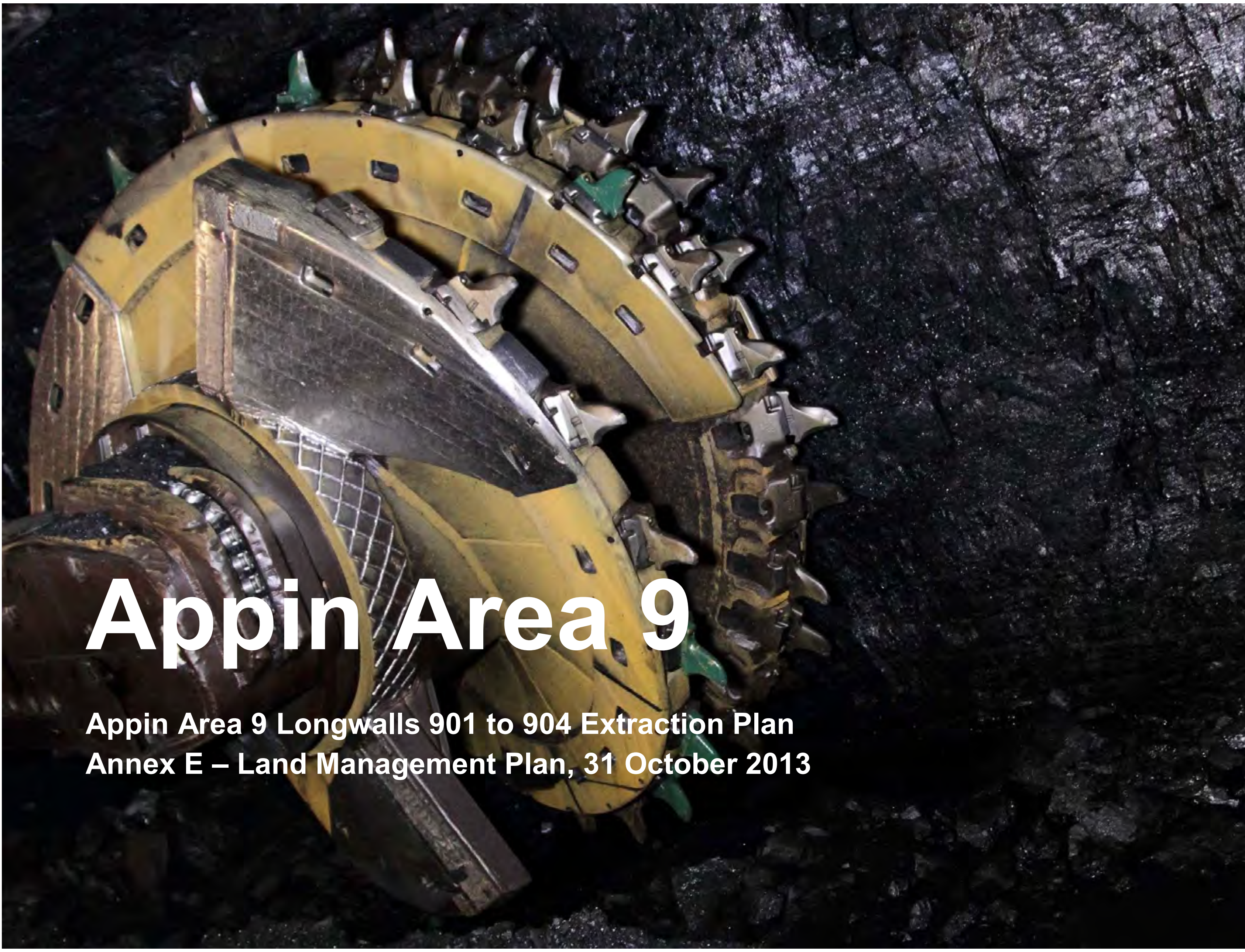
Illawarra Coal



Appin Area 9

Appin Area 9 Longwalls 901 to 904 Extraction Plan
Annex E – Land Management Plan, 31 October 2013

Table of Contents

Tables

Figures

Attachments

Review History

Revision	Description of Changes	Date	Approved
A	New Document	21 December 2011	
B	Final Document (revised with comments from BHBIC)	16 January 2012	
C	Final – Updated with new Mine Plan	1 May 2012	
D	Final – Updated with Agency Comments	31 October 2013	

Persons involved in the development of this document include:

Name	Title	Company
Daniel Thompson	Environmental Planner	Cardno
Danyil Skora	Senior Environmental Planner	Cardno
Gary Brassington	Manager Approvals (Mining)	BHP Billiton Illawarra Coal

1 INTRODUCTION

1.1 PROJECT BACKGROUND

BHP Billiton Illawarra Coal (BHPBIC) operates the Bulli Seam Operations (BSO) (Appin and West Cliff Collieries) extracting hard coking coal used for steel production.

On 22 December 2011 the Planning and Assessment Commission (PAC), under delegation of the Minister for Planning, approved BSO (MP 08_0150) under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to continue mining operations until 2041.

This Land Management Plan (LMP) supports the Longwall 901 to 904 Extraction Plan for mining of coal from Longwalls 901 to 904 in Appin Area 9 (AA9). The relationship between this LMP and the other components of the Extraction Plan is shown in Figure 1 of the Extraction Plan.

1.2 SCOPE

This LMP has been prepared by Cardno on behalf of BHPBIC in accordance with the BSO Approval *Condition 5(j), Schedule 3* as follows:

> 5. *The Proponent shall prepare and implement an Extraction Plan for first and second workings within each longwall mining domain to the satisfaction of the Director-General. Each extraction plan must:...*
>
> *(j.) include a Land Management Plan, which has been prepared in consultation with any affected public authorities, to manage the potential impacts and/or environmental consequences of the proposed second workings on land in general, with a specific focus on cliffs and steep slopes;*

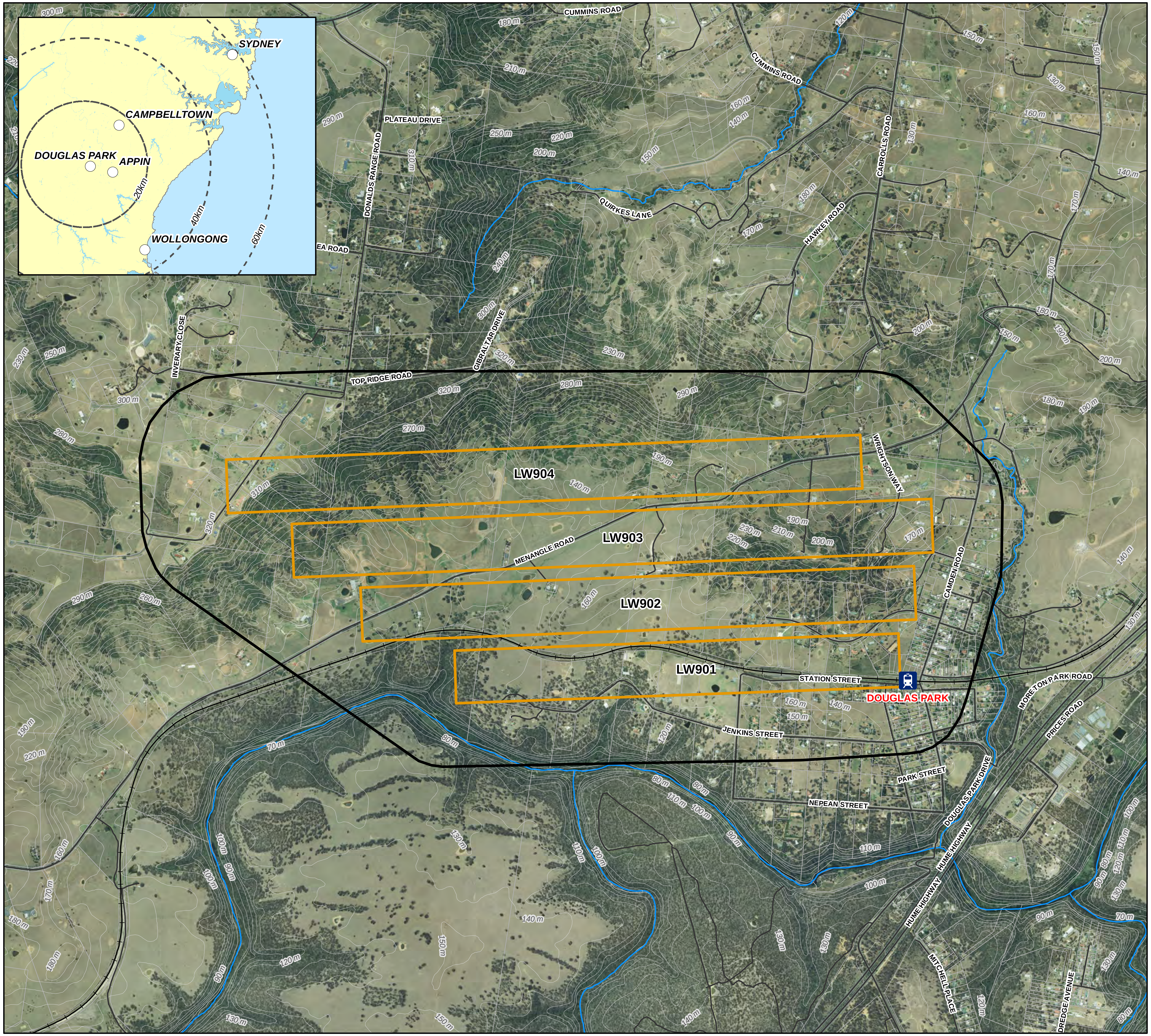
The Study Area for the Extraction Plan (refer **Figure 1**) is defined in accordance with MSEC (2012) as *the surface area predicted to be affected by the proposed mining of Longwalls 901 to 904 and encompasses the areas bounded by the following limits:-*

- *A 35° Angle of Draw line from the maximum depth of cover, which equates to a horizontal distance varying between 345 metres and 510 metres around the limits of the proposed extraction areas proposed for Longwalls 901 to 904, and*
- *The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the proposed Longwalls 901 to 904.*

Additionally, features potentially sensitive to far field movements, which includes horizontal, valley closure and upsidence movements that may be outside the 20 mm subsidence zone or 35° Angle of Draw line have been assessed.

The Study Area also includes cliffs within the valley of the Nepean River; and Harris Creek as they overhang Douglas Park Drive, as well as a larger slope stability study which extends into the Razorback Range. It is noted that while the Study Areas do traverse the Nepean River and Harris Creek, there is no proposed longwall mining beneath these watercourses.

Figure 2 illustrates the Study Area and the steep slopes, cliffs and rock outcrops for Longwalls 901 - 904, to which the Extraction Plan applies.



Appin Area 9
(LW 901- 904)
Study Area

Legend

- 🚉 Railway Stations (LPI)
- — Local Roads (LPI)
- ┼┼ Railway (LPI)
- — 10m Contours (LPI)
- — Watercourses (LPI)
- ☐ Cadastre (LPI)
- ☐ AA9 Longwall Layout
- ☐ Longwalls 901-904 Study Area

N
W E
S

FIGURE 1

Scale 1:20,000 (at A3)

Kilometres
0 0.25 0.5 0.75 1

Map Produced by Cardno Wollongong
Date: 31/10/2013
Coordinate System: GDA 1994 MGA Zone 56
Project: 109012-03
Map: 1801_AppinArea9_LW_StudyArea.mxd 07

Aerial imagery supplied by BHPBIC (2009)

1.3 OBJECTIVES

The objectives of this LMP are to identify at risk land geomorphology and manage the potential impacts and/or environmental consequences of the proposed workings on the land.

Specific focus will be on cliffs and steep slopes including cliffs of 'special significance' (i.e. longer than 200 m and/or higher than 40 m and cliff like rock faces higher than 5 m that constitute waterfalls, as defined by BSO approval *Condition1, Schedule 3*), and other cliffs flanking the Nepean River, as shown in **Figure 2** and the drawing in MSEC (2012), Drawing No. MSEC448-12

1.4 DISTRIBUTION

The finalised LMP will be distributed to:

- Department of Planning and Infrastructure (DP&I)
- Wollondilly Shire Council (WSC).

The Project Approval requires this LMP be developed in consultation with any potentially affected public authorities.

The Extraction Plan for Longwalls 901-904 will be developed in consultation with WSC.

Arrangements for individual private properties and assets will be made in the relevant Property Subsidence Management Plans (PSMPs) and or asset agreements to be negotiated with the property owners.

BHPBIC will make the LMP and other relevant documentation publicly available on the BHPBIC website (*Condition 11, Schedule 6*).

2 STATUTORY REQUIREMENTS

Extraction of coal from Longwall 901 to 904 will be in accordance with the conditions set out in the BSO Approval, applicable legislation as detailed in **Section 2.2** and the requirements of relevant licenses and permits (including conditions attached to mining leases).

2.1 BSO APPROVAL

Condition 5(j), Schedule 3 of the BSO Approval requires the preparation of an LMP to manage the potential impacts and/or environmental consequences of the proposed workings on land, including a specific focus on cliffs and steep slopes (refer **Section 1.3**).

This LMP also addresses the requirements detailed in *Condition 6, Schedule 3* and *Condition 2, Schedule 6* of the BSO Approval as shown in **Table 2.1**.

