised.

1. INTRODUCTION

1.1. BACKGROUND

BHP Billiton Illawarra Coal (IC) seeks to:

- Apply to modify the approval for Dendrobium Area 3, (in terms of the Area 3 footprint) pursuant to section 75W of the *Environmental Planning and Assessment Act 1979*.
- Submit a Subsidence Management Plan for part of the new proposed Area 3 referred to by Illawarra Coal as area 3A;

To support the submissions referred to above, Illawarra Coal has commissioned a Landscape Impact Assessment and Monitoring Report for the proposed mining in Dendrobium Area 3A (for which a mining layout is defined) and Areas 3B & 3C (for which a mining layout is not yet defined due to uncertainty regarding the area's geology). Refer to **Figure 1.1.**

1.2. OBJECTIVES

This *Landscape Impact Assessment and Monitoring Report* concentrates on features of the landscape that are considered to be potentially more sensitive to subsidence impacts due to their location in the landscape in relation to predicted subsidence contours and, due to potential impacts on hydrology etc. which interact with the features.

The objective of the study is to:

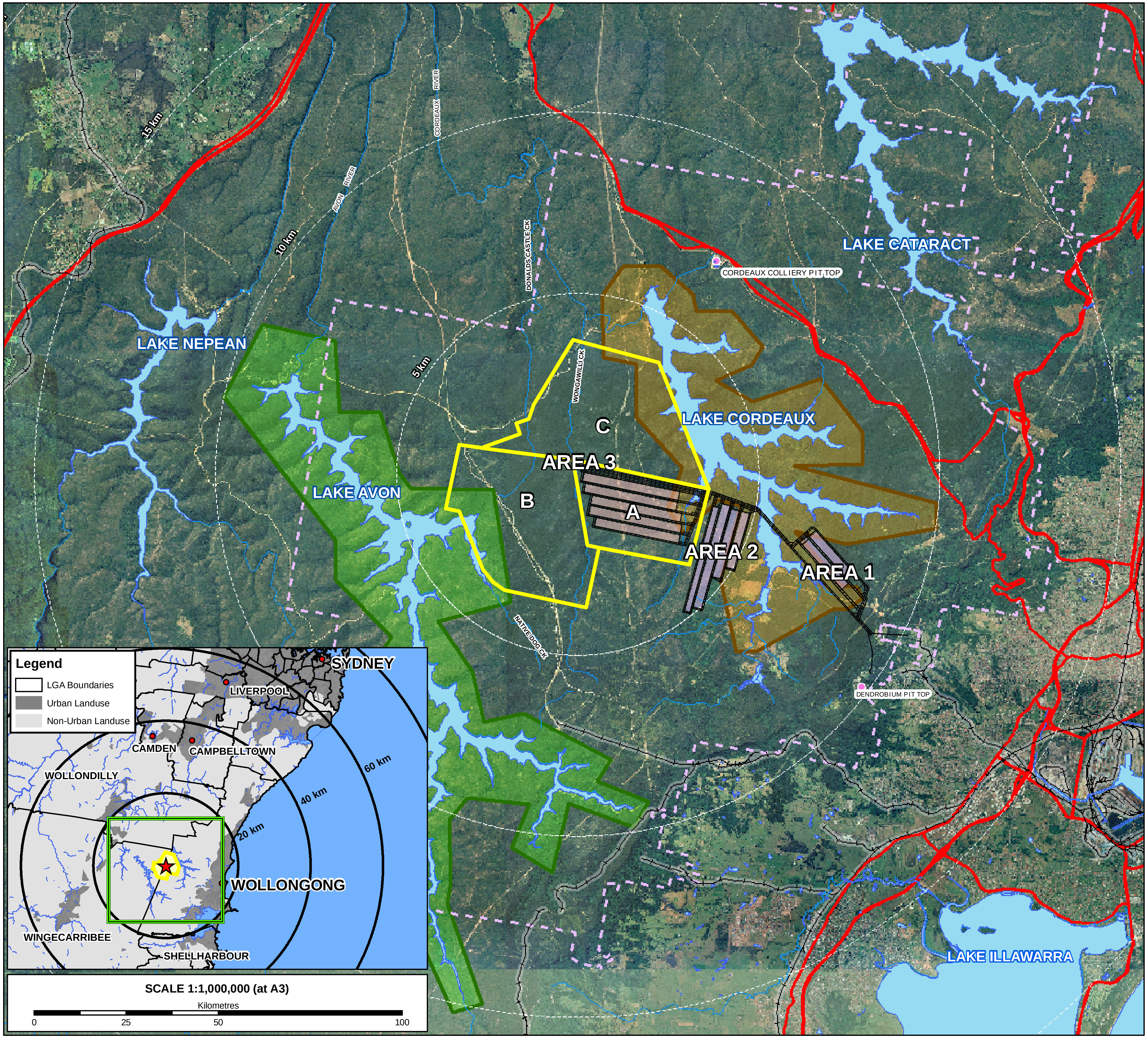
- Identify significant landscape features that are at greatest risk of experiencing adverse impacts such as rockfalls, erosion and sedimentation
- Assess the likely predicted impact that proposed mining may have
- Identify suggested monitoring points in areas shown by the analysis to be a greatest potential risk
- Outline a monitoring program with appropriate trigger levels for corrective management actions.

1.3. SCOPE

The study seeks to analyse sensitive landscape features with the greatest potential for adverse impacts such as:

- Rock falls from **cliffs and overhangs**
- Soil slippage, cracking, slump on **steep slopes**
- Increased/decreased gradients in **watercourses** and **swamps** that could lead to increased velocities and erosion, or pooling
- Increased/decreased gradients and surface cracking on **fire trails** or other **disturbed areas** that may modify flow paths, expose soil to erosion.
- Changes in sub-catchment areas associated with sensitive features (e.g. swamps)

Earthtech (2005) have identified swamp systems at greatest risk to increased scour have the following characteristics:



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Locality Plan

DENDROBIUM AREA 3

Legend

- Colliery Pit Tops
- Railway (LPI)
- Main Roads (LPI)
- Lease Boundaries
- Drainage (LPI)
- Waterbody (LPI)
- Proposed Longwall Layout
- Existing Longwall Layout
- Proposed Area 3 Footprint

DSC Notification Area

- Avon Dam
- Cordeaux Dam

N E S W

Figure 1.1

Scale 1:100,000 (at A3)

Kilometres

0 1 2 3 4 5

Cardno Forbes Rigby

Map Produced by Forbes Rigby Pty Ltd
Date: 13 September 2007
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
107055-01_1802_EIA_Locality_Plan_P1.mxd

- High stream order (catchment area)
- Poor vegetation condition;
- Swamps oriented perpendicular to longwalls
- Swamps located across the subsidence trough perimeter (subject to greater potential changes in gradient)

Earthtech (2005) have also determined indicative velocity and shear stress thresholds for swamps and different vegetation types from the literature.

Our methodology will continue this analysis in more detail by assessing combined risk factors and identifying where localised gradient changes can be expected due to subsidence, and if these are found to be significant. Significant gradient changes may justify further assessment of the swamp/channel for shear stress & velocities in design storms.

1.3.1. Staged Assessment Approach

The study will commence with a broad scale assessment, ie. a first pass to establish the magnitude/relative importance of surfaces feature related impacts associated with subsidence. After the most "significant" features and predicted impacts are established, more detailed assessment of these impacts will be undertaken if necessary.

The broad scale assessment is to be conducted for the entire new proposed Area 3 footprint, while the more detailed assessment will be applied to Area 3A, in order to support the SMP submission.

2. METHODOLOGY

2.1. METHODOLOGY FOR ANALYSIS OF CLIFFS, STEEP SLOPE, AND DISTURBED AREAS

A geographic information system (GIS) model was developed to aid decision making, impact assessment and justify landscape monitoring site selection. The outputs and methodology can act as a supporting attachment to the Landscape Monitoring SEMP.

The methodology can be summarised as follows:

- Data collection and collation (elevation data, watercourses, swamps, road and access ways, subsidence data)
- Create digital elevation model (DEM) from most recent IC airborne laser survey data
- Derive slope dataset from DEM. Define landscape features including cliffs, steep slopes, and watercourses in accordance with the Australian Soil and Land Survey Field Handbook based on the slope analysis
- Conduct a multi-criteria analysis to identify locations/areas of greatest predicted risk which will incorporate a range of factors including predicted subsidence contours (sourced from MSEC 2007), predicted tilt, predicted strain, vegetation type and cover, areas of disturbance, soil landscape type, slope length, slope gradient
- Prepare map of areas with greatest risk

- Prepare pre-mining and predicted post mining long sections across areas of greatest risk
- Conduct field inspections to ground truth the analysis, identify access to sites and identify any relevant features such as overhangs etc. that may increase risk or provide good monitoring points
- Liase MSEC RE any features that may increase the risk of impacts
- Prepare a map showing high risk sites and the proposed monitoring sites across the study area
- Prepare a monitoring and management plan.

2.2. METHODOLOGY FOR ANALYSIS OF WATERCOURSES AND SWAMPS

Impact Assessment will consider the following risk factors for ***major swamps*** and ***watercourses***:

- Location of swamp (valley floor, valley side, headwater) and associated catchment area
- Orientation of swamp compared to longwall (eg. perpendicular to, or parallel to longwall)
- Extent of natural confinement within valley
- Stream order and catchment area
- Relative likelihood of cracking due to subsidence, upsidence and closure (determined by MSEC 2007)
- Likelihood of hydrological changes due to cracking (determined by Ecoengineers 2007)
- Existing scour/erosion or initiation points for scour
- Predicted changes in gradient from subsidence and change in catchment area/volume
- Likelihood of scouring due to localised gradient change (determined by velocity estimates and comparison to previously determined velocity/shear stress to thresholds).

Tasks

- Review existing literature and topographic data (maps, aerial photos, digital elevation model) to identify sites.
- Prepare digital model of pre-mining surface and post mining predicted surface
- Identify any changes from pre to post-subsidence catchment boundaries
- Determine catchment hydrology and flow rates (only if catchment sizes are shown to be significantly impacted)
- Prepare cross-sections and longitudinal sections showing pre-mining surface and post mining predicted surface.
- Identify areas of high predicted gradient changes and high risk scour initiation points.

- Conduct desk top risk assessment based on known risk factors described above to determine swamps and watercourse areas at greatest risk
- Conduct site inspections to identify vegetation, hydraulic roughness, bed controls, existing scour points (existing scour is the biggest risk factor), and viability of proposed monitoring points.
- Conduct hydraulic modelling of swamps to identify shear stress, and velocity for a range of flow events for both the pre-mining and predicted post mining ground surfaces (only if catchment sizes are shown to be significantly impacted)
- Compare results with thresholds identified in literature review to determine if mining is predicted to have an impact on increased scour (only if catchment sizes are shown to be significantly impacted).
- Document analysis findings (prepare report) and make assessment of impact for each swamp its watercourse.
- Prepare proposed monitoring sites plan based on the analysis and field inspections.
- Prepare a monitoring and management plan.

2.3. INTERPRETATION OF SUBSIDENCE PREDICTIONS

2.3.1. Subsidence Prediction Data

It is noted this study is largely dependent on the subsidence predictions and impact assessments prepared by MSEC (2007). This section of the report is sourced from the MSEC Impact Assessment for Area 3, and data trends identified by MSEC since the early 1990's in relation to predicted and observed subsidence data, and the occurrence of landscape impacts.