Table 2.1 – Management Plan Requirements

Project Approval Condition	***Relevant LMP Section***
Condition 6 - Schedule 3 The Proponent shall ensure that the management plans required under *Condition 5 (g)-(l)* above include: (a) an assessment of the potential environmental consequences of the Extraction Plan, incorporating any relevant information that has been obtained since this approval; (b) a detailed description of the measures that would be implemented to remediate predicted impacts.	Section 4 Section 7
Condition 2 - Schedule 6 The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include: (a) detailed baseline data; (b) a description of: - the relevant statutory requirements (including any relevant approval, licence or lease conditions); - any relevant limits or performance measures/criteria; (c) a description of the measures that would be implemented to comply with the relevant statutory, limits, requirements or performance measures/criteria; (d) a program to monitor and report on the: - impacts and environmental performance of the project; - effectiveness of any management measures (see c above); (e) a contingency plan to manage any unpredicted impacts and their consequences and to ensure that ongoing impacts reduce to levels below relevant impact assessment criteria as quickly as possible; (f) a program to investigate and implement ways to improve the environmental performance of the project over time; (g) a protocol for managing and reporting any: - incidents; - complaints; - non-compliances with statutory requirements; and - exceedances of the impact assessment criteria and/or performance criteria; and (h) a protocol for periodic review of the plan.	Section 3 Section 2 Section 5 Sections 5 to 8 Sections 5 to 8 Section 6 Section 8 Section 10 Section 9 Section 10

Due consideration has been given to all the BSO Approval Conditions in the preparation of this LMP, including those relating to auditing, rehabilitation and environmental management.

2.2 LEGISLATION AND GUIDELINES

This LMP has been developed with due regard to the requirements of the relevant legislation and advisory documents and guidelines including:

- *Australian Geomechanics Society Landslide Risk Management Guidelines*, 2007.
- *Australian Soil and Land Survey Field Handbook*, 2009.

2.3 RELEVANT LEASES AND LICENCES

The following leases and licences may be applicable to BHPBIC's operations in AA9:

- Mining Leases as per **Table 2.2**.
- Environmental Protection Licence (EPL) 2504 which applies to BSO, including Appin and West Cliff Mines. A copy of the licence can be accessed at the EPA website via the following link http://www.epa.nsw.gov.au/prpoeo/index.htm
- BSO Mining Operation Plan (MOP) 1/10/2012 to 30/09/2019 (V1)
- All relevant OH&S and HSEC approvals
- Any additional leases, licences and approvals resulting from the BSO Approval.

Table 2.2 – Appin Mine Leases, Licences and Other Reference Documents

Mining Lease - Document Number	Issue Date	Expiry Date/ Anniversary Date
CCL 767	29/10/1991	08/07/2029
CL 388	22/1/1992	21/01/2013 Renewal Pending
ML 1382	20/12/1995	19/12/2016
ML 1433	24/7/1998	23/07/2019

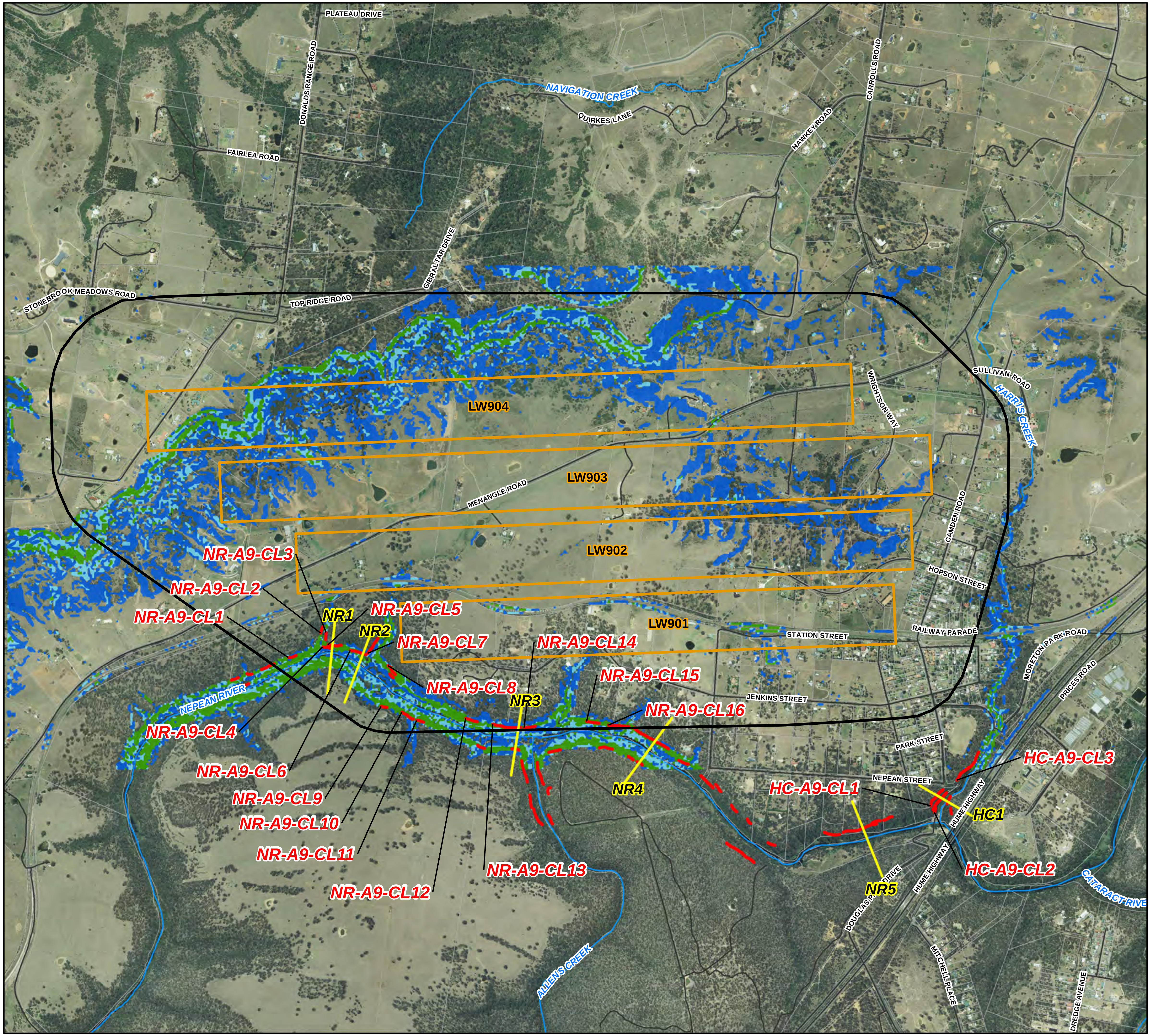
3 BASELINE ASSESSMENT

A Major Cliff Risk Assessment was conducted by BHPBIC (2009) for the BSO EA based on information provided by MSEC, Gilbert & Associates, FloraSearch and Biosis Research.

The Cliff Risk Assessment included a description of the BSO mine parameters and likely types of subsidence impacts that might occur, the identification of significant natural features including major cliff lines, cliff lines of special significance, and an assessment of the risk of impacts and consequences to each cliff line. The Study Area for the Major Cliff Risk Assessment included the Longwall 901 to 904 Study Area.

A revised Baseline Assessment of the cliffs, rock outcrops and steep slopes within the Study Area was conducted by MSEC (2012).

MSEC (2012) defines a *cliff* as a continuous rock face having a minimum height of 10 m and a minimum slope of 2 to 1 (i.e. having a minimum angle to the horizontal of 63 degrees). A *rock outcrop* is defined as an isolated rock-face having a height of less than 10 m. A *steep slope* is defined as an area of land having a natural gradient greater than 1 in 3 (i.e. grade of 33%, or an angle to the horizontal of 18°). The locations of cliffs, rock outcrops and steep slopes within the Longwall 901 to 904 Study Area are shown in **Figure 2**.



bhpbilliton
ILLAWARRA COAL

Location of Cliffs, Overhangs and Steep Slopes

APPIN AREA 9
LW 901-904

Legend

🟥	Cliffs (MSEC 2012)
🟨	Cross-Sections (MSEC 2012)
—	Local Roads (LPI)
—	Watercourses (LPI)
☐	Cadastre (LPI)
☐	AA9 Longwall Layout (BHPBIC)
☐	Longwalls 901-904 Study Area (MSEC 2012)

Steep Slopes (MSEC 2012)

🟩	1 in 1.5 to 1 in 1 Slope
🟦	1 in 2 to 1 in 1.5 Slope
🟦	1 in 3 to 1 in 2 Slope

N
W E
S

FIGURE 2

Scale 1:18,000 (at A3)

Kilometres
0 0.25 0.5 0.75 1

Cardno

Map Produced by Cardno Wollongong
Date: 25/10/2013
Coordinate System: GDA 1994 MGA Zone 56
Project: 109012-03
Map: 1809_Cliffs_SteepSlopes.mxd 01

Aerial imagery supplied by BHPBIC (2009)

Several additional studies have also been undertaken to increase the understanding of the baseline conditions, and potential impacts of mining on landscape features within the Longwalls 901 to 904 Study Area: These include the following:

- Nepean River Cliffs and Steep Slopes Management Plan (BHPBIC, 2012) – Refer **Attachment A.**
- Slope Stability Assessment (Coffey, 2013) – Refer **Attachment B.**
- Harris Creek Cliff Lines Assessment (GHD, 2012) – Refer **Attachment C.**

3.1 CLIFFS, STEEP SLOPES AND ROCK OUTCROPS

3.1.1 Existing Environment

Cliffs, steep slopes and rock outcrops have been identified within the Longwall 901 to 904 Study Area and surrounds at locations described in **Table 3.1.**

Table 3.1 – Details of Cliffs within the vicinity of the Study Area (MSEC, 2012)

Cliff Ref.	Overall Length (m)	Maximum Height (m)	Description
NR-A9-CL1	40	15	280 m south of the western end of Longwall 902
NR-A9-CL2	40	10	140 m south of the western end of Longwall 902
NR-A9-CL3	40	10	170 m south of the western end of Longwall 902
NR-A9-CL4	40	15	240 m south of the western end of Longwall 902
NR-A9-CL5	70	20	230 m south of the western end of Longwall 902
NR-A9-CL6	80	20	180 m west of the western end of Longwall 901
NR-A9-CL7	90	25	110 m west of the western end of Longwall 901
NR-A9-CL8	60	20	60 m south-west of the western end of Longwall 901
NR-A9-CL9	30	10	220 m south of the western end of Longwall 901
NR-A9-CL10	70	15	230 m south of the western end of Longwall 901
NR-A9-CL11	40	10	270 m south of the western end of Longwall 901
NR-A9-CL12	60	15	270 m south of Longwall 901
NR-A9-CL13	140	15	310 m south of Longwall 901
NR-A9-CL14	50	15	330 m south of Longwall 901
NR-A9-CL15	60	10	310 m south of Longwall 901
NR-A9-CL16	100	20	340 m south of Longwall 901
HC-A9-CL1	100	10	750 m south-east of the eastern end of Longwall 901
HC-A9-CL2	100	10	770 m south-east of the eastern end of Longwall 901
HC-A9-CL3	200	10	650 m south-east of the eastern end of Longwall 901

***Note:** that the maximum cliff heights in the above Table, are less than the overall heights of the Nepean River valley and the Harris Creek Valley. This is because the cliff heights do not include the talus slopes and because the slopes of some rock faces, though steep, are not considered steep enough to describe them as parts of the cliffs (MSEC, 2012).*

The characteristics of cliffs, steep slopes and rock outcrops within the Study Area include:

- The cliffs are generally located within the valley of the Nepean River and associated tributaries. There are no cliffs identified directly above the proposed longwalls.

- The cliffs within the valley of Harris Creek located just outside the Longwalls 901 to 904 Study Area have also been included in the assessments as they overhang Douglas Park Drive.
- Rock outcrops are primarily located along the Razorback Range and within the Nepean River gorge and associated tributaries.
- Steep slopes occur along Razorback Range and within the valleys of the Nepean River.
- Cliffs within the Study Area have predominately formed from the Hawkesbury Sandstone Sedimentary Group.
- No individual cliff lines in the Study Area are considered to be sufficiently unique or different to require identification as ‘special significance’ and thus requiring special consideration in a risk assessment framework.

3.2 BASELINE RECORDING

3.2.1 Slope Stability Assessment

Areas of sensitive terrain are located along the Razorback Range or on the lower Douglas Park Ridge. The Razorback Range area is known for its numerous historical and complex landslides.

A terrain sensitivity risk assessment of the Razorback Range was conducted by Coffey (2013) to assess the potential effects of longwall mining on the known slope stability hazards of the Razorback Range and the Douglas Park Ridge.

The objectives included:

- Compilation of an inventory of historic landslide and instabilities using ALS data and aerial photography (in collaboration with UoW, 2011).
- Ground truthing of the desktop assessment and aerial photo interpretation.
- Subsurface investigation of 13 test pits to assess the composition of materials within the slide debris and depths of debris.
- Assessment of the processes and mechanisms of slope movement within the Slope Stability Study Area.
- Assessment of whether assets and infrastructure will be impacted if landslides are reactivated by mining activities.

The Slope Stability Study Area encompassed the Razorback Range and the south east facing ridge of the Douglas Park Ridge as well as the Longwall 901 to 904 Study Area.

The risk to existing property within the Longwalls 901 to 904 Study Area was assessed by Coffey (2013) for all known assets, with risks being deemed (Very Low to Moderate). Notwithstanding, some residential dwellings and associated infrastructure were identified within or close to areas of medium to high sensitivity as classified by Coffey (**Attachment B**) and are mainly located as follows:

- Along the top of the Razorback escarpment on Donald Range Road and off Top Range Road.
- Off Menangle Road where it crosses the Menangle Ridge.
- Off the southern end of Carroll’s Road.
- Properties on the sloping parts of McWilliam Drive.

The detailed baseline information for terrain sensitivity at the Razorback Range and Douglas Park Ridge is provided in **Attachment B**.

3.2.2 Nepean River Cliff Lines

The cliffs flanking the Nepean River have been deemed to be of higher significance comparative to other cliff lines in the Study Area. The cliffs along the Nepean River are therefore subject to separate Performance Measures, which require no more than 0.5% of the cliff lines along the river to have rockfalls, displacements or dislodgement of boulders or slabs, or fracturing.

Baseline recording of the Nepean River Cliff has been undertaken in support of the BSO EA and by MSEC (2012). BHPBIC has also prepared a *Nepean River Cliff Lines Management Plan*, to support the extraction of longwalls in Appin Area 7 which will be updated to include AA9 (refer **Attachment A**).

3.2.3 Harris Creek Cliff Lines

Harris Creek is an incised gully with sides that steepen as the creek deepens towards the Nepean River. The nearest proposed longwall, Longwall 901, is located to the north approximately 650 m minimum distance to Harris Creek cliff line.

The cliffs also overhang Douglas Park Drive resulting in the potential for severe consequences from any rockfalls that occur along these cliff lines.

There is potential for these cliffs to be affected by non-systematic mine subsidence effects. Should non-systematic mine subsidence occur, it is considered possible that the road cuttings, escarpments above and embankments below this section of Douglas Park Drive could be affected.

GHD (2012) has therefore assessed the existing geotechnical hazards at Harris Creek. The report describes existing features/hazards and their potential to become exacerbated due to the extraction of Longwalls 901 to 904.

A total of 122 hazard and mechanism features were observed during an assessment of the Douglas Park Drive road cuttings, the natural escarpment above the road, and the embankments below the road. These included features such as boulders or rock blocks, toppled trees, blocked drainage culverts, rock bolts, colluvial soil zones, flood mark carvings and retaining walls.

Data collection included:

- Compilation of a table of identified features (122).
- Photomosaics along Douglas Park Drive.
- Cross-sections for a series of embankment traverses along the length and perpendicular to the road alignment.
- Key photographs with labels for each of the features.
- Two quantitative NSW Road and Maritime Services (RMS) slope risk assessments of features either above or below the road.

The RMS slope risk assessment undertaken for the upslope side of the road indicates some detached boulders and blocks are medium risk according to the AGS Guidelines. Risk assessments undertaken for the down slope side of the road indicates that the fill embankments are experiencing creep settlement and could fail more rapidly and slump if inundated during periods of wet weather.

The assessment also identified a section of sandstone block retaining wall that is currently experiencing bulging and cracking and is in need of urgent repair.

The detailed baseline information for the Harris Creek Cliff line is provided in **Attachment C**.

4 PREDICTED IMPACTS

In accordance with the findings of the Southern Coalfield Inquiry (SCI):

- **Subsidence effects** are defined as the deformation of ground mass such as horizontal and vertical movement, curvature and strains.
- **Subsidence impacts** are the physical changes to the ground that are caused by subsidence effects, such as tensile and sheer cracking and buckling of strata.
- **Environmental consequences** are then identified, for example, as a loss of surface water flows and standing pools.

4.1 STEEP SLOPES

4.1.1 Subsidence Effects

The maximum predicted total conventional subsidence after the extraction of Longwalls 901 to 904, as determined by MSEC (2012) is provided in **Table 4.1**.

Table 4.1 – Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of each of the Proposed Longwalls (MSEC, 2012)

Longwalls	Maximum predicted Total Conventional Subsidence	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Curvature Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
LW901	600	3.0	0.03	0.04
LW902	925	6.5	0.06	0.12
LW903	1150	6.0	0.07	0.12
LW904	1200	6.0	0.07	0.12

Slope instability is governed by slope angle, soil strength, and concentrations of water within the potentially unstable soil or rock mass (Coffey, 2013).

For slope stability the *"tilt"* subsidence parameter has been considered more likely to impact landslide risk than curvature, and stresses and strains (Coffey, 2013). Tilt is defined as the *changes in slope of the ground slope.*

There is the potential for minor tilts associated with mine subsidence to alter the angle of potential slide planes. Where sliding occurs on low angle slide planes sliding can be triggered where tilts increase the angle of the slide planes in the down-slope direction.

The maximum predicted tilt to occur in the Study Area during the extraction of Longwalls 901 to 904 is 6.34 mm/m, thus the slope angle change predicted is 0.364 degrees.

The maximum predicted ground curvatures for the steep slopes in the Study Area are similar to those typically experienced in the Southern Coalfield.

Other forms of ground movements besides systematic subsidence movements may occur within the Study Area as a result of the extraction of Longwalls 901 to 904. These are referred to as irregular subsidence movements and far-field effects.

A number of geological conditions may influence these non-systematic subsidence movements. These may include the blocky nature of near surface sedimentary strata layers and the possible presence of unknown dykes, faults, or other anomalous geological structures, cross-bedded strata, thin and brittle near surface strata layers and pre-existing natural joints.

The presence of these natural features could result in changes to an otherwise smooth subsidence profile. They are also usually accompanied by locally increased tilts and strains (MSEC, 2012).

4.1.2 Subsidence Impacts

Potential impacts on steep slopes from the extraction of Longwalls 901 to 904 are predicted to be similar to those previously observed in the Southern Coalfield (MSEC, 2012). To date no large-scale mining induced slope failures have been identified, even where longwalls have been mined directly beneath existing areas of instability.

Tilting Impacts

Tilts within the Longwalls 901 to 904 Study Area are predicted to be less than 10 mm/m which is considered unlikely to cause greater than negligible impacts. Low shear strength on some bedding planes could make these areas sensitive to some movement in combination with other contributing factors such as undercutting, or prolonged rainfall events.

Strength Reduction

Subsidence movements can reduce the strength of a slope profile by introducing cracking that reduces the tensile resistance of a slope to failure. Also, in sedimentary sequences bedded at low angles, differential movement along low angle bedding planes can introduce shearing along the plane. These shear movements reduce the available shear strength of the plane and can contribute to slope failure.

The subsidence effects predicted for the Study Area are minor, and are not expected to produce significant cracking or differential lateral movements.

Water Concentration

Cracking associated with mine subsidence can allow ingress of water into a slope. This could potentially introduce water to slide planes within the soil or weathered rock horizons that may assist in triggering instability.

The estimated effects from systematic subsidence movements on the surface within the Study Area are unlikely to produce cracking that would significantly promote ingress of water to the slope or to failure planes where there is terrain sensitivity. However, where non-systematic (down-slope) movements occur there is potential for increased tension and cracking at the tops of slopes and on slopes which, if not mitigated, could increase water infiltration and associated pore pressures.

Strain

MSEC (2012) predicts the maximum systematic tensile strain after extraction of Longwalls 901 to 904 to be less than 1 mm/m. Bands of maximum strain exceeding 0.5 mm/m occur along the northern sides of Longwalls 902, 903 and 904. Tensile strain also occurs along the north-south orientated zones short of the western ends of the same longwalls.

It is not possible to predict the locations and magnitudes of non-conventional anomalous ground movements, however, in some cases approximate predictions can be made where the underlying geological or topographic conditions are known in advance.

The developments of strain at anomalies identified in the Southern Coalfield and elsewhere have been assessed by MSEC (2012). For these cases, the maximum rate of development of anomalous strain was 1.1 mm/m per week, or 0.4 mm/m per 10 m of longwall advance. This rate of development of strain allows for mitigative actions to be implemented prior to significant impacts occurring.

4.1.3 Environmental Consequences

Slopes outside the Nepean River Valley and the alignments of the creeks would be likely to remain stable during and after mining, and the chance of soil slippage is small (MSEC, 2009).

Past slope failures on the Razorback Range have typically occurred on the upper slopes well above any infrastructure. The visible flow paths and toe lobes do not, in all but a few cases, reach infrastructure which are generally confined to the foot-slopes. The Douglas Park slope failures are smaller in scale and are located on steeper slopes on the sides of hills and on side slopes of ridges.

It is considered unlikely that mine subsidence will have a greater than negligible impact on slope stability within the Study Area. The most likely trigger event for slope failure on the hill slopes (other than over steepening of the slope by manmade activities) will be significant rainfall events (e.g. intense or prolonged rain).

Further, Coffey (2013) utilized Slope W analysis, a computer software program to analyse data obtained from subsurface investigations. This analysis involved the application of different soil parameters, water levels and various slope angles to the software model. The aim of the analyses was to determine the factors of safety (FOS) against sliding for the slopes within the Study Area.

The Slope W analysis found the Factors Of Safety (FOS) against sliding (in the Study Area) are relatively low (Coffey, 2013). These FOS indicate marginal stability. Coffey (2011) also determined that sliding is largely driven by water level changes in the soil mass, rather than small changes in slope angle or tilt resulting from mine subsidence effects.

Notwithstanding, slope instabilities, as well as surface cracking, have potential to impact public safety. Public safety is addressed in the Public Safety Management Plan (PMP). Other potential environmental consequences of slope instabilities may include impacts on stream water quality, flora and fauna or their habitats, and Aboriginal heritage sites. These potential environmental consequences are addressed in the Water Management Plan (WMP), Biodiversity Management Plan (BMP) and Heritage Management Plan (HMP).

If required, remediation works will be undertaken to ensure that mining-induced cracking does not result in significant soil erosion or an increase in water infiltration. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the slopes in the longer term.

4.2 CLIFFS AND OVERHANGS

4.2.1 Subsidence Effects

A summary of maximum predicted total conventional subsidence of cliffs within the Longwalls 901 to 904 Study Area is provided in **Table 4.2**. The cliffs are located outside the extents of mining, at a minimum distance of 60 m from the proposed longwalls.

4.2.1 Subsidence Impacts

Tilting Impacts

The maximum predicted tilts at the cliffs within the Study Area are very small in comparison to the existing slopes of the cliff faces and are unlikely, therefore to result in toppling type failures in these cases.

Some sections of rock may fracture along existing bedding planes or joints due to conventional subsidence effects. This may result in toppling type failures along the cliffs, especially during or after heavy rainfall events.

Table 4.2 – Maximum Predicted Total Conventional Subsidence Parameters for Cliffs resulting from the Extraction of Proposed Longwalls 901 to 904 (MSEC, 2012)

Cliff Reference	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
NR-A9-CL1	<20	<0.5	<0.01	<0.01
NR-A9-CL2	75	0.5	<0.01	<0.01
NR-A9-CL3	50	<0.5	<0.01	<0.01
NR-A9-CL4	25	<0.5	<0.01	<0.01
NR-A9-CL5	50	<0.5	<0.01	<0.01
NR-A9-CL6	50	<0.5	<0.01	<0.01
NR-A9-CL7	100	0.5	<0.01	<0.01
NR-A9-CL8	50	<0.5	<0.01	<0.01
NR-A9-CL9	<20	<0.5	<0.01	<0.01
NR-A9-CL10	<20	<0.5	<0.01	<0.01
NR-A9-CL11	<20	<0.5	<0.01	<0.01
NR-A9-CL12	<50	<0.5	<0.01	<0.01
NR-A9-CL13	<25	<0.5	<0.01	<0.01
NR-A9-CL14	<25	<0.5	<0.01	<0.01
NR-A9-CL15	<25	<0.5	<0.01	<0.01
NR-A9-CL16	<25	<0.5	<0.01	<0.01
HC-A9-CL1	<20	<0.5	<0.01	<0.01
HC-A9-CL2	<20	<0.5	<0.01	<0.01
HC-A9-CL3	<20	<0.5	<0.01	<0.01

Other Impacts

Although mining is unlikely to significantly increase the risk of cliffs and steep slope instabilities, the cliffs in the area are already inherently unstable. Consequently there is the possibility that a rock fall associated with the cliffs may occur naturally during or following the period of mining.

Natural hazards and mechanisms have been identified as root jacking, tree growth, soil wash-out/erosion, and weathering of rock mass or defects. In a few cases, minor movement such as that induced by mining related non-systematic subsidence could potentially exacerbate or further develop existing hazards by the following mechanisms:

- Altering/steepening the centres of gravity a dislocated block or boulders.
- Further tilting or steepening of blocks or boulders already at their angle of repose.
- Exacerbating basal crushing on weak seams.

Nepean River Cliff Lines

The cliffs along the Nepean River are subject to Performance Measures, which require no more than 0.5% of the face area of cliffs along the river to have rockfalls, displacements or dislodgement of boulders or slabs, or fracturing.

The risks to these cliffs are reduced, compared to other cliff lines and overhangs in that the longwalls will be offset from the river. According to MSEC (2012), based on the history of mining at Appin and Tower Collieries, it is possible that isolated rock falls could occur as a result of the extraction of the proposed longwalls. It is not expected, however, that any large cliff instabilities would occur as a result of the extraction of the longwalls, as the longwalls are not proposed to be extracted directly beneath the cliffs.

Harris Creek Cliff Lines

As detailed in **Section 3.2.3**, most of the potential hazard and failure mechanisms that have been identified at the Harris Creek Cliff occur progressively over time, and would not be significantly modified or affected by any minor mine subsidence occurrences.

Geotechnical mapping indicates that it is possible that 13 of the 122 documented features may be impacted by the effects of non-systematic mine subsidence.

By targeting those 13 features the risk of a failure event (rockfall/embankment failure) during the extraction of Longwalls 901 to 904 would be minimised. Mitigation measures to alleviate or significantly minimise the environmental consequences at the Harris Creek cliff lines are provided in **Section 7**. With these management and mitigation measure in place the environmental consequences at Harris Creek cliff lines are expected to be negligible to minor.