2.3.2. The Development of Subsidence.

As a coal seam is mined using the longwall method, the immediate roof strata, (ie, the rocks immediately above the seam), collapse into the goaf. The rocks above them lose support and sag to fill the void beneath them. The mechanism progresses towards the surface and the affected width increases so that at the surface, an area somewhat larger than the extracted panel of coal undergoes settlement. **Figure 2.1** shows a typical subsidence profile above an extracted longwall panel and it can be seen that the majority of the subsidence occurs over the centre of the longwall and tapers off around the perimeter of the longwall. The surface subsidence is typically less than 65% of the thickness of coal extracted underground.

It is generally accepted that subsidence of less than 20 mm will have negligible effect on surface infrastructure and this is generally adopted as the cut-off point for determination of the angle of draw. In the Coalfields of NSW, if local data is not available, the cut-off-point is taken as a point on the surface defined by an angle of draw of 26.5 degrees from the edge of the extraction, i.e. a point on the surface at a distance of half the depth of cover from the goaf edge.

Subsidence, tilt, horizontal displacement, curvature and strain are the subsidence parameters normally used to define the extent of the surface movements that will occur as mining proceeds and generally form the basis for the assessment of the impacts of subsidence on surface infrastructure. These parameters are illustrated in **Figure 2.2** which shows a typical subsidence profile drawn to an exaggerated vertical scale.

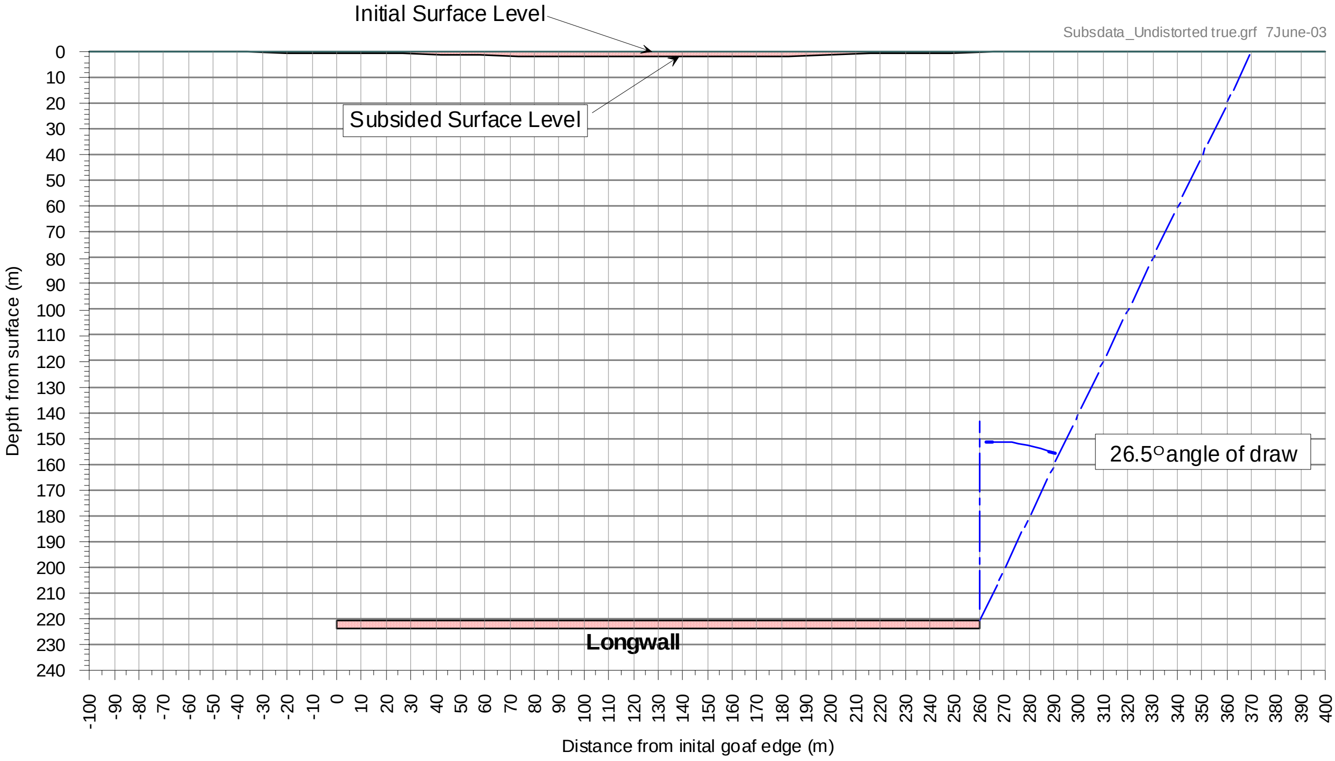

Figure 2.1 - Typical Subsidence Profile (Source: MSEC)

Subsidence

Subsidence usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements can in many cases be greater than the vertical subsidence, where the subsidence is small. The amplitude of subsidence is usually expressed in millimetres.

Tilt

Tilt is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. The sign of tilt is not important, but the convention usually adopted is for a positive tilt to indicate the ground increasing in subsidence in the direction of measurement.

The maximum tilt, or the steepest portion of the subsidence profile, occurs at the point of inflection in the subsidence trough, where the subsidence is roughly equal to one half of the maximum subsidence. Tilt is usually expressed in millimetres per metre.

Horizontal Displacement

The horizontal component of subsidence, or horizontal displacement, is greatest at the point of maximum tilt and declines to zero at the limit of subsidence and at the point of maximum subsidence. Horizontal displacement is usually expressed in millimetres.

Curvature

Curvature is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the radius of curvature with the units of 1/km, or km^{-1}, but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in kilometres.

Curvature is convex or 'hogging' over the goaf edges and concave or 'sagging' toward the bottom of the subsidence trough. The convention usually adopted is for convex curvature to be positive and concave curvature to be negative.

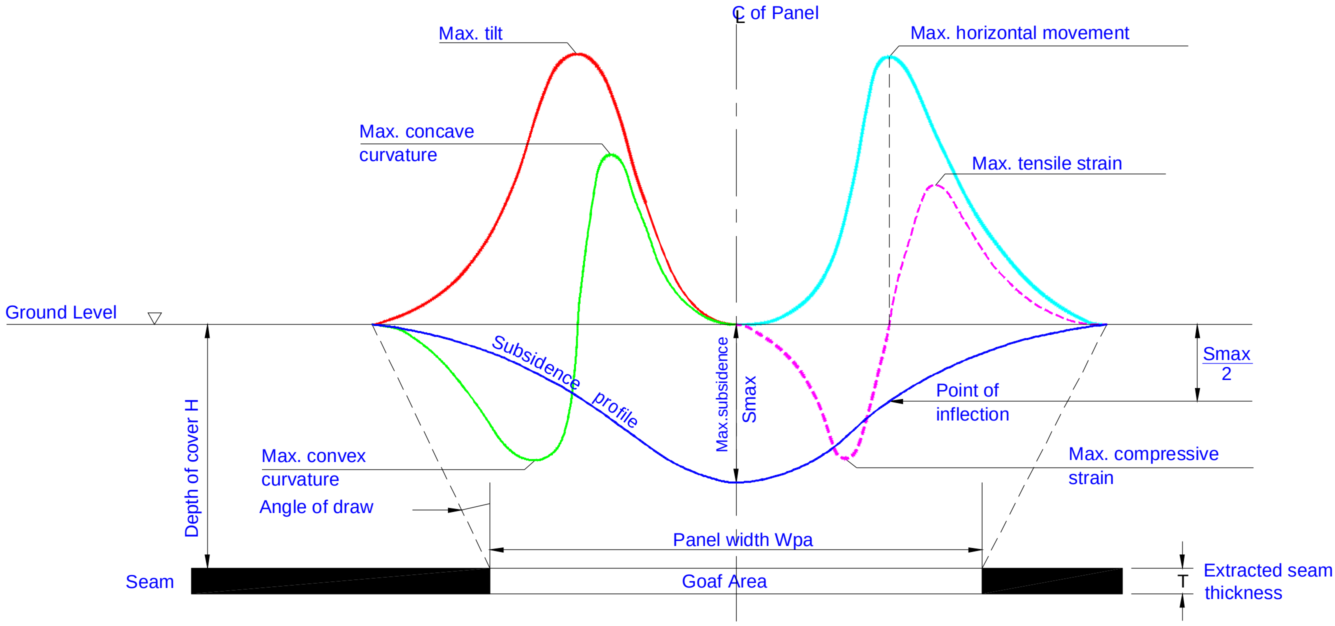

Figure 2.2 - Subsidence Parameter Profiles above a Single Longwall Panel

Source: MSEC 2007

2.3.3. Subsidence Impacts at the Surface

The most significant impacts on surface infrastructure are experienced during the development of the subsidence trough, when maximum ground movements normally occur. As the subsidence wave approaches a point on the surface, the ground starts to settle, is displaced horizontally towards the mined void and is subjected to tensile strains, as shown in **Figure 2.3**.

The position of maximum hogging curvature is the position of maximum tensile strain. When vertical subsidence is approximately half of the maximum subsidence, i.e., as the face passes under the surface point, the ground reaches its maximum horizontal displacement and the strain reduces to zero again.

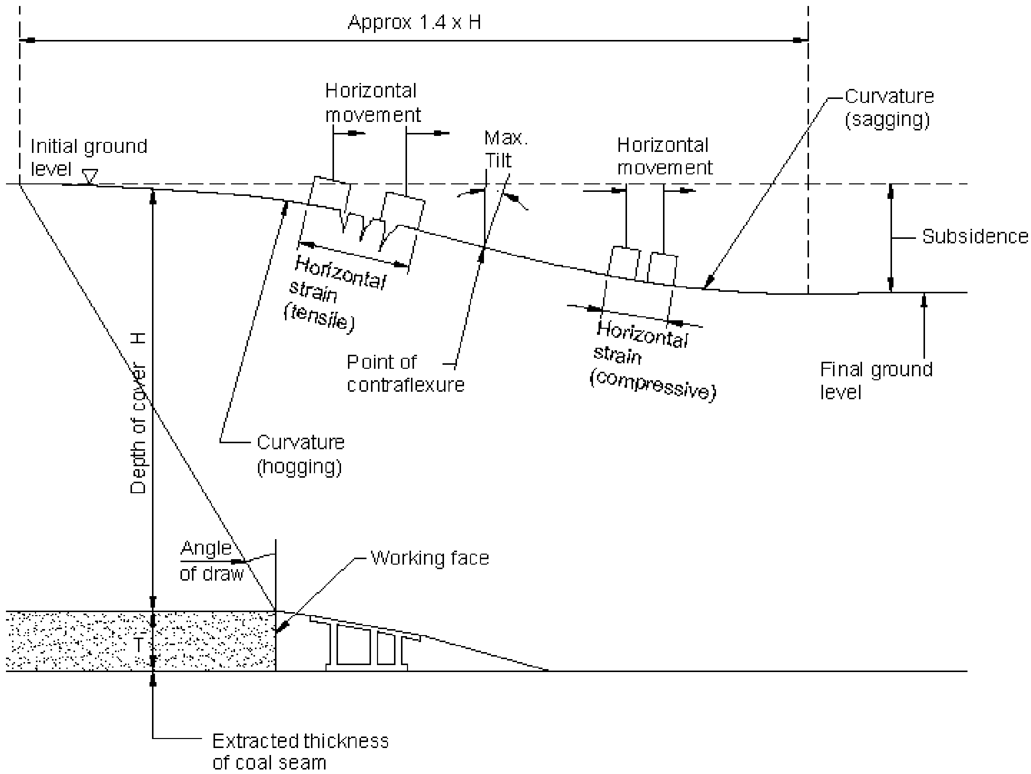

Figure 2.3 - Development of a Subsidence Trough (to an exaggerated vertical scale)

Source: MSEC 2007

As the longwall face moves further away from the surface point the settlement continues, horizontal displacement reduces and the ground is subjected to compressive strains, which build from zero to a maximum over the length of concave or sagging curvature and then decline to zero as maximum subsidence is reached. The position of maximum sagging curvature is the position of maximum compressive strain. When the subsidence is complete, the ground is commonly left with no horizontal displacement and little residual tilt or strain.

Between the tensile and compressive zones is the point of inflection, which is the point at which maximum tilt and maximum horizontal displacement occurs. For critical extraction conditions, it is also the point at which the subsidence is, approximately, equal to half the maximum subsidence.

As the longitudinal wave passes, the transverse subsidence profile gradually develops and is completed as maximum subsidence is reached. The transverse subsidence profiles over each side of the panel are similar in shape to the longitudinal subsidence profile and have the same distribution of tilts, curvatures and strains. Most of the points on the surface will thus be subjected to three-dimensional movements, with tilt, curvature and strain in both the transverse and longitudinal directions. The impact of subsidence on surface infrastructure is therefore dependent upon its position within the trough.

The above sequence of ground movements, along the length of a panel, only applies to surface structures if they are located at a point where the maximum subsidence is likely to occur. Elsewhere, the impacts, in the both the transverse and longitudinal direction are reduced.

For the purposes of interpreting subsidence predictions and the figures presented in this report then, the following points are noted:

- If a structure is located on the perimeter of the subsidence trough, it will only be slightly affected, will suffer little settlement and will have little residual tilt or strain.
- A surface feature on the side of the trough between the tension and compression zones will experience some subsidence, and will be left with residual horizontal displacement and tilt, but will be subjected to lower curvatures and strains.
- Structures or surface features located at the positions of maximum curvature and strain will generally suffer the greatest impact.

As each panel within a series is extracted in turn, an incremental subsidence trough is formed above it. If the width-to-depth ratios of the panels are low (which they are for Dendrobium Area 3), the incremental subsidence troughs overlap at the surface and the resulting subsidence at any point, in these circumstances, is a combination of the effects of a number of panels.

A point on the surface may then be subjected to a series of subsidence waves, which occur as each panel is extracted, and the duration of these impacts will depend upon the position of the point relative to each of the subsidence troughs that are formed.

2.3.4. Subsidence Data Trends Relating to Landscape Impacts in the Southern Coalfields

The Increased Likelihood of Ponding, Flooding and Scouring

An increased likelihood of ponding or flooding can occur in the locations along the creeks where the maximum predicted tilts, due to the net vertical movements, oppose and are greater than the natural creek gradients that exists before mining. An increased likelihood of scouring of the banks can occur in the locations along the creeks where the predicted tilts, due to the net vertical movements, considerably increase the natural creek gradients that exist before mining.

The Likelihood of Fracturing of the Bedrock

Fractures and joints in the bedrock and rockbars occur naturally from erosion and weathering processes and from natural valley bulging movements. Where underground longwall mining occurs in the vicinity of creeks and rivers, mine subsidence movements can result in additional fracturing or reactivation of the existing joints. The causes of these mining-induced fractures are difficult to determine as the mechanisms are complex, although the main mining-related mechanisms are systematic mine subsidence and valley related upsidence and closure movements.

The experiences gained from previous longwall mining in the Southern Coalfield indicate that mining induced fracturing in bedrock and rockbars are commonly found in sections of creeks and rivers that are located directly above mined longwalls. However, minor fracturing has also occurred in isolated locations beyond extracted longwall goaf edges, the majority of which are within the limit of systematic subsidence. In rare and isolated cases, fracturing has been observed up to approximately 400 metres outside extracted longwall goaf edges.

Upsidence and Closure

MSEC (2007) reports that only minor impacts occurred where the predicted closure was typically less than 200 mm.

Where Wongawilli and Native Dog Creeks were previously mined beneath by Elouera Longwalls 1 to 10, the significant fracturing **in the bedrock and rockbars occurred directly above the longwalls**. Only isolated minor fractures were identified outside the extracted longwall goaf edges.

3. BROAD SCALE LANDSCAPE IMPACT ASSESSMENT CLIFFS, STEEP SLOPE, AND DISTURBED AREAS

3.1. LOCATIONS OF CLIFFS, STEEP SLOPES, FIRE ROADS AND SOIL LANDSCAPES

Figure 3.1 shows the locations of cliffs, steep slopes and Fire Roads within mining area 3A, and the location of the proposed longwalls.

Figure 3.2 shows the locations of cliffs, steep slopes and Fire Roads within the entire proposed Area 3 footprint. It is noted that the mining plans for Areas 3B and 3C have not yet been determined, and therefore no longwall layouts are presented in **Figure 3.2**.

Figure 3.3 shows the soil landscapes for mining area 3A and **Figure 3.4** shows the soil landscapes for the entire proposed Area 3 footprint.

Figure 3.1 shows that cliffs (defined by MSEC as a continuous rock face with a minimum height of ten metres and a minimum slope of 2 in 1, i.e. having a minimum angle to the horizontal of 63°) only occur at the western end of longwall 10. Steep slopes however are distributed across the proposed longwall panels and the varying slope gradients are represented by the slope analysis as differing shades of colour in **Figure 3.2.**

Long Sections 1 and 2 showing the existing ground surface and the predicted post mining ground surface are presented in **Appendix B**. These sections have been drawn from the 20mm subsidence contour (normally associated as the limit of vertical subsidence) on either end of the section, as shown on **Figure 3.1.**

3.2. RISK FACTORS FOR CLIFFS, STEEP SLOPES AND FIRE ROADS

Table 3.1 outlines the risk factors considered for Cliffs, Steep Slopes and Fire Roads. The primary factors are subsidence related. A large database of subsidence prediction, and monitoring data has been collected on behalf of IC by MSEC since the early 1990's. The risk factors in **Table 3.1** have been identified in consultation with MSEC, by correlation of subsidence prediction/ monitoring data from IC mines and observed landscape impacts.

The main points to note in regard to risk factors considered for Cliffs, Steep Slopes and Fire Roads are:

- Very few subsidence induced rock falls have occurred outside goaf areas in the Southern Coalfields.
- Tensile and compressive Strains may result in fracturing of sandstone, especially where predicted maximums exceed 0.5 and 2mm/m respectively.
- Impacts such as of rock falls or soil slippage are more likely to occur on steeper slopes due to decreasing stability of fractured rocks and soils.
- Secondary factors such as the degree of vegetation cover, soil type, slope length may increase the risk of impacts such as erosion and sedimentation of receiving waters.

3.3. IMPACT ASSESSMENT FOR CLIFFS, STEEP SLOPES, FIRE ROADS

3.3.1. Impact Assessment for Cliffs

MSEC define cliffs as "a continuous rockface with a minimum height of ten metres and a minimum slope of 2 in 1, i.e. having a minimum angle to the horizontal of 63". **Figure 3.1** shows only two minimal cliffs of approximately 25m in length within the goaf of Area 3A, these being DA3-CF7 & DA3-CF8. The significant clifflines of DA3-CF17 and DA3-CF18 are located immediately adjacent to the western end of Longwall 10. Other clifflines in Area 3 are located along the alignment of Wongawilli Ck as shown in **Figure 3.2**.

Tilt does not directly induce differential movements along a cliff, which is the main cause of cliff instabilities. Tilt, however, can increase the overturning moment in a steep or overhanging cliff which, if of sufficient magnitude, could result in a toppling type failure. It is unlikely, however, that the maximum predicted tilt in this case would be of sufficient magnitude to directly result in topping type failures along the clifflines. It is possible, however, that if the systematic strains were of sufficient magnitude, existing sections of rock could fracture along existing bedding planes or joints and become unstable, resulting in a sliding or toppling type failures along the clifflines. (MSEC 2007)

The fracturing of sandstone has generally not been observed in the Southern Coalfield where systematic tensile and compressive strains are less than 0.5 mm/m and 2 mm/m, respectively. It is possible, therefore, that the maximum predicted systematic tensile strain is of sufficient magnitude to result in the fracturing of sandstone and, hence, potential rockfalls at the Clifflines DA3-CF7 & DA3-CF8, and Clifflines DA3-CF17 and DA3-CF18 immediately adjacent to the western end of Longwall 10. Elsewhere, the predicted systematic strains for Cliffs are unlikely to be of sufficient magnitude to result in the fracturing of sandstone and, hence, the potential for rockfalls. (MSEC 2007)

Previous experience in the Southern Coalfield indicates that only a small percentage of rockfalls have occurred outside longwall goaf areas.

Dendrobium Area 1 employed 250m wide longwalls and had a depth of cover varying from 170 to 320 metres. It extracted a seam height of 3.2 to 3.4 m. Area 3A will also employ 250m wide longwalls but the depth of cover is slightly larger, varying from 255m at the eastern end of Longwall 10, to 400m above the tailgate of longwall 6.

In Dendrobium Area 1, the total width of disturbance (observed rockfalls) resulting from the extraction of Longwalls 1 and 2 was approximately 135 to 175 metres. The total plan length of ridgeline located directly above the Dendrobium Area 1 longwalls is approximately 1800 to 2000 metres. It should be noted, however, that the actual widths of the observed rockfalls at some of the sites were less than the overall widths of the disturbance recorded in **Table 3.1**.

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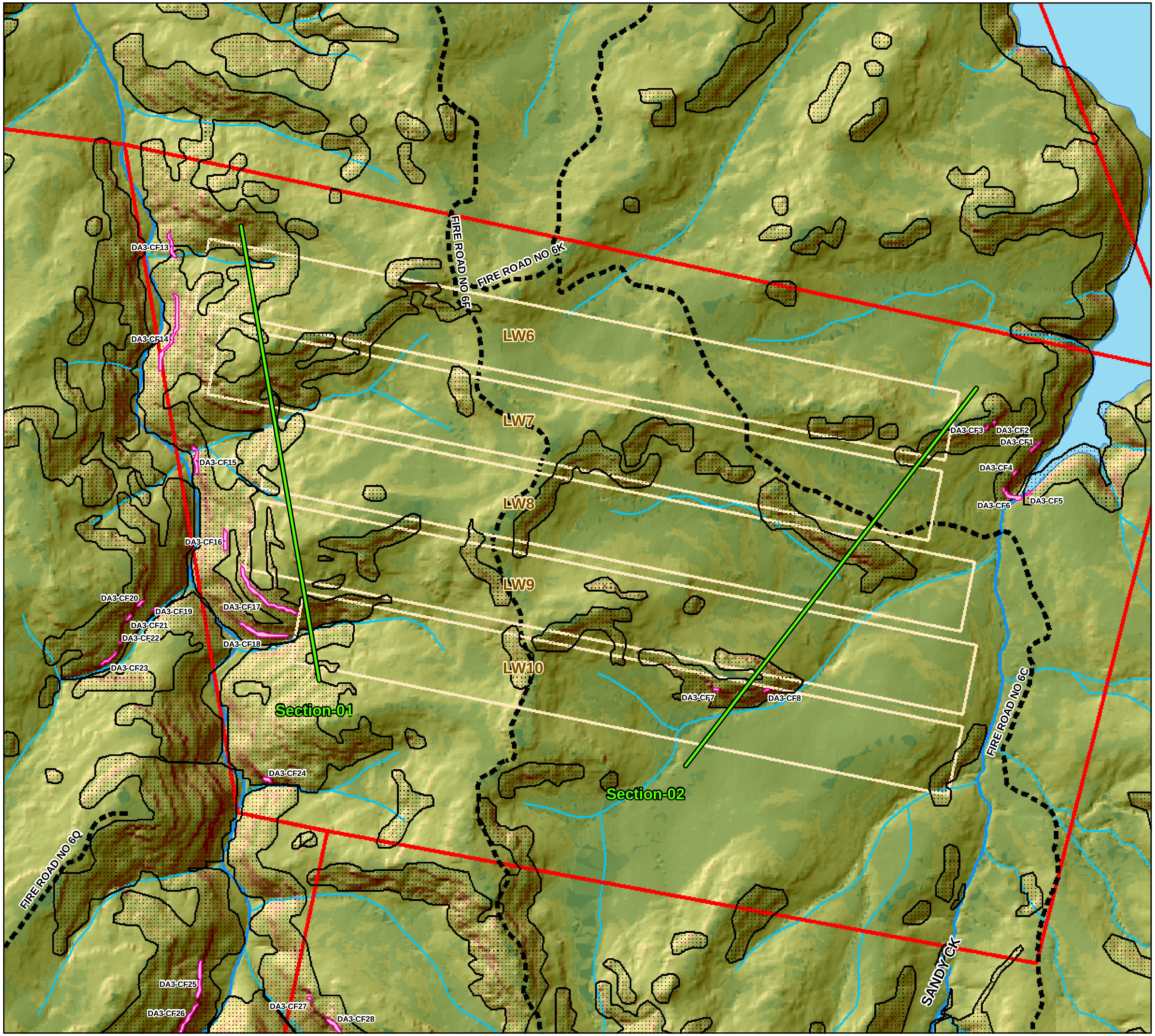
Cliffs, Slopes and Fire Roads