4.2.2 Environmental Consequences

Whilst the cliffs within the Study Area are expected to exhibit minor environmental consequences as a result of the extraction of Longwalls 901 to 904 (except in the case of those along the Nepean River, which are only permitted negligible consequences), occasional rock-falls, displacement or dislodgement of boulders or slabs, or fracturing may still occur to a minor degree.

Environmental consequences of a rock fall could potentially include changes to the visual landscape of the Study Area. A rock fall or landslide may result in the exposure of a fresh face of rock and debris scattered around the base of the cliff. As with naturally occurring instabilities, the exposed fresh rock-face weathers and erodes over time to a point where it blends in with the remainder of the cliff face and in time the vegetation below the cliff regenerates.

Cliff and overhang instabilities as well as surface cracking have potential to impact public safety. Public safety is addressed in the Public Safety Management Plan (PMP). Other potential environmental consequences of cliff/overhang instabilities may include impacts on stream water quality, flora and fauna or their habitats, and Aboriginal heritage sites. These potential environmental consequences are addressed in the Water Management Plan (WMP), Biodiversity Management Plan (BMP) and Heritage Management Plan (HMP).

Rock-fall of the escarpments above and failure of the embankments below Douglas Park Drive have the potential to cause consequences to the road. Risk minimization measures to address these potential consequences will be undertaken by the asset owner and are addressed in the Built Features Management Plan (BFMP).

5 PERFORMANCE MEASURES AND INDICATORS

The BSO Approval provides Subsidence Impact Performance Measures (*Condition 1, Schedule 3).* **Table 5.1** below details the conditions relevant to the general land surface, cliffs and steep slopes.

The term negligible is defined within the Project Approval as "*small and unimportant, such as not to be worth considering"* or as otherwise defined in **Table 5.1** for cliffs of 'special significance' and those flanking the Nepean River.

Table 5.1 – Subsidence Impact Performance Measures

Land (Condition 1, Schedule 3)	
Cliffs of 'Special Significance' (i.e. cliffs longer than 200 m and/or higher than 40 m; and cliff-like rock faces higher than 5 m that constitute waterfalls).	Negligible environmental consequences (that is occasional rock falls, displacement or dislodgement of boulders or slabs, or fracturing, that in total do not impact more than 0.5% of the total face area of such cliffs within any longwall mining domain).
Other cliffs flanking the Nepean River.	Negligible environmental consequences (that is occasional rock falls, displacement or dislodgement of boulders or slabs, or fracturing, that in total do not impact more than 0.5% of the total face area of such cliffs within any longwall mining domain).
Other cliffs.	Minor environmental consequences (that is occasional rock falls, displacement or dislodgement of boulders or slabs, or fracturing, that in total do not impact more than 3% of the total face area of such cliffs within any longwall mining domain).

As noted in **Sections 4.1.3** and **4.2.2** the environmental consequences of rock falls, fracturing and other impacts may include consequences to other environmental components or systems such as groundwater, biodiversity or heritage. As such a range of other Impact Performance Measures related to those environmental factors are applicable to this LMP, and are discussed in the relevant Management Plan.

In order to mitigate the potential subsidence impacts and environmental consequences from the mining of Longwalls 901 to 904 monitoring and recording will be undertaken prior to mining, throughout the extraction and at the completion of subsidence (refer **Section 6**).

In the event that any subsidence impact is recorded, consideration would be given to implementing appropriate management, remediation and/or mitigation measures in consultation with relevant stakeholders (refer **Section 7**).

If the subsidence impact performance measures are exceeded, BHPBIC will notify the appropriate stakeholders and implement the Contingency Plan (**Section 8**).

6 MONITORING AND REPORTING

6.1 MONITORING PROGRAM

General landscape monitoring will be undertaken by BHPBIC as a part of routine subsidence monitoring. This will generally include visual inspections of the land and monitoring actual subsidence against the predictions along selected survey lines. Specific monitoring for slope instability will be added to this program as required.

Depending on the terrain sensitivity of each property, as defined by Coffey (2013), slope monitoring will be undertaken as in **Table 6.1** (in consultation with the landowner where necessary).

Table 6.1 – Slope Stability Monitoring

Terrain Sensitivity	**Monitoring Method**			
	Observations by Experienced Engineer / Photographic Records	**On ground Survey**	**Groundwater Monitoring (Piezometers)***	**Slope Inclinometers***
Low	• 6 months before commencement of mining. • 6 months after completion of mining.	No	No	No
Medium	• 6 to 12 months before commencement of subsidence. • 3 monthly during major subsidence period. • 6 months after completion of subsidence.		No	No
High	• 12 months before commencement of subsidence for visual and on ground survey. • Monthly for visual during major subsidence period. • 3 monthly for ground survey during major subsidence period. • Installation of piezometer with data logger (remotely accessed) prior to commencement of subsidence. Monthly readings of piezometer prior to subsidence commencing. Weekly readings of piezometer during major subsidence period and on completion of subsidence. • Use of down borehole inclinometer installed 12 months prior to subsidence, subject to trigger (visual assessment or on ground survey shows landslide movement or high piezometer reading).			

**Note the requirement to use piezometers and slope inclinometers will be assessed on a case by case basis and in consultation with the landowner as part of the PSMP process.*

The monitoring program will particularly target those areas of sensitive terrain in close proximity to buildings or other infrastructure. A summary of methods for assessing ground movement which may be implemented as required in consultation with landowners as a part of the PSMP process is provided below:

- Site observations by an experienced geotechnical engineer familiar with slope behaviour.
- Survey monitoring of on-ground markers and fixed surface features including buildings, concrete pavements, trees and other fixed points.
- Installation of piezometers to monitor groundwater within and/or downhill of identified landslides that present an increased risk to property. These would normally be located within the slide area and between the toe of the landslide where the property (buildings) is located downhill, or between the head of the slide and property where the property is located uphill. The inclinometer casing is installed in boreholes drilled through the soil mass and socketed into rock. Groundwater levels in the piezometers would be monitored by data loggers with regular downloads of recorded information, or alternatively by real time monitoring before and after the commencement of mining. Groundwater levels could then be plotted against rainfall and mine subsidence to assess whether landslide activity is increasing and presenting a risk to property.
- Monitoring of landslide movement by inclinometer. This would involve the installation of inclinometer casing in boreholes within the landslide and between the toe of the landslide and buildings downhill of the slide, or between the head of the slide and buildings where uphill of the slide. Inclinometers would be monitored at regular

intervals before the commencement of mining and during the anticipated period of subsidence. In conjunction with the above monitoring methods this will provide information on the rate of movement and depth of the slide for any active slides.

6.2 REPORTING

Monitoring results will be presented and reviewed at the monthly BHPBIC Subsidence Management Meeting. However, if the findings of monitoring are deemed to warrant an immediate response the Manager Approvals will initiate the requirements of the Trigger Action Response Plan (TARP).

Monitoring results will be made publically available in accordance with BSO Approval *Condition 8 & 11, Schedule 6* and will also be included in the Annual Reporting *Condition 4, Schedule 6*.

7 MANAGEMENT AND MITIGATION STRATEGIES

7.1 PROPERTY IN AREAS OF SENSITIVE TERRAIN

Sensitive terrain is defined as *areas which may be sensitive to changes in slope conditions, and are a reflection of existing conditions in combination with possible changes following longwall mining* in the Study Area.

A review of slope stability conditions around structures in sensitive areas on private property will be undertaken in consultation with the landowner prior to mining, during and on completion of longwall mining activities. Monitoring, management and mitigation measures for properties that are located in areas of sensitive terrain will be undertaken where appropriate and in consultation with the landowner where required. These measures will be provided as part of the BFMP and PSMPs processes.

Mitigation of any subsidence cracks by infilling and re-profiling will be conducted with the approval of the landholder in any areas of high susceptibility (e.g. steep slopes) to minimise the ingress of water into the soil profile.

Where slope instability on areas of sensitive terrain is ongoing or increasing, or where a property exists on a hillside or close to a steep hillside, measures that may be implemented with the approval of the landholder to reduce the risk to property resulting from slope instability include:

- The installation of subsoil drains.
- Regrading of slopes and sealing of tension cracks in active landslides.
- Provision of surface water cut-off drains above potential landslides.
- Provision of shear piles through the slide zone.
- Improvements to vegetation including slashing of thick matted grass and planting of suitable trees.
- Removal or re-shaping of the soil slope to reduce loads within the sliding mass.
- Provision of toe support and associated drainage to support the soil mass depending on the scale of the landslide.
- Diverting overland flows around the slide area and providing localised drainage improvements e.g. repair leaking drains or re-direct drains that may discharge into landslide areas, or improvements to septic seep-away systems.
- Redirect stock where tracks are disturbing slope or creating flow paths in landslide areas.

- Restrict grazing in areas where slope instability is indicated by monitoring.

The implementation of management measures will be related to the scale of impacts and the ability for and value in undertaking mitigation measures on a case by case basis, as negotiated with the landowner and described in the relevant PSMP. This means that management measures will be considered and implemented prior to the land performance measure being exceeded.

Management measures will be implemented, as appropriate, to comply with the relevant statutory requirements and the subsidence performance measures.

7.2 NEPEAN RIVER CLIFF LINES

Monitoring of the cliff lines along the Nepean River will be undertaken in accordance with the *Nepean River Cliff and Slope Management Plan* already being implemented by BHPBIC for mining activities in AA7. This will include:

Table 7.1 – Monitoring of Nepean River Cliff line (from BHPBIC, 2009)

Monitoring Proposed	Description	Timing/ Frequency	Reporting
Baseline studies prior to mining	Photographic record with details of site locations including cliff formations	Once prior to mining. Photographic records will be prepared	Via regular reporting processes including annual reports and subsidence management meetings
Monitoring during mining	Visual observations of cliff formations Visual observations of steep slopes	Monthly routine inspections with weekly inspections during active subsidence	Via regular reporting processes including annual reports and subsidence management meetings
	Valley closure monitoring	During mining at a frequency to be determined with the PSE	Via regular reporting processes including annual reports and strategy and management group meetings
In the event that specific impacts are identified	Discussions with authorities and development of mitigation measures	Notification as soon as practical Development of mitigation measures as required	Via impact reporting processes including reports and site visits
If impacts are noted, photographs will record the level of impact and where necessary, remedial action will be taken in consultation with appropriate stakeholders.			

7.3 HARRIS CREEK CLIFF LINES

Mitigation and management measures would be detailed in the BFMPs/PSMPs for identified features at the Harris Creek Cliff lines and may include:

- Shotcrete to support surface materials.
- Buttress support.
- Rock bolt and/or scale.
- Removal of boulders and debris infill.
- Installation of a rockfall fence.
- Retaining wall repair/or demolish.

- Scale and groom.
- Rock armour.
- Rock fall protection.

A comprehensive list of features observed at the Harris Creek cliff lines is provided in **Attachment C**. Suitable remediation options for each feature are included in GHD (2012). These are specifically in relation to possible remediation measures, which may be implemented to reduce risk to high risk features.

7.4 TARPS

The AA9 Land TARP is shown as **Table 7.2**.

More detailed TARPs for individual properties will be developed (if required) during the PSMP process. Monitoring will be undertaken in consultation with the landowner where necessary.

Table 7.2 – AA9 Trigger Action Response Plan (TARP)

Monitoring	Trigger	Action
Landscape Features		
Cliffs and Steep Slopes • Nepean River cliff lines • Harris Creek cliff lines • Sensitive terrain near built features (Razorback Range, Douglas Park Ridge) Monitoring locations on private properties to be determined as appropriate/required in consultation with landowner	***Level 1*** • Rock fall from a cliff where the cliff is left mostly intact (<10% length of any single cliff) • Surface movement or rock displacement where any exposed soil surface is stable • Crack at the surface which does not result in ongoing erosion or ground movement • Erosion which stabilises within the period of monitoring without CMA • Crack or fracture up to 100 mm width • Crack or fracture up to 10 m length	• Continue monitoring program • Submit an Impact Report to OEH, DoPI, DPI and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 • Rock fall from cliff where the characteristics of the cliff change (>10% length of any single cliff) • Ground disturbance that is unlikely to stabilise within the period of monitoring without CMA • Mass movement of a slope causing areas of exposed soil • Crack or fracture between 100 – 300 mm width • Crack or fracture between 10 – 50 m length	• *Actions stated for Level 1* • Report trigger to key stakeholders • Review monitoring program • Notify relevant specialists and develop and implement any CMA required. • Provide safety signage and barricades where appropriate in areas as required for public safety (refer PSMP) • Implement agreed CMA's as approved *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*

Monitoring	Trigger	Action
	Level 3 * • Cliff collapse (100% length of any single cliff) • Ground disturbance that does not stabilise within the period of monitoring • Mass movement of a slope causing areas of exposed soil that does not stabilise within the period of monitoring • Crack or fracture over 300 mm width • Crack or fracture over 50 m length	• *Actions stated for Level 2* • Notify OEH, DP&I, DPI, NoW, DRE, relevant resource managers and technical specialists and seek advice on any CMA required. • Invite stakeholders for site visit • Develop site CMA (subject to stakeholder feedback). This may include: – Erosion prevention works – Establishment of vegetation • Completion of works following approvals, including monitoring and reporting on success • Review the TARP and Management Plan in consultation with key stakeholders *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*
	Exceeding Performance Measures • For cliffs of 'special significance' and other cliffs flanking the Nepean River - mining results in more than negligible environmental consequences (i.e. more than occasional rockfalls, displacement or dislodgement of boulders or slabs, or fracturing, that in total impact more than 0.5% of the total face area of such cliffs within any longwall mining domain • Other cliffs – mining results in more than minor environmental consequences (that is occasional rockfalls, displacement or dislodgment of boulders or slabs or fracturing, that in total impact more than 3% of the total face area of such cliffs within any longwall mining domain	• *Actions stated for Level 3* • Make area safe • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide environmental offset if CMAs are unsuccessful

* *These may be revised in consultation with DP&I, DRE and other key stakeholders following analysis of natural variability within the pre-mining baseline data.*

8 CONTINGENCY AND RESPONSE PLANS

8.1 CONTINGENCY PLAN

In the event the Subsidence Performance Measures detailed in **Section 5** of this LMP are considered to have been exceeded, or are likely to be exceeded, BHPBIC will implement a Contingency Plan to manage any unpredicted impacts and their consequences.