DENDROBIUM AREA 3A

FIGURE 3.1



- Section Line
- Mine Layout - SMP Area A
- Fire Roads
- Creeks
- Minor Streams
- Lakes
- Steep Slopes
- Proposed Area 3 Footprint (IC)
- Cliffs (IC)

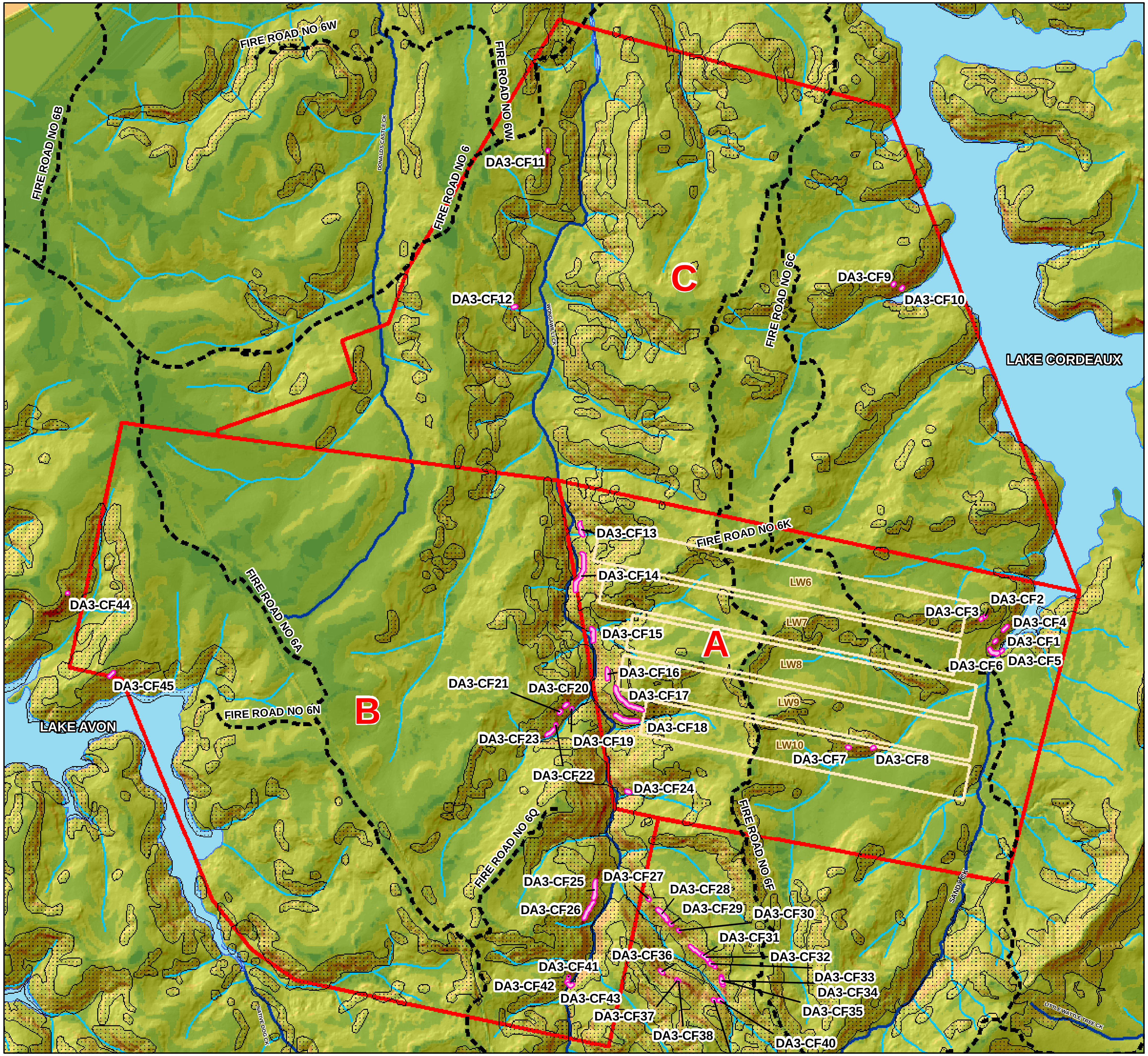
SLOPE CLASS (Handbook)	SLOPE RANGE (Degrees)	% Within SMP Area
Level (LE)	<0º 35'	2.30%
Very gently inclined (VG)	0º35' - 1º45'	0.47%
Gently inclined (GE)	1º45' - 5º45'	33.48%
Moderately inclined (MO)	5º45' - 18º	51.01%
Steep (ST)	18º - 30º	10.27%
Very Steep (VS)	30º - 45º	2.18%
Precipitous (PR)	45º - 72º	0.29%

Scale 1:13,000 (at A3)

Metres
0 100 200 300 400 500

Cardno Forbes Rigby

Map Produced by Cardno Forbes Rigby Pty Ltd
Date: 24 September 2007
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
107055-02_2816_Slope_3A.mxd



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Cliffs, Slopes and Fire Roads

DENDROBIUM AREA 3

Figure 3.2

Legend

- Creeks
- Minor Streams
- Fire Roads
- Mine Layout - SMP Area A
- Steep Slopes
- Proposed Area 3 Footprint (IC)
- Lakes
- Cliffs (IC)

SLOPE CLASS (Handbook)	SLOPE RANGE (Degrees)	% Within SMP Area
Level (LE)	<0º 35'	1.95%
Very gently inclined (VG)	0º35' - 1º45'	4.05%
Gently inclined (GE)	1º45' - 5º45'	28.96%
Moderately inclined (MO)	5º45' - 18º	51.58%
Steep (ST)	18º - 30º	11.66%
Very Steep (VS)	30º - 45º	1.71%
Precipitous (PR)	45º - 72º	0.09%

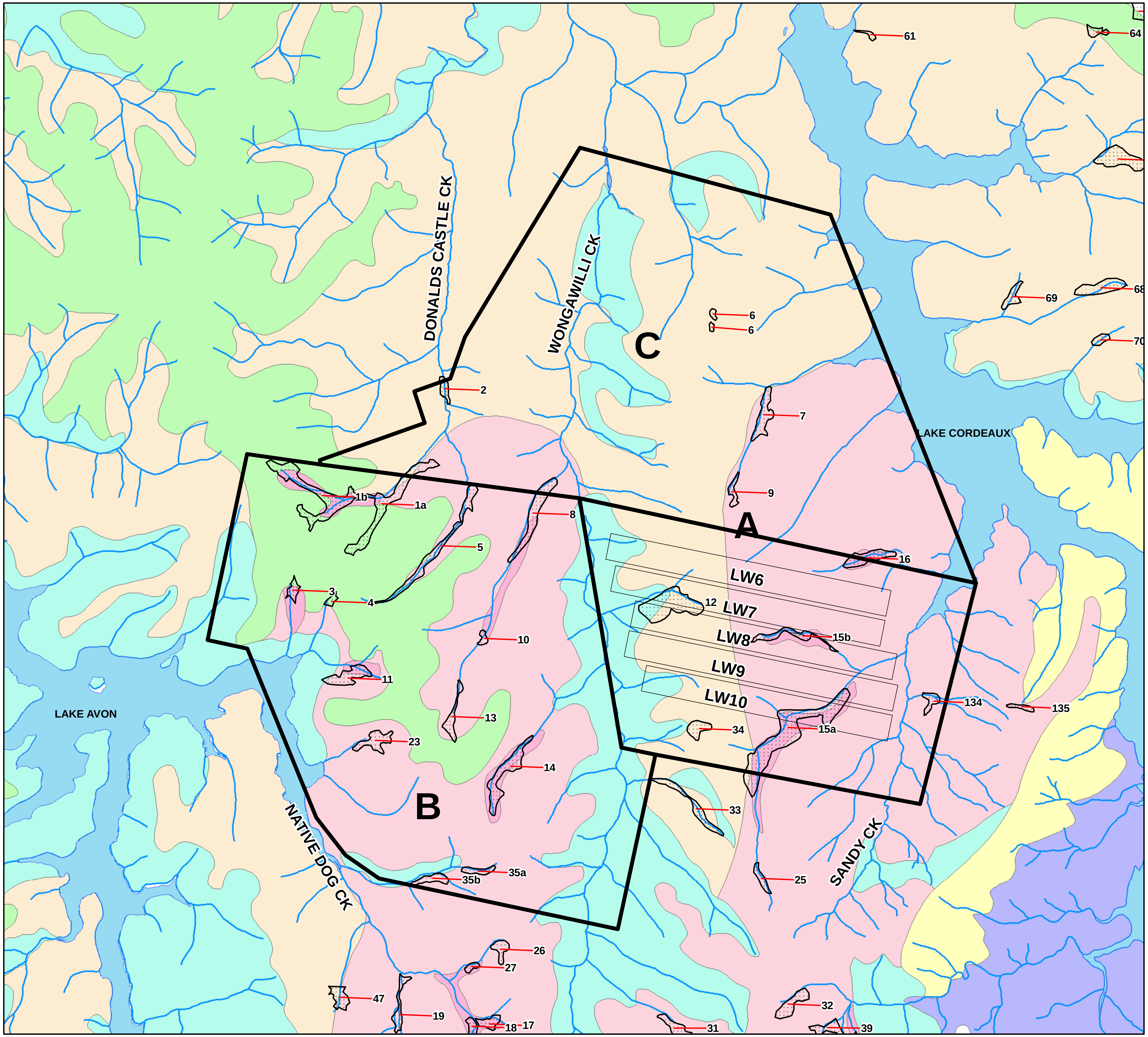
Scale 1:27000 (at A3)

Metres

0 255 510 1,020 1,530

Cardno Forbes Rigby

Map Produced by Cardno Forbes Rigby Pty Ltd
Date: 24 September 2007
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
107055-02_2804_Slope.mxd



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Soil Landscapes

DENDROBIUM AREA 3

Legend

Layer

- Mine Layout - SMP Areas
- Rivers & Creeks
- Swamps
- Site Boundary
- Waterbodies

Soil Landscape/Erosion Hazard *

- Hawkesbury (COha) - Extreme
- Warragamba (COwb) - High-Extreme
- Avoca (ERav) - High
- Gymea (ERgy) - High-Extreme
- Penrose Variant A (ERpea) - Moderate-High
- Lucas Heights (RElh) - Moderate
- Stockyard Swamp (SWss) - Moderate-High

* Concentrated flow erodibility

N
W E
S

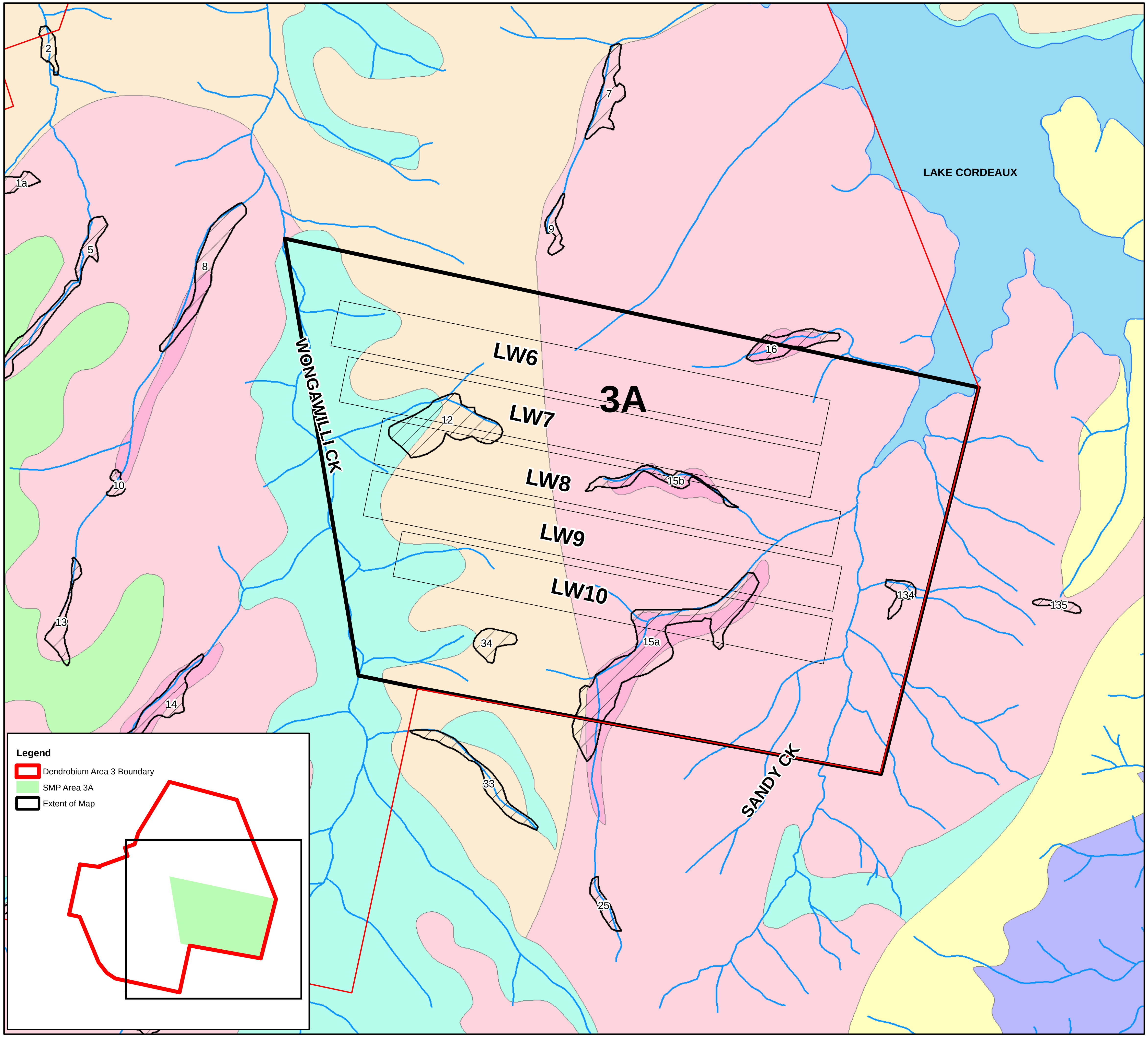
FIGURE 3.3

Scale 1:35,000 (at A3)

Metres
0 250 500 1,000 1,500

Cardno Forbes Rigby

Map Produced by Cardno Forbes Rigby
Date: 17 July 2007
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
107055_02_2812_Soil_Landscapes.mxd



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Soil Landscapes

DENDROBIUM AREA 3A

Legend

- Mine Layout - SMP Area 3A
- Creeks & Rivers
- Waterbodies
- SMP Area 3A
- Dendrobium Area 3 Boundary
- Swamps

Soil Landscapes/Erosion Hazard *

- Hawkesbury (COha) - Extreme
- Warragamba (COwg) - High-Extreme
- Avoca (ERav) - High
- Gymea (ERgy) - High-Extreme
- Penrose Variant A (ERpea) - Moderate-High
- Lucas Heights (RElh) - Moderate
- Stockyard Swamp (SWss) - Moderate-High

* Concentrated flow erodibility

N
W
E
S

FIGURE 3.4

Scale 1:20,000 (at A3)

Metres
0 250 500 1,000

Cardno Forbes Rigby

Map Produced by Cardno Forbes Rigby
Date: 17 July 2007
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
107055_02_2813_Soil_Landscapes_Site3A.mxd

The total width of disturbance, therefore, provides a conservative estimate of the total width of observed rockfalls. Note that the length of ridgelines in Dendrobium Area 1 are significantly longer than the Cliffs in Area3. Refer **Figure 3.2**.

The width of cliffline disturbed as a result of the extraction of Dendrobium Longwalls 1 and 2 (in Area 1) was between approximately 7 and 10 % of the total plan length of cliffline, where the longwalls mined directly beneath the cliffs. The percentage of disturbed cliffline, resulting from the extraction of the proposed longwalls in Areas 3A, is expected to be similar to that observed in Area 1. (MSEC 2007).

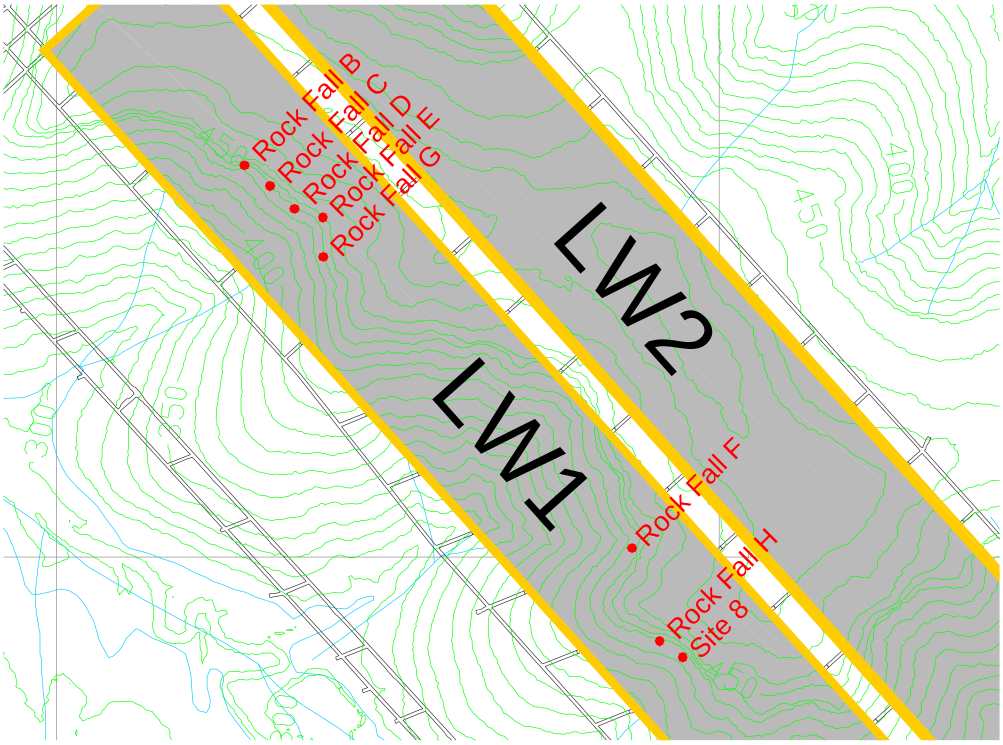


Figure 3.5 - Locations of Observed Rockfalls above Longwall 1 in Area 1 at Dendrobium Mine

Details of the observed rockfalls along the ridgeline above Longwall 1 in Area 1 at Dendrobium Mine are provided in **Table 3.1**.

Table 3.1 - Observed Disturbances along the Ridgeline above Dendrobium Area 1 Longwalls

Location	Approximate Width of Disturbance (m)	Approximate Height of Disturbance (m)	Total Height of Cliff (m)
Rock Fall B	35 ~ 45	5 ~ 15	20
Rock Fall C	10 ~ 15	6	13
Rock Fall D	10 ~ 15	4	18
Rock Fall E	15 ~ 20	5	5
Rock Fall F	50 ~ 60	10	10
Rock Fall G	5	3	7
Rock Fall H	10 ~ 15	6	20
Site 8	Rock fragments only		

Since the combined length of cliffs DA3-CF7 and DA3-CF8 within Area 3A is 50 metres (refer **Table 3.2** below), we could use the previous experience of Dendrobium Area 1 as a guide to predict that it is probable that up to 10% of the length of cliffline undermined by Area 3A may experience rockfalls, however since this would only equate to a length of 5 metres, and most rockfalls observed in Area 1 were 5-20 metres in width, it is more appropriate to consider that the clifflines (of shorter length) in Area 3A have approximately a 10% chance of experiencing a rockfall.

Table 3.2 - Details of the Cliffs within the 3A SMP Area

Cliff ID	Overall Length (m)	Maximum Height (m)
DA3-CF13	100	10
DA3-CF14	300	15
DA3-CF15	100	15
DA3-CF16	70	10
DA3-CF17	280	10
DA3-CF18	180	15
DA3-CF7	25	15
DA3-CF8	25	10
DA3-CF2	20	15
DA3-CF3	15	15
DA3-CF5	85	25

(Source: MSEC 2007)

The maximum predicted systematic tensile and compressive strains at the cliffs in Area 3A which are located outside the longwall goaf areas are 1.4 mm/m and 0.4 mm/m, respectively, at Cliffs DA3-CF17 and DA3-CF18, respectively. Although previous experience in the Southern Coalfield indicates that very few rockfalls have occurred outside longwall goaf areas, and none of these have occurred in the Dendrobium area, the magnitude of these strains means that there is a possible risk of Cliffs DA3-CF17 and DA3-CF18 experiencing rockfalls adjacent to Longwall 10, but the percentage of disturbed cliffline is expected to be very much less than that observed in Area 1.

Similarly, the cliffs along the alignment of Wongawilli Creek in Areas 3B and 3C, which are not directly mined beneath, are expected to be subjected to similar magnitudes of strain, and the percentage of disturbed cliffline is expected to be very much less than that observed in Area 1.