This would involve:

- Capture photographic record.
- Notify relevant stakeholders soon as practicable.
- Notify relevant agencies and specialists soon as practicable.
- Offer site visits with stakeholders.
- Contract specialists to investigate and report on changes identified.
- Provide incident report to relevant agencies.
- Undertake a condition assessment to record impacts completed within 14 days.
- Establish weekly monitoring frequency until stabilised.
- Updates from specialists on investigation process.
- Inform relevant agencies and stakeholders of results of investigation.
- Develop site Corrective Management Action (CMA) in consultation with key stakeholders if required, (pending stakeholder availability) and seek approvals.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting of CMA completion.
- Review Management Plan.
- Report in regular reporting and AEMR.

BHPBIC will consult with appropriate specialists and relevant agencies in order to devise an appropriate response in respect to the identified exceedance.

The development and implementation of contingency measures will be specifically designed to address the specific circumstances of the exceedance and assessment of environmental consequences.

If the contingency measures implemented by BHPBIC fail to remediate the impact or the Director-General determines that it is not reasonable or feasible to remediate the impact BHPBIC will provide a suitable offset to compensate for the impact to the satisfaction of the Director-General of DP&I in accordance with the BSO Approval *Condition 2, Schedule 3*.

All incidents will be reported internally through BHPBIC's Incident Procedure and related records will be maintained in accordance with the Records Management Procedure (refer **Section 10.4**).

9 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

9.1 INCIDENTS

BHPBIC will notify DP&I and any other relevant agencies of any incident associated with the Appin Mine as soon as practicable after BHPBIC becomes aware of the incident. BHPBIC will provide DP&I and any relevant agencies with a detailed report on the incident within seven days of the date of the occurrence.

9.2 COMPLAINTS HANDLING

BHPBIC will:

- Provide a readily accessible contact point through a 24 hour toll-free Community Call Line (1800 102 210). The number will be displayed prominently on BHPBIC sites in a position visible by the public as well as on publications sent to the local community.
- Respond to complaints in accordance with the BHPBIC Community Complaints and Enquiry Procedure.
- Maintain good relations and communication lines between the community members and BHPBIC staff.
- Keep a register of any complaints, including the details of the complaint with information such as:
    - Time and Date.
    - Person receiving the complaint.
    - Complainant's contact name and phone number.
    - Description of the complaint.
    - Work area where complaint relates to.
    - Details of any verbal response.
    - Details of any written response where appropriate.

9.3 NON-CONFORMANCE PROTOCOL

The requirement to comply with all approvals, plans and procedures is the responsibility of all personnel (staff and contractors) employed on or in association with the BSO. Regular inspections, internal audits and initiation of any remediation/rectification work will be undertaken by the Manager Approvals.

Non-conformities, corrective actions and preventative actions are managed in accordance with the BHPBIC *Non-Conformance, Preventative and Corrective Action Procedure (ICHP0107)*. This procedure details the processes to be utilised with respect to the identification of non-conformances, the application of appropriate corrective actions(s) to address non-conformances and the establishment of preventative actions to avoid non-conformances. The key elements of the process include:

- Identification of non-conformance and/or non-compliances.
- Recording of non-conformance and/or non-compliance.
- Evaluation of the non-conformance and/or non-compliance to determine specific corrective and preventative actions.
- Corrective and preventative actions to be assigned to responsible person.
- Management review of corrective actions to ensure the status and effectiveness of the actions.

An Annual Review will be undertaken to assess BHPBIC's compliance with all conditions of the BSO Approval, mining leases and all other approvals and licences.

An independent environmental audit will also be undertaken (*Condition 9, Schedule 6*) to review the adequacy of strategies, plans or programs under these approvals and if appropriate, recommend actions to improve the environmental performance of the BSO. The independent environmental audit will be undertaken by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Director-General of DP&I.

10 PLAN ADMINISTRATION

This LMP will be administered in accordance with the requirements of the AA9 Environmental Management System (EMS) and the BSO Approval Conditions. A summary of the administrative requirements is provided below.

10.1 ROLES AND RESPONSIBILITIES

All statutory obligations applicable to the AA9 operations are identified and managed via an online compliance management system (TICKIT). The online system can be accessed from the following link https://illawarracoal.tod.net.au/login

The overall responsibility for the implementation of this LMP resides with the Manager Approvals who shall be the LMP's authorising officer.

Parties responsible for environmental management in AA9 and the implementation of the LMP include:

Head of External Affairs

- Ensure that the requisite personnel and equipment are provided to enable this LMP to be implemented effectively.

Manager Approvals

- Authorise the LMP and any amendments thereto.
- Delegate to an appropriately qualified person the responsibility to document any changes to the LMP, recognising the potential for those changes to affect other aspects of the LMP.
- Provide regular updates to BHPBIC on the results of the LMP.
- Arrange information forums for key stakeholders as required.
- Prepare any report in accordance with the LMP. Maintain records required by the LMP.
- Organise and participate in assessment meetings called to review mining impacts.
- Within 24 hours, respond to any queries or complaints made by members of the public in relation to aspects of the LMP.
- Organise audits and reviews of the LMP.
- Address any identified non-conformances, assess improvement ideas submitted and implement if considered appropriate.
- Arrange for the implementation of any agreed actions, responses or remedial measures.
- Ensure surveys required by this LMP are conducted and record details of instances where circumstances prevent these from taking place.

Environmental Field Team Coordinator

- Instruct suitable person(s) in the required standards for inspections, recording and reporting and be satisfied that these standards are maintained.
- Investigate significant subsidence impacts.

- Identify and report any non-conformances with LMP provisions.
- Participate in any other assessment meetings called to review subsidence impacts in the area affected by mining

Survey Coordinator

- Collate survey data and present in an acceptable form for review at assessment meetings.
- Bring to the attention of the Manager Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Manager Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the LMP.

Technical Experts

- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Manager Approvals and formally provide expert opinion as requested.

Person(s) Performing Inspections

- Formally bring to the attention of the Environment Field Team Coordinator any non-conformances identified with the Plan, or ideas aimed at improving the Plan.
- Conduct inspections in a safe manner.

10.2 RESOURCES REQUIRED

The Head of External Affairs provides resources sufficient to support this LMP.

Equipment will be needed for the TARPs provisions of this LMP. Where this equipment is of a specialised nature, it will be provided by the supplier of the relevant service. All equipment is to be appropriately maintained, calibrated and serviced as required in operation manuals.

It shall be the responsibility of the Manager Approvals to ensure that personnel and equipment are provided as required to allow the provisions of this Plan to be implemented.

10.3 TRAINING

All staff and contractors working on BHPBIC sites are required to complete the BHPBIC training program which includes:

- An initial site induction (including all relevant aspects of environment, safety and community).
- Safe Work Methods Statements and Job Safety Analyses, Toolbox Talks and Pre-shift communications.
- On-going job specific training and re-training (where required).

All training records are maintained by the BHPBIC Safety and Training Department (STAX database system), which can be accessed via the iPick system.

It shall be the responsibility of the Manager Approvals to ensure that all persons and organisations having responsibilities under this Plan are trained and understand their responsibilities.

The person(s) performing regular inspections shall be under the supervision of the Environment Field Team Coordinator and be trained in observation and reporting. The Environment Field Team Coordinator shall be satisfied that the person(s) performing the inspections are capable of meeting and maintaining this standard.

10.4 RECORD KEEPING AND CONTROL

Environmental Records are maintained in accordance with the BHPBIC procedure *Records Management (ICHP0108)*.

10.5 DOCUMENT CONTROL

The BHPBIC *Document Control procedure (ICHP0103)* outlines the method for control of defined 'business critical' documentation for all Illawarra Coal operations. The system has been designed in such a manner to ensure that:

- Documents are approved for adequacy by authorised personnel prior to use.
- Obsolete documents are promptly removed from circulation.
- Documents are reissued, or made available, to relevant persons in a timely fashion after changes have been made and the authorisation process is complete.

The LMP and other relevant documentation will be made available on the BHPBIC website (*Condition 11, Schedule 6).*

10.6 MANAGEMENT PLAN REVIEW

A comprehensive review of the objectives and targets associated with the BSO is undertaken on an annual basis via the BHPBIC Balanced Planning (1 year outlook) and Balanced Strategy (5 year outlook) processes. These reviews, which include involvement from the senior site management and other key site personnel, assess the performance of the mine over the previous year and develop goals and targets for the following period.

An annual review of the environmental performance of the BSO will also be undertaken in accordance with *Condition 4, Schedule* 6. More specifically this LMP will be subject to review (and revision if necessary, to the satisfaction of the Director-General) within three months of:

- The submission of an annual review under *Condition 4 of Schedule 6.*
- The submission of an incident report under *Condition 7 of Schedule 6.*
- The submission of an audit report under *Condition 9 of Schedule 6.*
- Any modification to the conditions of this approval.

If deficiencies in the EMS and/or LMP are identified in the interim period, the plans will be modified as required. This process has been designed to ensure that all environmental documentation continues to meet current environmental requirements, including changes in technology and operational practice, and the expectations of stakeholders.

11 REFERENCES

Australian Geomechanics Society, 2007. *Landslide Risk Management Guidelines*, Vol 42 No. 1, March 2007.

BHPBIC, 2009. *Major Cliff Line Assessment*, Bulli Seam Operation Environmental Assessment. Appendix R.

Coffey Geotechnics, 2013. *Landslide Risk Assessment from Mine Subsidence Effects - Appin Area 9 Proposed Longwalls, Razorback Range, Douglas Park, NSW.* Report prepared for BHP Billiton Illawarra Coal.

Cruden D.M., Varnes D. J, 1996. *Landslide types and processes. In: Turner A.K.; Shuster R.L. (eds) Landslides: Investigation and Mitigation. Trans. Res Board, Spec Rep 247, pp 36–75.*

GHD Geotechnics, 2012. *Harris Creek Cliff Lines, Douglas Park.* Report prepared for BHP Billiton Illawarra Coal.

Mine Subsidence Engineering Consultants, 2009. *Bulli Seam Operations Subsidence Assessment*. Report prepared for BHP Billiton Illawarra Coal.

Mine Subsidence Engineering Consultants, 2012. *Appin Colliery – Longwalls 901-904. Subsidence Predictions and Impact Assessments for the Natural Features and Surface Infrastructure in support of the Extraction Plan: Report Number: MSEC448 Revision 3*. A report to BHPBIC.

The National Committee on Soil and Terrain, 2009. *Australian Soil and Land Survey handbook.* CSIRO March 2009.

Attachment A – Nepean River Cliff Lines Management Plan (BHPBIC, 2011)

Metallurgical Coal

NEPEAN RIVER CLIFFLINES STEEP SLOPES MANAGEMENT PLAN

APPIN AREA 7 & APPIN AREA 9
LONGWALLS 701 TO 710 AND 901 TO 904

Document No: <ADD No. HERE>

Rev: D

bhpbilliton
resourcing the future

Table of Contents

Tables

Figures

Review History

Revision	Description of Changes	Date	Approved
A	New Document	6 November 2008	RW
B	AW/BB	21 October 2009	RW
C	Addition of Longwalls 901-904	8 February 2012	GB
D	Updated - various	31 October 2013	GB

Persons involoved in the development of this document include:

Name	Title	Company
Bruce Blunden	Environmental Approvals Manager	BHP Billiton Illawarra Coal
Richard Walsh	Approvals Manager	BHP Billiton Illawarra Coal
Adam West	Environment and Community Coordinator	BHP Billiton Illawarra Coal
Gary Brassington	Manager Approvals (Mining)	BHP Billiton Illawarra Coal

1 INTRODUCTION

1.1 PROJECT BACKGROUND

BHP Billiton Illawarra Coal (BHPBIC) operates the Bulli Seam Operations (BSO) (Appin and West Cliff Collieries) extracting hard coking coal used for steel production.

On 22 December 2011, the Planning and Assessment Commission (PAC), under delegation of the Minister for Planning, approved the BSO (MP 08_0150) under Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act) to continue mining operations until 31 December 2041.

This Nepean River Cliffs and Steep Slopes Management Plan (NRMP) has been adapted from the Approved Longwall 701 to 710 Cliff and Steep Slope Management Plan to incorporate environmental and public safety elements for cliffs and steep slopes for Longwalls 901 to 904.

1.2 SCOPE

This NRMP has been prepared in support of the ongoing mining in Appin Area 7 (AA7) and proposed future longwall mining in Appin Area 9 (AA9). More specifically it supports the:

- Longwalls 701 to 704 Subsidence Management Plan (SMP)
- Longwalls 705 to 710 SMP
- Longwalls 901 to 904 Extraction Plan.

SMP Approval for Appin Longwalls 701 to 704 was issued 1 November 2006. The SMP Application for Appin Longwalls 705 to 710 was approved on 28 February 2012.