In summary then, we can say that:

- Within Area 3A, only cliffs DA3-CF7 and DA3-CF8 are undermined and can be viewed as having about a 10% chance of experiencing a rockfall, while Cliffs DA3-CF17 and DA3-CF18, which are immediately adjacent to Longwall 10 are at some risk of experiencing rockfalls due to the predicted systematic tensile strains.
- The cliffs in Areas 3B & 3C, which are undermined are likely to experience some rockfalls. The extent of these would be expected to less than 10% of their length.
- The cliffs in Areas 3B & 3C, which are not undermined are much less likely to experience rockfalls with the percentage of disturbed cliffline is expected to be very much less than that observed in Area 1.
- Cliffs in Areas 3B & 3C which are not directly undermined and are some distance (eg. Several hundred metres) from the goaf area are not likely to experience rockfalls.

The size and extent of previous rock falls observed in Dendrobium Area 1 were identified as minor impacts under the impact assessment trigger levels outlined in the Landscape monitoring plan. GSS (2005). The nature of these rock falls is presented photographically in **Figure 3.6** taken from the monitoring reports from GSS.

3.3.2. Impact Assessment for Rock Outcrops

MSEC define rock outcrops as typically discontinuous and having a maximum continuous height of less than 5 metres. They are not represented on figures as they are scattered densely across the landscape.

The total width of disturbance resulting from the extraction of Area 1 (Longwalls 1 and 2) was approximately 135 to 175 metres.

The total plan length of ridgeline located directly above the Dendrobium Area 1 longwalls is approximately 1800 to 2000 metres. It should be noted that there are two levels of cliff in some locations and, therefore, the total length of cliffline/rocky outcrop is greater than the total plan length of the ridgeline. (MSEC 2007)

The width of ridgeline disturbed as a result of the extraction of Longwalls 1 and 2 was, therefore, between approximately 7 and 10 % of the total plan length of ridgeline directly above the longwalls. The width of rockfalls which occurred as a result of the extraction of Longwalls 1 and 2 was, however, less than the width of disturbed ridgeline. (MSEC 2007)

Previous experience in the Southern Coalfield indicates that the percentage of rock outcrops that are likely to be impacted by mining is small. Rockfalls are more likely to occur where rock outcrops are continuous, massive, overhanging and marginally stable. (MSEC 2007). It is expected, therefore, that a lower percentage of the rock outcrops above the proposed Area 3A longwalls would be impacted than that observed in Dendrobium Area 1 because aerial photography and site inspections show that the rock outcrops in Area 3A are not as continuous and massive as those in Area 1. This is also the assessment for Areas 3B and 3C.

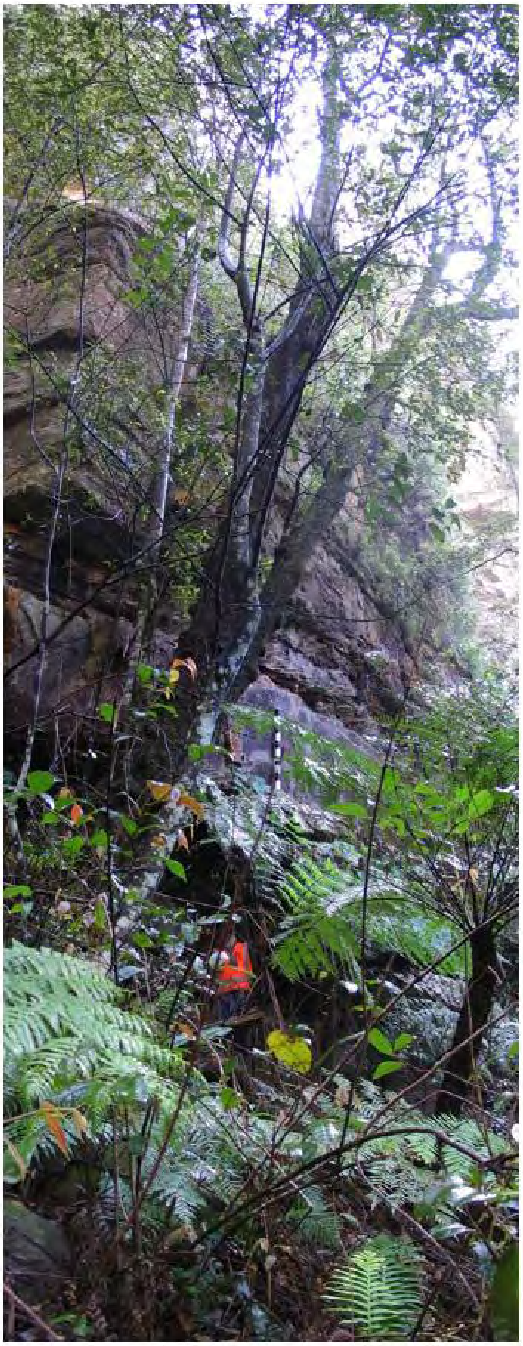
3.3.3. Impact Assessments for the Steep Slopes

MSEC define steep slopes as an area of land having a gradient between 1 in 3 (ie: a grade of 33 %, or an angle to the horizontal of 18°) and 2 in 1 (ie: a grade of 200 %, or an angle to the horizontal of 63°). **Figure 3.2** shows the results of the slope analysis and mapped areas of steep slopes. Numerous steep slopes exist over the proposed mining area and they lie in various orientations compared to the proposed Longwalls.

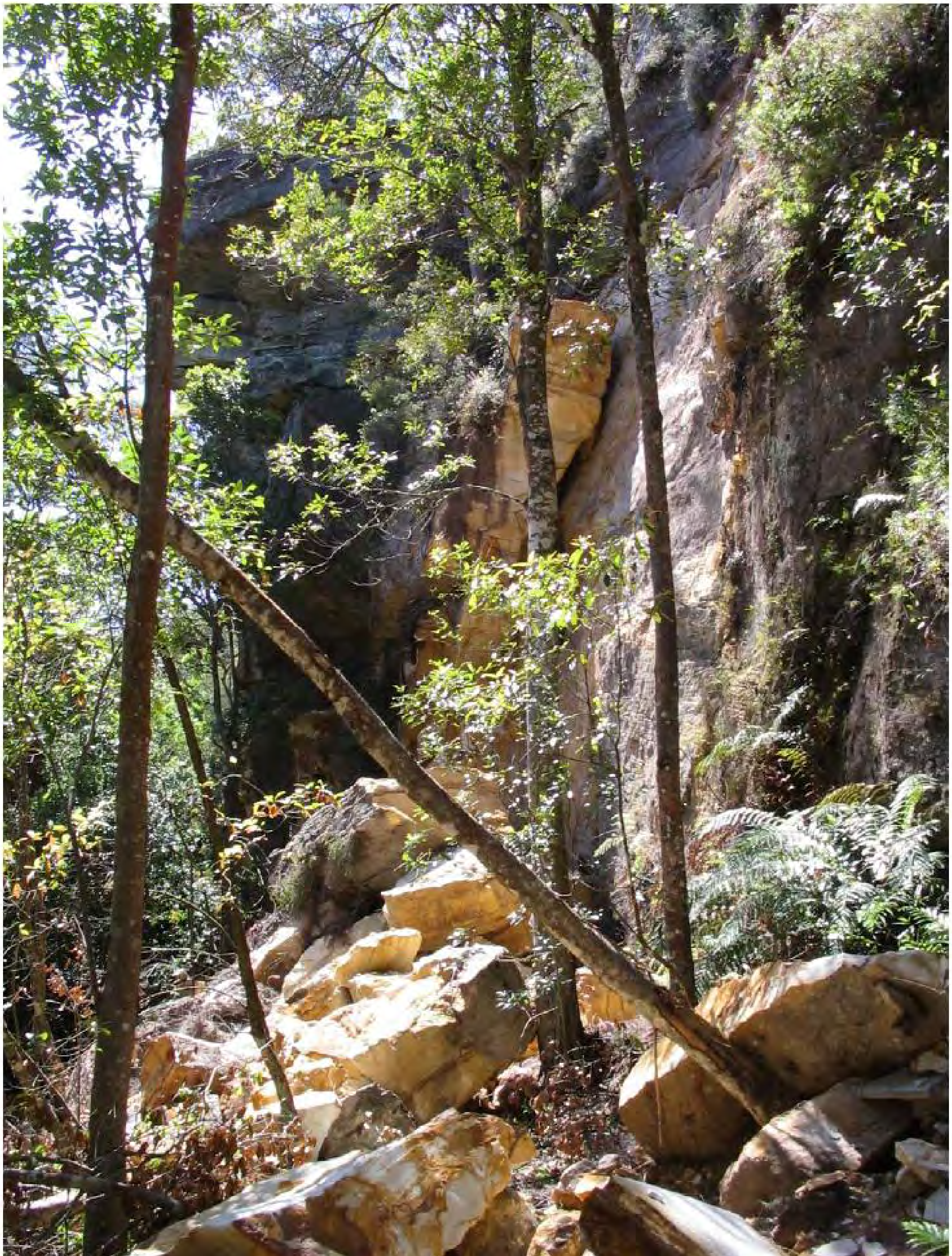
The maximum predicted tilt at the steep slopes, resulting from the extraction of the proposed longwalls, is 23 mm/m (ie: 0.2 %), or a change in grade of 1 in 45. The steep slopes are more likely to be impacted by the systematic strains, rather than tilt, as the maximum predicted tilt is small when compared to the existing surface gradients of the steep slopes. (MSEC 2007)

The maximum predicted systematic tensile and compressive strains at the steep slopes, resulting from the extraction of the proposed longwalls, are 4.5 mm/m and 12 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted tensile and compressive strains are 3.3 kilometres and 1.3 kilometres, respectively. (MSEC 2007).

Figure 3.6 Area 1 Landscape Impact Photographs
(from GSS Monitoring Reports 2004-2005)

CLIFF SITE: 08	
	
November 2004 (Photo Date)	December 2005 (Photo Date)
Rep_Site 8 Cliff_stitched (23&24).jpg	Site 8 stitched (39&40).jpg
	'*negligible*' impact

ROCK FALL SITE: B



IMG_1731_rock fall B.jpg	December 2005 (Photo Date)

'*minor*' impact

ROCK FALL SITE: C

IMG_1733_rock fall C.jpg	December 2005 (Photo Date)

'*minor*' impact

ROCK FALL SITE: D	
	
IMG_1734_rock fall D.jpg	December 2005 (Photo Date)
'minor' impact	

ROCK FALL SITE: E	
	
Site E Stitched (01&02).jpg	August 2005 (Photo Date)
'minor' impact	

ROCK FALL SITE: F	
	
Rock Fall F stitched (45&46).jpg	December 2005 (Photo Date)
'*minor*' impact	

FIRETRAIL CRACK: 01

IMG_1470_firetrail crack 1.jpg	August 2005 (Photo Date)

'moderate' impact

ROCKFALL: UNIDENTIFIED SITE

Rock Fall Dendrobium Area 1.ppt	November/December 2005 (Photo Date)

This photo was taken by a third party, and it is presumed to be of one of the Rock Falls B, C, D, E or F.

The maximum predicted systematic tensile strains at the steep slopes are likely to be of sufficient magnitude to result in surface cracking. The maximum predicted compressive strains at the steep slopes are likely to be of sufficient magnitude to result in the buckling of underlying strata, which could in turn result in surface cracking, where the depths of the overlying soils are shallow. (MSEC 2007).

It is also possible that the maximum predicted systematic strains could result in the slippage of soils down the steep slopes, resulting in tension cracks at the tops of the slopes and compressive ridges at the bottoms of the slopes. These movements are consistent with observations of upsidence and closure in creek valleys where compression is developed at the bottoms of the valleys and tension is developed at the tops of the valleys. (MSEC 2007).