As per *Condition 5, Schedule 3* of the BSO Approval an SMP that is substantially consistent with *Condition 5* and approved by DRE prior to 30 September 2012 is taken to satisfy the requirements for Extraction Plan Approval.

This Plan is also being submitted as a component of the Longwalls 901 – 904 Landscape Management Plan, SMP and Extraction Plan.

This NRMP specifically deals with the Nepean River gorge and adjacent areas within the Appin Longwalls 701 to 710 and 901 to 904 Subsidence Management and Extraction Plan areas. The Harris Creek Cliff and Razorback Range associated with AA9 are addressed within the Land Management Plan (LMP).

1.3 OBJECTIVES

This NRMP has been developed to prevent environmental impacts and personal injuries as a result of possible cliff and steep slope instability within the Nepean River gorge as a result of BHPBIC mining activities. This will be achieved by regular monitoring of ground movement and rock face stability in potentially unstable areas and implementing appropriate controls where necessary.

To meet these objectives it is necessary to define:

- The locations, standards and frequencies to apply to subsidence and horizontal movement monitoring of the surface topography of the Nepean River gorge,
- The standards relating to initial controls, and in particular any warning signs or barricades that may be required,
- Ongoing inspections of the area to monitor cliff and steep slope stability during and after longwall extraction,

- Responses to any observed ground movement or deterioration of cliffs and steep slopes, and
- Responsibilities for the various actions and responses required.

1.4 DISTRIBUTION

As a component of the LMP the finalised NRMP will be distributed to:

- Department of Planning and Infrastructure (DP&I)
- Wollondilly Shire Council (WSC).

The Project Approval requires that the LMP, be developed in consultation with any potentially affected public authorities.

BHPBIC will make the NRMP and other relevant documentation publicly available on the BHPBIC website (*Condition 11, Schedule 6*).

2 STATUTORY REQUIREMENTS

Extraction of coal from Area 7 and Area 9 will be in accordance with the conditions set out in the BSO Approval, applicable legislation as detailed in **Section 2.2** and the requirements of relevant licenses and permits (including conditions attached to mining leases).The requirements of the existing SMPs will also be taken into account.

2.1 BSO APPROVAL

The requirements for this NRMP are identical to those described in and for the LMP, in which this Management Plan is contained.

2.2 RELEVANT LEASES AND LICENCES

The following leases and licences may be applicable to BHPBIC's operations in AA9:

- Mining Leases as per **Table 2.1**.
- Environmental Protection Licence (EPL) 2504 which applies to BSO, including Appin and West Cliff Mines. A copy of the licence can be accessed at the EPA website via the following link http://www.epa.nsw.gov.au/prpoeo/index.htm.
- BSP Mining Operation Plan (MOP) 1/10/2012 to 30/09/2019 (V1)
- All relevant OH&S and HSEC approvals
- Any additional leases, licences and approvals resulting from the BSO Approval.

Table 2.1 – Appin Mine Leases, Licences and other Reference Documents

Mining Lease - Document Number	Issue Date	Expiry Date/ Anniversary Date
CCL 767	29/10/1991	08/07/2029
CL 388	22/1/1992	Renewal Pending
ML 1382	20/12/1995	19/12/2016
ML 1433	24/7/1998	23/07/2019

3 BASLINE ASSESSMENT

3.1 SITE LOCATION AND MINING OPERATIONS

The Area 7 longwalls are located west of the Nepean River between the Douglas Park and Menangle Weirs. Natural features have been identified within the vicinity of the Area 7 longwalls, including cliffs and steep slopes adjacent of the Nepean River and are shown in **Figure 1**.

Extraction of Longwall 901 is expected to commence in 2016 with the transfer of the longwall operations from West Cliff Mine. The AA9 longwalls are also located west of the Nepean River upstream of the Douglas Park Weir as shown in **Figure 2.** These longwalls will be operated from the same main headings as the AA7 longwalls.

Surface features within AA9 also include cliffs and steep slopes associated with Harris Creek, which overhangs Douglas Park Drive and the Razorback Range. Harris Creek and Razorback Range are managed separately to the Nepean River Gorge and hence are addressed in separate Management Plans within the LMP.

3.2 BASELINE ASSESSMENTS

Baseline assessments of the cliffs and steep slopes along the Nepean River gorge have been undertaken and presented in a series of reports by Mine Subsidence Engineering Consultants (MSEC) as follows:

MSEC (2006) and MSEC (2008), report the predicted subsidence parameters and the assessment of mine related subsidence impacts on natural features and surface infrastructure resulting from the extraction of proposed Longwalls 705 to 710 at Appin Colliery. This documentation was prepared in support of a SMP Application.

MSEC (2012) undertook subsidence prediction and impact assessments for the natural features and surface infrastructure in support of the Extraction Plan for Appin Colliery Longwalls 901 to 904.

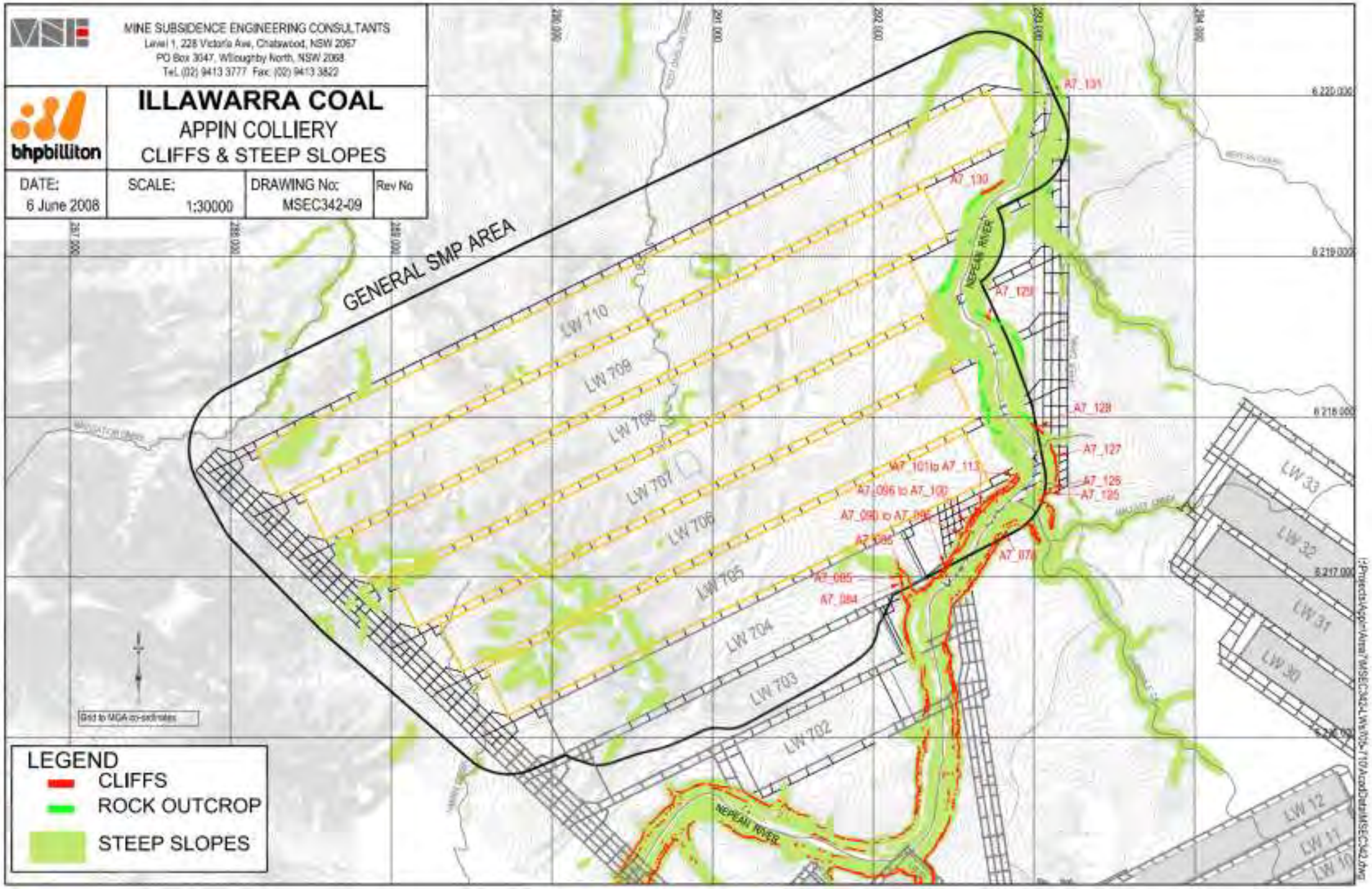


Figure 1 – Appin Area 7 Longwalls 701 to 710 with Respect to the Nepean River Gorge Cliffs and Steep Slopes

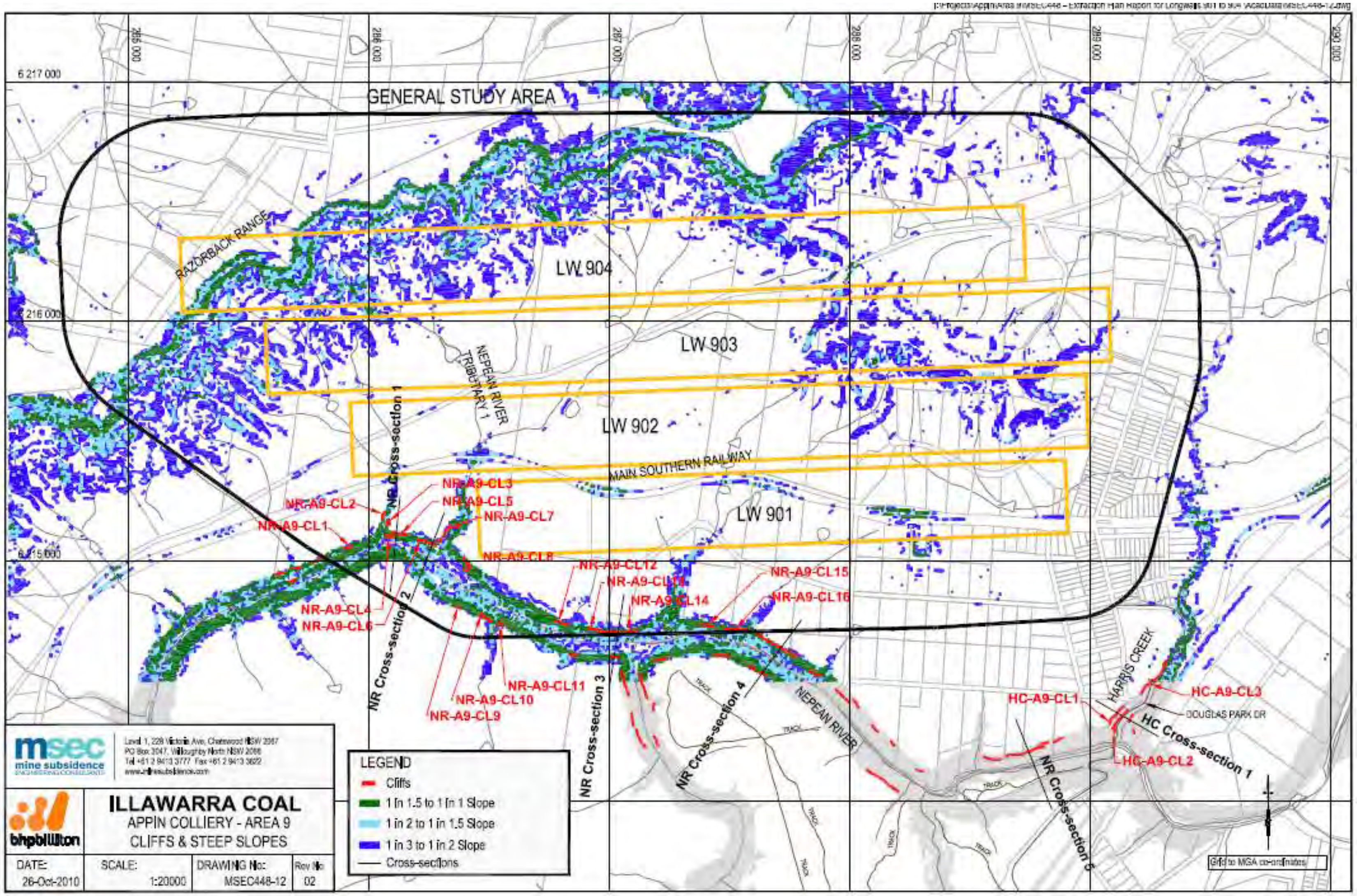


Figure 2 – Appin Colliery Area 9 Longwalls 901 to 904 with Respect to the Nepean River Gorge Cliffs and Steep Slopes

4 PREDICTED IMPACTS

4.1 MINING INFLUENCE ON CLIFFS AND STEEP SLOPES

Extraction of coal by longwall methods results in disturbance to the surface above and adjacent to the zone of extraction. In addition to vertical subsidence, horizontal ground movements also occur. These movements are particularly important where the surface topography includes gorges, cliffs and steep slopes. These horizontal movements may be directed towards the extracted mining area, in the direction of the principal horizontal in-situ stress or in a down slope direction. Such movements may be observed well beyond the vertical projection of the excavation. Following completion of mining of a longwall, movement above and adjacent to the extracted area will continue for some time, at a reduced rate, until maximum subsidence and horizontal movement is complete.

The stability of a cliff can be affected by mining due to the differential movements that occur along the length or height of the cliff. The differential movements induce stresses within the rockmass which, if sufficiently large, can result in sections of the rock cracking, potentially leading to instability. The impact of mining on cliffs can be affected by a number of factors, discussed in detail in the cliff study carried out for AA7 (MSEC, 2006, 2008) and AA9 (MSEC, 2012).