The natural grades of the steep slopes across Area 3 are generally less than the natural grades of the steep slopes in Dendrobium Areas 1 and 2. In addition to this, the depths of cover across Areas 3 are generally greater than the depths of cover in Areas 1 and 2 at the mine. (MSEC 2007). It is likely, therefore, that the maximum size and extent of surface cracking at the steep slopes within Area 3 will be less than that observed during the extraction of Area 1 and Longwall 3 in Area 2.

Several cracks of have been observed in Areas 1 and 2 with the majority of these being identified as negligible or minor impacts under the impact assessment trigger levels. Refer **Figure 3.6** for photos in Area 1. The most significant crack in Area 1 was up to 350mm in width and 270m long. Monitoring has found it is stable and is identified as a moderate impact. GSS (2005, 2006, 2007). Refer **Figures 3.7** and **3.8** for crack locations.

An inspection of the Dendrobium Longwall 3 goaf area in Area 2 (undertaken 18 June) identified a zone of down slope soil movement consisting of a series of sub parallel surface cracks on the uphill slopes draining to Creek 11. Refer **Figure 3.8.** Each zone consists of up to five cracks with an average strike of 203 deg mag. The width of cracking in these zones is mostly <0.1m with a maximum width of 0.2m. The cracking is an extension of cracking reported earlier (25/05/07) but are much less pronounced and discontinuous. The cracking occurs parallel to the slope for approximately 150m. The likely mechanism resulting in the cracking was assessed as mining induced systematic tensile strain and associated down slope movements. With respect to the Trigger Levels contained in the subsidence landscape monitoring and management program (SLMMP) the impact in Area 2 is considered minor.

The inspection also aimed to identify any erosion or sedimentation associated with recently identified soil cracking over Longwall 3. The cracking previously reported over Longwall 3 was found to be substantially the same as previous inspections and no significant erosion or sedimentation impacts were observed.

It is unlikely that mine subsidence within the proposed Area 3 will result in any large-scale slope failure, since such failures have not been observed as the result of longwall mining in the Southern Coalfield. (MSEC 2007)

If any significant cracking were left untreated, soils erosion channels could potentially develop within the drainage lines. It is noted that soil landscape mapping presented in **Figure 3.3** shows that of the four soil landscapes identified in Area 3A, the Hawkesbury and Gymea landscapes (located in the western half of Area 3A) are associated with a higher erosion hazard for concentrated flow erodibility than the two landscapes located in the east of Area 3A. The erosion hazard for concentrated flow erodibility of the Hawkesbury (extreme) and Gymea (high-extreme) landscapes contrast with the Penrose Variant A (moderate –high) and Stockyard Swamp (moderate –high) landscapes. Therefore we assess there is a higher erosion hazard from rock fall and cracking impacts that occur in the western portion of Area 3A than that expected in the eastern portion of Area 3A.

It is recommended that appropriate remediation measures are undertaken in already disturbed areas such as roads or easements, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. With these remediation measures in place, it is unlikely that there would be any significant impact on the environment.

Long Sections showing the existing ground surface and the predicted post mining ground surface are presented in sheets 1 and 2 of **Appendix A**. These sections have been drawn (from the 20mm subsidence contour on either end of the section) across the proposed mining area where the *greatest areas of steep slopes are located*, as indicated on **Figure 3.1**.

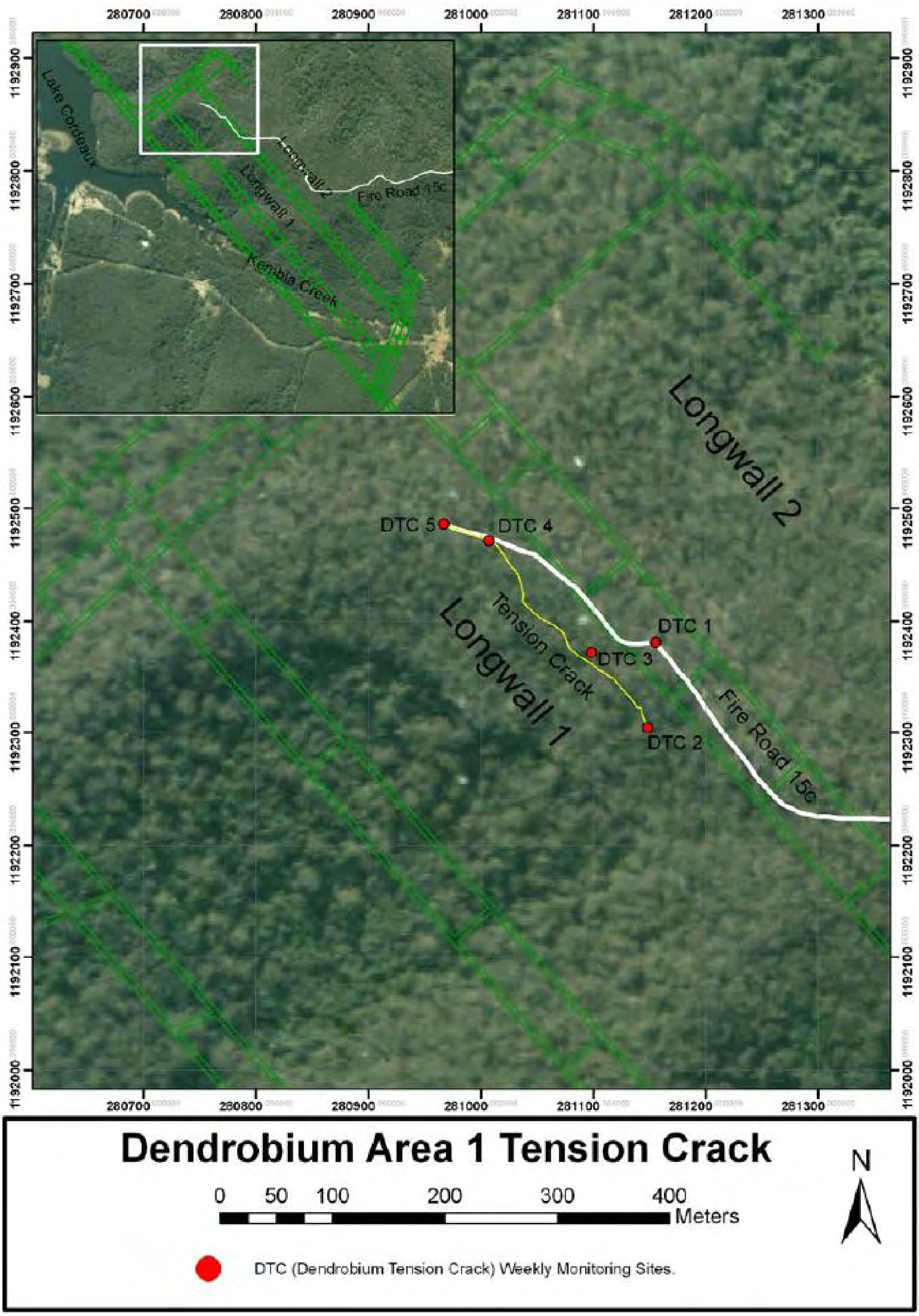
The sections show the existing ground surface and the predicted post mining ground surface to an exaggerated vertical scale in order to show a difference in the surfaces. The sections show the stark changes in elevation across the area, and where these changes in elevation lie in relation to the proposed longwalls in Area 3A.

The monitoring results in Dendrobium Area 1 and 2 show that the surface cracks observed (which are assumed to be mining induced), occur in areas of the subsidence trough that would be associated with the areas of highest predicted tensile strains. Refer to **Figure 2.2.**

This can be observed in the following **Figures 3.7** and **3.8** which show the location of cracking observed in landscape monitoring Dendrobium Areas 1 and 2. Note the cracking is located just within and parallel to the edges of the longwall in both cases.

Sections 1 and 2 (**Appendix A**) lay across the areas of steepest slopes located in Area 3A, and the most likely zones of tensile cracking that may be expected to occur are noted on the sections.

As these sections also lay across incised drainage lines, the beds of these minor watercourses (WC14, WC17, WC19) will be subject to upsidence and closure movements and potential impacts associated with compressive buckling of strata, as also indicated on the sections.



Figures 3.7 - Tension Cracks Observed in Area 1

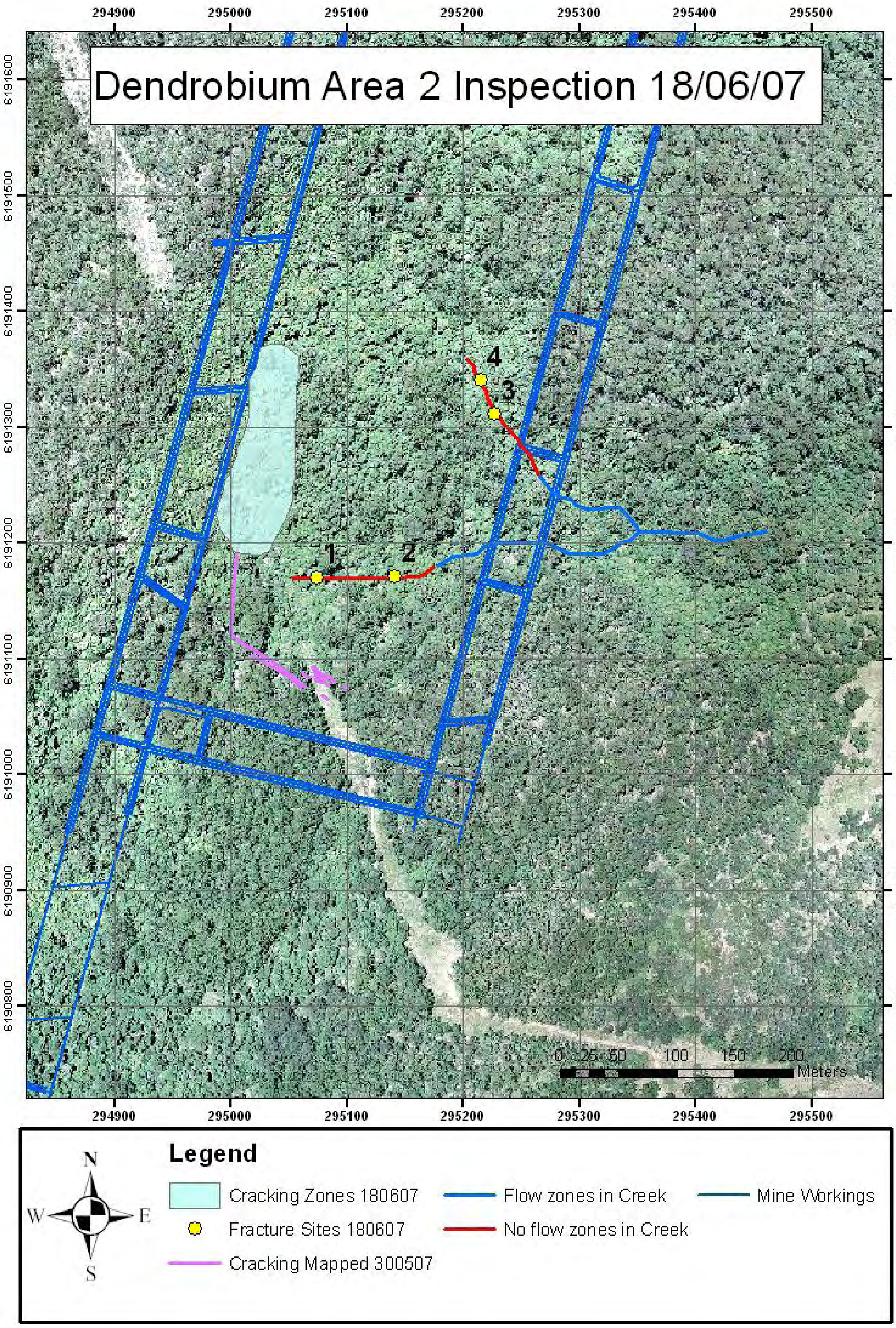


Figure 3.8 - Tension Cracks Observed in Area 2

3.3.4. Impact Assessments for Fire Roads

Figure 3.1 shows that Fire Roads 6F and 6C follow ridgelines located above the proposed longwall panels. Fire Road 6F runs across the proposed Area 3A longwall panels and for the most part is oriented perpendicular to (or transversely) to the longwall panels. Fire Road 6C runs diagonally across the proposed Area 3A longwall panel 6 and 7.

Sections of Fire Roads 6F and 6C showing the existing ground surface and the predicted post mining ground surface are presented in **Appendix A.** These sections have been drawn from the 20mm subsidence contour on either end of the section, as shown on the layout plan in **Appendix A.**

The maximum predicted total subsidence along Fire Road 6C of 1855 mm occurs above Longwall 7. The maximum predicted total subsidence along Fire Road 6F of 1780 mm occurs above Longwall 9 after the extraction of Longwall 10.

The maximum predicted tilt along the fire trails, at any time during or after the extraction of the proposed longwalls, is 14 mm/m (ie: 1.4 %), or a change in grade of 1 in 70, which occurs along Fire Road 6F above the maingate of Longwall 10. It is unlikely that the predicted tilts would result in any significant changes in the surface water drainage along the trails, as the maximum predicted changes in grades are an order of magnitude smaller than the existing gradients along the trails, which are as high as 200 mm/m (20%) in the steepest sections. (MSEC 2007).

The maximum predicted systematic tensile and compressive strains at the trails, at any time during or after the extraction of the proposed longwalls, are 3.2 mm/m and 5.2 mm/m, respectively, which occur along Fire Roads 6C and 6F, respectively. (MSEC 2007)

Tensile strains greater than 0.5 mm/m may be of sufficient magnitude to result in cracking in the unsealed surfaces of the trails. Compressive strains greater than 2 mm/m may be of sufficient magnitude to result in the underlying strata to buckle and fracture, which could induce cracking in the unsealed surfaces of the trails. (MSEC 2007)

Therefore the fire roads will experience the full range of subsidence movements and surface cracks may occur along the fire roads over the goaf areas.

Fire Road Impacts Observed in Areas 1

Extraction from Dendrobium Area 1 commenced in March 2005. Monthly monitoring of Landscape impacts was conducted by GSS for from April 2005 to mid 2006.

These inspections identified some cracking of the firetrail which traverses the Area 1 goaf areas. The most significant crack (#1) was identified near the northern end of the firetail, which had a length of about 270m and maximum width (between crack walls) of 350 mm. With respect to the Trigger Levels contained in the subsidence landscape monitoring and management program (SLMMP) the impacts at this site are considered to be *moderate*. The location of the crack is shown in **Figure 3.7**, and a photo of the crack is shown in **Figure 3.6**. In a small number of locations along the crack the edge material has broken away to form a width of approximately 1m. Detailed monitoring by IC has shown that this crack has remained in relatively unchanged condition since it was initially observed.

A second crack (#2) was observed through the firetail, which had a maximum width (between crack walls) of 100 mm. With respect to the Trigger Levels contained in the subsidence landscape monitoring and management program (SLMMP), the impacts are considered to be *negligible*. A photo of the crack is shown in **Figure 3.6.**

A new firetrail crack (# 3) was observed approximately 20 metres north-west along the firetrail from the remediated firetrail crack (#1). Refer **Figure 3.8**. The new firetrail crack (# 3):

- is located along the centreline of the firetrail at GPS 297137 E & 6191592 N (AMG);
- consists of a closed 'hairline' fracture and an open section. The open section has a maximum inside width of approximately 120 mm, and a maximum width at the surface of 180 mm;
- extends for a total length of about 8 metres, with the open part of the crack being
- approximately 2 metres in length; and
- does not prevent safe vehicle passage and is not expected to cause erosion.
- With respect to the Trigger Levels contained in the SLMMP the impact of the firetrail crack (#3) is considered to be *Minor*.

Based on the subsidence predictions, location of Fire Roads in Area 3 (which traverse goaf areas) and the experiences of Area 1 then, it may be expected that cracking of the firetrails in throughout areas 3A, 3B, and 3C may occur in certain locations where undermined. Cracking would be expected to constitute negligible, minor or moderate impacts as experienced in Area 1.

It would be expected that the trails could be easily repaired using normal road maintenance techniques, by filling, regrading and recompacting the unsealed trail surfaces. With these remediation measures implemented, the trails can be maintained in a safe and serviceable condition throughout the mining period.

3.4. LOCATIONS AT GREATEST POTENTIAL RISK AND PROPOSED MONITORING

Based on the subsidence predictions, the location of landscape features in Area 3A and the experiences of Dendrobium Area 1 and 2, the locations of cliffs, slopes and fire roads at greatest risk of subsidence impacts such as rock falls, tensile cracking and subsequent erosion within Area 3A are:

- Cliffs DA3-CF7 and DA3-CF8;
- Cliffs DA3-CF17 and DA3-CF18, immediately adjacent Longwall 10;
- The Rock outcrops occurring on steep slopes *within Goaf areas*.
- The Steep slopes above 30 degrees within Goaf areas with risk increasing with slope gradient.
- Fire roads over goaf areas.

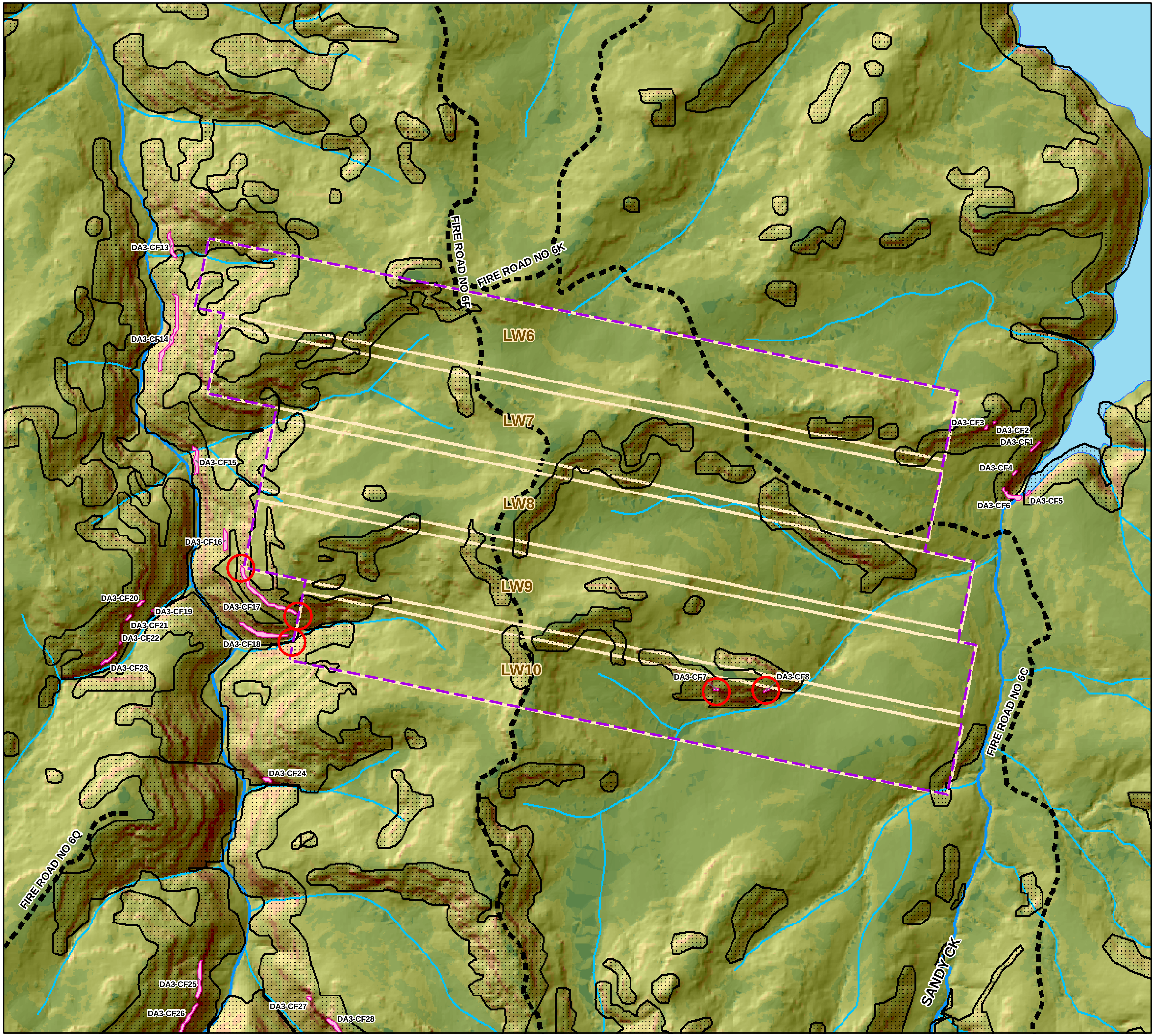
For all of these features, those located at the side of the subsidence trough in positions of maximum compressive and tensile strain would generally suffer the greatest impact. These locations are indicated in sections 1 and 2 of **Appendix A.**

Within Areas 3B and 3C, the locations of cliffs, slopes and fire roads at greatest risk of subsidence impacts such as rock falls, tensile cracking and subsequent erosion within Area 3A are:

- Cliffs located within *Goaf areas*;
- The Rock outcrops occurring on steep slopes *within Goaf areas*.
- The Steep slopes above 30 degrees within Goaf areas with risk increasing with slope gradient.
- Fire roads over goaf areas

Landscape impacts in Areas 3B and 3C will be assessed in detail as part of the SMP assessment process for each area, when the exact mine layout will be known.

Refer **Figure 3.9**, a plan of cliffs, slopes and fire roads with greatest predicted risk of landscape impacts in Area 3A. The locations identified in this plan have been inspected in order to ground truth the data and identify the proposed monitoring locations as outlined in section 5 in order to prepare the monitoring plan.



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Cliffs, Slopes and Fire Roads with the Greatest Predicted Risk

DENDROBIUM AREA 3A

FIGURE 3.9

- Mine Layout - SMP Area A
- Fire Roads
- Creeks
- Minor Streams
- Cliffs (IC)
- Area of greatest predicted risk of landscape impacts
- Steep Slopes
- Lakes
- Cliffs of greatest potential risk

SLOPE CLASS (Handbook)	SLOPE RANGE (Degrees)	% Within SMP Area
Level (LE)	<0º 35'	2.30%
Very gently inclined (VG)	0º35' - 1º45'	0.47%
Gently inclined (GE)	1º45' - 5º45'	33.48%
Moderately inclined (MO)	5º45' - 18º	51.01%
Steep (ST)	18º - 30º	10.27%
Very Steep (VS)	30º - 45º	2.18%
Precipitous (PR)	45º - 72º	0.29%

Scale 1:13,000 (at A3)

Metres
0 100 200 300 400 500

Cardno Forbes Rigby

Map Produced by Cardno Forbes Rigby Pty Ltd
Date: 24 September 2007
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
107055-02_2816_Slope_3A.mxd