The majority of the observed cliff instabilities in the Southern Coalfield due to mining have occurred after the cliffs have been directly mined beneath and, therefore, have been located over the goaf. There have been very few recorded cliff instabilities outside the extracted goaf areas of longwall mining in the Southern Coalfield (MSEC 2012).

4.2 NEPEAN GORGE (APPIN AREAS 7 AND 9)

Cliffs were identified within the general application area for the Nepean River using a number of techniques, including ortho-photograph, 1 m surface level contours from ALS scanning, as well as field mapping.

The 701 to 710 and 901 to 904 Longwalls do not directly mine beneath any of the identified cliffs on the Nepean River. The identified cliffs are all located a minimum distance of 60 m from the goaf edge of any of the longwalls planned for AA7 and 9. Consequently, based on the proximity of mining to the cliffs alone, it is considered unlikely that any cliffs will become unstable due to mining of Longwalls 701 to 710 or 901 to 904.

The subsidence studies also conclude that the slopes outside the Nepean River gorge and the alignments of the creeks would be likely to remain stable during and after mining, and that the chance of soil slippage is small (MSEC, 2008 and 2012). However, it is possible that some remediation might be required to ensure that mining-induced cracking does not result in the formation of soil erosion. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the slopes in the long term.

Although mining is unlikely to destabilise cliffs and steep slopes, the cliffs in the area are already inherently unstable. Consequently there is the possibility that a rock fall associated with the cliffs may occur naturally during or following the period of mining.

4.3 PRINCIPAL IDENTIFIED HAZARDS

Potential hazards associated with natural instabilities, horizontal ground movement, local stress redistribution and other subsidence related effects, applying to the cliff faces, steep slopes and edges of the Nepean River gorge and tributaries include:

- Rock falls resulting in injury to persons.

- Unstable ground associated with the steep slopes, faces and edges of cliffs leading to the risk of persons falling.
- Unstable ground associated with the faces and edges of cliffs resulting in injury to persons walking through these areas.

Management of the identified hazards will be by way of:

- Initial controls appropriate to the level of risk.
- Regular monitoring and reporting on areas of potential instability, before, during and after longwall mining.
- Regular inspections and investigations.
- Action plans for response to defined events.

These control measures apply to all areas of the Nepean River gorge with the potential to be adversely affected by the extraction of longwall mining by BHPBIC.

4.4 LIMITATIONS AND ASSUMPTIONS

This NRMP uses a combination of initial controls - ongoing monitoring, inspections and investigations, and appropriate responses to identify adverse conditions. These controls and responses are to minimise risk to people who may enter the Nepean River gorge from exposure to ground instability in the area.

While it is the intention of BHPBIC to maintain safety at all times, there are certain limitations that need to be recognised, despite the fact that mining induced cliff and slope instability is not likely in AA7 or AA9. These limitations stem from:

- There is natural instability associated with the cliff faces and edges in the area.
- The interaction of mining induced movements on the natural instability of cliff faces and edges cannot be precisely quantified.
- Results from inspections, photographing and monitoring cliff faces and edges in the more heavily vegetated areas of the Nepean River gorge will not be as precise as non-vegetated areas.
- In the absence of information to the contrary, it is assumed the effects of mining will be similar in nature and magnitude to those associated with previous longwalls located in similar areas and the initial controls implemented on this basis.
- It is difficult to quantify the risks associated with rock falls and while the probability of resultant injuries may be remote, the potential consequences are severe. Controls will be implemented on this basis.
- The Nepean River gorge is rugged and relatively difficult to traverse with only a limited number of practical access points. At the request of any landholder, warning signs will be displayed at access points. It is expected that observational monitoring will be undertaken from the river using boat access as well as from properties where access is granted by landholders for routine monitoring.

5 PERFORMANCE MEASURES AND INDICATORS

The aim of this NRMP is to ensure public safety and to comply with the requirements of the relevant approvals with regards to the cliffs in the Nepean george.

The proposed mining is to be undertaken under the BSO Approval and as such the following Performance Measures (refer **Table 5.1**) as detailed in *Schedule 3 of* the Approval are required to be met.

Table 5.1 – Subsidence Impact Performance Measures

Land (Condition 1 Schedule 3)	
Other cliffs flanking the Nepean River.	Negligible environmental consequences (that is occasional rock falls, displacement or dislodgement of boulders or slabs, or fracturing, that in total do not impact more than 0.5% of the total face area of such cliffs within any longwall mining domain).

In order to mitigate the potential subsidence impacts and environmental consequences from the mining of Longwalls 701 – 710 and Longwalls 901 to 904 monitoring and recording will be undertaken prior to mining, throughout the extraction and at the completion of subsidence (refer **Section 6**).

In the event that any subsidence impact is recorded, consideration would be given to implementing appropriate management, remediation and/or mitigation measures in consultation with relevant stakeholders (refer **Section 7**).

If the subsidence impact performance measures are exceeded, BHPBIC will notify the appropriate stakeholders and implement the Contingency Plan (**Section 8**).

6 MONITORING AND REPORTING

The ongoing effectiveness of the NRMP requires personnel to be able to highlight non-conformances with Plan provisions and make recommendations to improve the Plan. The corrective action requirements of this Plan facilitate the continual monitoring and improvement of Plan provisions.

6.1 MONITORING PROGRAM

6.1.1 Monitoring/Communications

The Manager Approvals shall institute regular subsidence management meetings during the extraction for the purpose of maintaining communications necessary for the effective operation of this Management Plan. Should any Management Plan triggers be met the Manager Approvals shall convene an exceptional subsidence management meeting to discuss the trigger and any actions required.

Should any ground movement trigger be met the Manager Approvals shall convene a subsidence management meeting to formulate an agreed and appropriate response. The Manager Approvals shall be responsible for implementation of the agreed actions and the Manager Landholder Relations for communication to affected landowners.

6.1.2 Data Collection and Interpretation

The processes defined within this Management Plan can be demonstrated as being effective in the control of hazards over the mining period. It specifically addresses hazards associated with cliff face and edge deterioration resulting from ground movement.

The following information is collected, reported and maintained to improve the understanding of the effect of subsidence on cliffs and steep slopes:

- Subsidence movement surveys conducted.
- Regular review of subsidence movement monitoring and inspections.
- Interpretation and assessment of the data derived from surveys and observations.
- Assessment of any response actions implemented.

6.1.3 Inspections and Investigations during Mining

Inspections of the cliff faces and edges likely to be affected by longwall extraction will be conducted where practical. Monthly inspection will be conducted during active subsidence and will include photographs of any deterioration of cliff faces with the potential to result in a rock fall.

These inspections shall be performed by person(s) assessed as competent by the BHPBIC Environment Field Team Coordinator and be carried out while the river valley is affected by the mining operations.

An investigation shall be conducted by the Environment Field Team Coordinator of any rock fall identified associated with the cliff faces or edges in the area of the river gorge that may be affected by past or present mining. The results of this investigation shall be used in the assessment of the relationship between ground movements, cliff face and edge deterioration and failures.

Surveys prior to the commencement, during extraction, and following completion of each longwall will be conducted according to the schedule contained in **Table 6.1**.

Table 6.1 – Cliff and Steep Slope Management

Monitoring Proposed	Description	Timing/ Frequency	Reporting
Baseline studies prior to mining	Photographic record with details of site conditions including cliff formations	Once prior to mining. Photographic records will be prepared.	Via regular reporting processes including annual reports and subsidence management meetings
Monitoring during mining	Visual observations of cliffs, steep slopes and other mining impacts	Monthly routine inspections with weekly inspections during critical periods	Via regular reporting processes including annual reports and subsidence management meetings
	Valley closure monitoring	During mining at a frequency to be determined with the PSE	Via regular reporting processes including annual reports and subsidence management meetings
In the event that impacts are identified	Reports to key stakeholders and development of mitigation measures	Notification as soon as possible after an impact is confirmed	Written report to stakeholders and development of mitigation measures as required
If impacts are noted, photographs will record the level of impact and where necessary, remedial action will be taken in consultation with DoPI and DRE.			

6.2 REPORTING

Reporting of monitoring results will include the following information:

- Date of monitoring.
- Location including easting and northing positions.
- Distance the longwall has travelled from the face starting position.
- Distance from the nearest edge of the extracted longwall to the monitoring site at the time of monitoring.
- Subsidence survey measurement data.

The monitoring report will be collated and assessed against the results of the cliff inspection and presented at the monthly BHPBIC Subsidence Management Meeting. However, if the findings of a particular monitoring result are deemed to warrant an immediate response the Survey Coordinator and/or Environmental Field Team Coordinator shall immediately notify the Manager Approvals who will call a special assessment meeting at the earliest opportunity. Any large rock fall will be notified to key stakeholders within 24 hours of it being confirmed.

The frequency of surveys nominated in **Table 6.1** is subject to change based on practical implications with access to the river gorge. Delays may be caused, in some cases, by adverse weather conditions, restricted access or safety concerns.

Monitoring results will be made publicly available in accordance with BSO Approval *Condition 8 &11, Schedule 6* and will also be included in the Annual Reporting *Condition 3, Schedule 6.*

7 MANAGEMENT AND MITIGATION STRATEGIES

7.1 BASELINE INVESTIGATION AND INITIAL CONTROL MEASURES

The Nepean River is not mined under by Longwalls 701 to 710 or Longwalls 901 to 904, but their extraction will induce some movement within the river gorge.

The following control measures shall be established:

- Where practical a baseline inspection of the cliff faces and edges likely to be affected by longwall mining will be conducted prior to mining. It will include photographing any existing deterioration to establish the natural risk associated with such locations. A file of these locations, their initial condition and photographic data shall be established prior to mining and updated during the mining period.
- Any rock or cliff face identified in the baseline inspections as being at high risk of falling shall be signposted if requested by the landholder.
- The location of any signs, barricades, other remedial or warning provisions established and the location of any rock falls in the area potentially affected shall be marked on a Plan which is maintained during the mining period.
- Signs shall be prominently displayed at any key access point to the river gorge, at prominent locations within the valley and at any rock fall site if requested by the landholder.

These signs shall read as below or similar:

BHP BILLITON ILLAWARRA COAL

WARNING

Rock falls may occur from time to time in the Nepean River Gorge.

Subsidence from coal mining activities may increase the risk of these falls.

Please be careful near steep cliffs.

If you notice any rock falls or changes in rock faces,

Please report them:

Illawarra Coal Community Call Line 1800 102210

8 CONTINGENCY AND RESPONSE PLANS

8.1 CONTINGENCY PLAN

“Trigger” levels have been developed that relate to response actions as detailed in the Trigger Action Response Plan (TARP) located at **Table 8.1** below. **Table 8.1** summarises the “trigger events” and the associated actions required.

Table 8.1 – AA9 Trigger Action Response Plan (TARP)

Level	Trigger Event	Action	Responsibility
Survey Based			
1	Closure across the valley within prediction	Continue monitoring and reporting	Survey Coordinator
2	If closure across the valley exceeds predicted movements	Increase frequency of inspections of adjacent cliff faces	Manager Approvals
Event Based			
1	If identified or informed of a large rock or cliff fall	Initiate an investigation and report results to stakeholders. Initiate appropriate remedial action (if required) after gaining agreement of DP&I and landowner	Manager Approvals
2	Where public safety is reduced	Initiate an investigation at the earliest opportunity and take appropriate action in accordance with DP&I and landholder requirements	

Note: *Appropriate action will depend on accessibility, safety of persons required to take the action, restrictions imposed by landowners or statutory bodies, the level of assessed risk to others etc. It may include the erection of signs and/or fences, intentionally collapsing strata in a controlled manner, or any other measure agreed as appropriate.*

In the event the Performance Measures detailed in **Section 5** of this NRMP are considered to have been exceeded, or are likely to be exceeded, BHPBIC will implement a Contingency Plan to manage any unpredicted impacts and their consequences.

This would involve:

- Capture photographic record.
- Notify relevant stakeholders soon as practicable.
- Notify relevant agencies and specialists as soon as practicable.
- Conduct site visits with stakeholders as required.
- Contract specialists to investigate and report on changes identified.
- Provide incident report to relevant agencies.
- Weekly monitoring until stabilised.
- Monthly updates from specialists on investigation process.
- Inform relevant agencies and stakeholders of results of investigation.
- Develop site Corrective Management Action (CMA) in consultation with key stakeholders if required and seek approvals.

- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting following CMA completion.
- Review Management Plan.
- Report in regular reporting and End of Panel Reports and AEMR.

BHPBIC will consult with appropriate specialists and relevant agencies in order to devise an appropriate response in respect to any identified exceedance.

The development and implementation of contingency measures will be designed to address the specific circumstances of the exceedance and assessment of environmental consequences.

If the contingency measures implemented by BHPBIC fail to remediate or mitigate the impact or the Director-General determines that it is not reasonable or feasible to remediate the impact BHPBIC will provide a suitable offset to compensate for the impact to the satisfaction of the Director-General of DP&I in accordance with the BSO Approval *Condition 2, Schedule 3*.

All incidents will be reported internally through BHPBIC's Incident Procedure and related records will be maintained in accordance with the BHPBIC procedure Records Management (*ICHP0108*).

9 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

9.1 INCIDENCES

BHPBIC will notify DP&I and any other relevant agencies of any incident associated with the BSO as soon as practicable after BHPBIC becomes aware of the incident. BHPBIC will provide DP&I and any relevant agencies with a detailed report on the incident within seven days of the date of the occurrence.

9.2 COMPLAINTS HANDLING

BHPBIC will:

- Provide a readily accessible contact point through a 24 hour toll-free Community Call Line (1800 102 210). The number will be displayed prominently on BHPBIC sites in a position visible by the public as well as on publications sent to the local community.
- Respond to complaints in accordance with the BHPBIC Community Complaints and Enquiry Procedure.
- Maintain good relations and communication lines between the community and BHPBIC.
- Keep a register of any complaints, including the details of the complaint with information such as:
    - Time and Date.
    - Person receiving the complaint.
    - Complainant's contact name and phone number.
    - Description of the complaint.
    - Work area where complaint relates to.
    - Details of any verbal response.

  - Details of any written response where appropriate.

Through these means the Douglas Park community has an opportunity to report any concerns regarding the safety of cliffs and steep slopes in the Nepean River gorge.

In the event that complaints are received in relation to mining impacts there may be a requirement for management and or mitigation of the impact. Any complaints will be forwarded to the most appropriate member of the ICHPL External Affairs Department. The response will depend on the nature of the impact or complaint and will be recorded in BHPBIC's incident/complaint tracking and reporting system.

9.3 NON-CONFORMANCE PROTOCOL

The requirement to comply with all approvals, plans and procedures is the responsibility of all personnel (staff and contractors) employed on or in association with the BSO. Regular inspections, internal audits and initiation of any remediation/rectification work will be undertaken by the Manager Approvals.

Non-conformities, corrective actions and preventative actions are managed in accordance with the BHPBIC *Non-Conformance, Preventative and Corrective Action Procedure (ICHP0107)*. This procedure details the processes to be utilised with respect to the identification of non-conformances, the application of appropriate corrective actions(s) to address non-conformances and the establishment of preventative actions to avoid non-conformances. The key elements of the process include:

- Identification of non-conformance and/or non-compliances.
- Recording of non-conformance and/or non-compliance.
- Evaluation of the non-conformance and/or non-compliance to determine specific corrective and preventative actions.
- Corrective and preventative actions to be assigned to responsible person.
- Management review of corrective actions to ensure the status and effectiveness of the actions.

An Annual Review will be undertaken to assess BHPBIC's compliance with all conditions of the BSO Approval, mining leases and all other approvals and licences.

An independent environmental audit will also be undertaken (*Condition 9, Schedule 6*) to review the adequacy of strategies, plans or programs under these approvals and if appropriate, recommend actions to improve the environmental performance of the BSO. The independent environmental audit will be undertaken by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Director-General of DP&I.

10 PLAN ADMINISTRATION

This NRMP will be administered in accordance with the requirements of the AA9 EMS and the BSO Approval Conditions. A summary of the administrative requirements are provided in the LMP.

11 REFERENCES

MSEC (2006). *Report on the prediction of subsidence parameters and the assessment of mine related subsidence impacts on surface and sub-surface features due to mining longwalls 701 to 704 at the Douglas Project*. In support of an EIS and SMP Application.

MSEC (2008). *Report on the prediction of subsidence parameters and the assessment of mine related subsidence impacts on natural features and surface infrastructure resulting from the extraction of proposed Longwalls 705 to 710 at Appin Colliery*. In support of an EIS and SMP Application.

MSEC (2012). *Appin Colliery – Longwalls 901 to 904. Subsidence Prediction and Impact Assessments for the Natural Features and Surface Infrastructure in Support of the Extraction Plan.*

Attachment B – Slope Stability Assessment (Coffey, 2013)

LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS - APPIN AREA 9 PROPOSED LONGWALLS, RAZORBACK RANGE, DOUGLAS PARK NSW

Cardno NSW/ACT Pty Ltd

GEOTWOLL02834AA-AG
2 March 2012

Coffey Geotechnics Pty Ltd ABN 93 056 929 483
118 Auburn Street Wollongong NSW 2500 Australia

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

2 March 2012

Cardno NSW/ACT Pty Ltd
Level 1, 47 Burelli St.
WOLLONGONG NSW 2500

Attention: Ms Toni Stevens

Dear Ms Stevens,

RE: LANDSLIDE RISK ASSESSMENT FROM MINE
SUBSIDENCE EFFECTS
APPIN AREA 9 PROPOSED LONGWALLS
RAZORBACK RANGE
DOUGLAS PARK NSW

Please find enclosed our draft report on a landslide risk assessment from mine subsidence effects in relation to properties within or in close proximity to the proposed Appin Area 9 Longwalls beneath the eastern side of the Razorback Range near the village of Douglas Park NSW.

The attached document titled "Important Information about your Coffey Report" should be read in conjunction with this report.

Should you have any questions in relation to this report, please contact the undersigned.

For and on behalf of Coffey Geotechnics Pty Ltd

Jon Thompson CPEng

Principal

Distribution: Original held by Coffey Geotechnics Pty Ltd
1 copy held by Coffey Geotechnics Pty Ltd
1 electronic copy to Cardno Forbes Rigby Pty Ltd

CONTENTS

CONTENTS

Tables

Figures

CONTENTS

Appendices

1 INTRODUCTION AND OBJECTIVES

Longwall coal mining identified as Appin Area 9 Proposed Longwalls is proposed beneath the eastern side of the Razorback Range near the village of Douglas Park. Coffey Geotechnics Pty Ltd (Coffey) was commissioned by Cardno, on behalf of BHP Billiton Illawarra Coal (BHPB-IC) to assess the potential effects of longwall mining on the known landslide hazards on the slopes of the Razorback Range within the study area.

The study area for the Appin Area 9 Proposed Longwalls is shown outlined in blue in Figure 1. This is part of a larger landslide study which covers an area of approximately 100km^2 within the Wollondilly local government area and extending into the Razorback Range.

The Razorback Range area is known for its numerous historical and complex landslides[1,2]. The occurrence of various types of land instability such as failures of escarpment areas and rock falls elsewhere in the Sydney Basin is well documented with some references to the effects of mine subsidence on landslides[3]. However, published data on the occurrence and mechanisms of the landslides in the Razorback Range area (such as debris flows) is not as well documented.

Based on the Cardno brief for the study, Coffey's role in this project as the nominated Geotechnical Consultant included the following:

- Geotechnical assessment of the effects of mine subsidence on landslide activity within the study area and preparation of a report for incorporation into subsequent applications to the relevant Government agencies.
- Working with Dr Phil Flentje during the data collection, field mapping and reporting phases of the project.
- Use of information provided by BHPB-IC and other consultants working on the project, to assist in the landslide assessment including:-
    - Mine Subsidence Engineering Consultants (MSEC) subsidence predictions and impacts for both the natural and man-made surface features within the study area;
    - BHPB-IC provided Digital Orthphotography 2007, Digital Terrain Model (DTM) based on a 2007 Airborne Laser Scan, geological information and modelling;
    - Cardno provided GIS support staff and resources.

---

[1] Local experience by Coffey carrying out numerous geotechnical investigations in the area.

[2] Blong, RJ and Dunkerley, DL '**Landslides in the Razorback Area, New South Wales, Australia', (1976)** *Geografiska Annaler. Series A, Physical Geography*, Vol. 58, No. 3, Case Studies of Rapid Mass Movements in Different Climates (1976), pp. 139-147

[3] Pells, PJN 'A note on escarpment instability associated with mining subsidence' (1991) *Second conference on buildings and structures subject to mine subsidence.* Mine Subsidence Technical Society, pp66-73

Significant literature review work was carried out by Dr Flentje for this project and further literature review was carried out by Coffey on previous relevant studies and landslide information.

Dr Flentje was commissioned by Cardno to provide the following:-

- A landslide inventory where each landslide is identified and given a unique site reference code. Dr Flentje has carried out significant similar studies of the Illawarra Escarpment for Wollongong City Council.
- A landslide susceptibility map, grouping areas into ‘very low’, ‘low’, ‘moderate’ or ‘high’ landslide susceptibility.

Dr Flentje’s work overlapped with the Coffey assessment in most stages of the study, in particular for the air photo interpretation and field ground truthing and mapping. Landslide maps and terrain sensitivity figures presented in this report as appendices have been prepared by Dr Flentje based on the combined API and fieldwork with Coffey and the subsidence prediction data provided by MSEC.

1.1 Investigation Objectives

The objectives of the geotechnical assessment were to:

- Identify roles that regional stratigraphy, geotechnical strength parameters, hydrogeology, geomorphology, slope inclination and pore water pressure, seasonal rainfall patterns will play in the existing and potential future landslide activity in the study area.
- Assess the likely predicted impacts that the proposed mining may have on the landscape features susceptible to landslide risk in the study area, and provide an analysis of the relative (semi-quantitative) extent of the impacts.
- Assess the potential of earthquake risk in the area that may augment the slope instability induced by the subsidence impacts;
- Perform a Geotechnical Risk Assessment in general accordance with the Australian Geomechanics Society ‘Landslide Risk Management’ document[4] published in 2007;
- Outline a monitoring program (including identification of monitoring points) with appropriate trigger levels for corrective management actions for areas at most risk of landslide;
- Provide descriptors of the corrective management actions proposed; and
- Assess any cumulative effects.

---

[4] ‘Landslide Risk Management’ *Australian Geomechanics, Journal and News of the Australian Geomechanics Society’, Volume 42, No. 1, March 2007*

2 SCOPE OF WORK

The scope of work for this assessment including the following:-

- Literature review of existing landslide information and geological data;
- Air photo interpretation in conjunction with Dr Flentje and entry of air photo interpretation into GIS by Coffey's Dr Ellis and Dr Flentje (UOW);
- Field reconnaissance and mapping, in conjunction Dr Flentje;
- Subsurface investigation work to investigate geotechnical properties of 'typical' landslides in the area, comprising 13 test pits on the Lot 1/DP 553170;
- Coffey to review and assist with the input of landslide inventory mapping data into ArcGIS in conjunction with Dr Flentje;
- Carry out preliminary risk assessment to assess risk associated with slope instability and failure due to subsidence impacts;
- Provide recommendations on management and mitigation measures in relation to landside risk before commencement of mining, during mining and following the subsidence period; and
- Preparation of a report of the study.

3 COFFEY LITERATURE REVIEW

Coffey has reviewed available literature covering the following subjects:

- Geotechnical assessments within, or close to, the study area;
- Research papers documenting landslides which have been either triggered or reactivated by mining-related subsidence.

Our review of available literature has indicated the following:

- There are several detailed geotechnical assessments of landslide activity within the Razorback study area. These include evidence to indicate that landslides are widespread throughout the Slope Stability Study Area. Also, in the Cummins Road area, the assessed or recorded landslides did not exhibit noticeable movement between 1961 and 1995, despite periods of prolonged, intense rainfall (Refer to Appendix A).
- Our review of case studies of landslides triggered or reactivated by mining subsidence has emphasised certain global similarities in landform response to these ground movements:
    - Areas with high relief are subject to greater and different ground movement than areas with flatter topography. Valley closure and upsidence are common responses to mine-related subsidence in these high-relief areas;
    - Along plateau edges and cliff lines, horizontal movements always occur towards the valley, no matter the direction of mining;
    - Rock falls from cliff lines may fail due to shearing along the base of a detached slab of rock, which becomes back-tilted. Toppling failures are thought to be less common;

- Cliff line and slope instability is more pronounced where permeable, strong rock overlies impermeable, weaker rock. Opening or creation of vertical joints in the cap rock provides pathways for more rapid transmission of water;
- The formation of tension cracks behind cliff lines is common, particularly above the centre of the longwall panels;
- Cracking and other ground movements can alter the surface and groundwater systems. This alteration of local drainage networks has been an important factor in the triggering of some mining-related landslides;
- First-time landslides have occurred as an indirect consequence of mine subsidence, following faulting and rockfalls; and
- The effects of subsidence is generally limited to the area within the predicted subsidence zone (refer MSEC, 2011). Far-field effects can be experienced.

4 AIR PHOTO INTERPRETATION

Coffey and Dr Flentje compiled a desktop landslide inventory which commenced in November 2008 and has been updated as fieldwork progressed. Information from the literature search was used to compare some landslides over periods of some years. Some examples of these landslides are presented in Appendix A of this report. The aerial views show that the landslides have not expanded significantly over the periods between photos.

The landslide inventory was carried out at a scale of 1:5000 or larger scale. A total of 888 landslides were initially identified within the larger Razorback study area using ArcGIS prior to field checking. Following the field mapping within or nearby the Study Area the total number of landslides was reduced to 874.

The various types of landslides identified in the Longwalls 901 to 904 study area and their approximate extent are shown in Figure 3. The landslides have been given a Cruden and Varnes classification as shown in Figure 3.

5 FINDINGS OF FIELD RECONNAISSANCE AND LANDSLIDE MAPPING

5.1 General

Coffey has carried out site surface mapping and ground truthing within the Slope Stability Study Area in conjunction with Dr Flentje. A summary of fieldwork carried out for the Longwall 901 to 904 Study Area. The following fieldwork was carried out:

- On 5 and 6 July 2010, Senior Geomorphologist, Dr Lucy Ellis (Coffey Geotechnics), Dr Phil Flentje (University of Wollongong) and Amy Steiger (Cardno) visited properties within the predicted subsidence zone of Longwalls 901 to 904.
- On 20 July 2010, Senior Engineering Geologist, Andrew Hunter (Coffey Geotechnics) and Dr Phil Flentje (University of Wollongong) carried out fieldwork on Lot 3/DP 1001897 located off Menangle Road which covers an area of approximately 120 hectares. This property is just outside the Longwalls 901 to 904 Study Area but is within the broader Slope Stability Study Area.

Fieldwork objectives were as follows:

- Ground truth the landslides in the existing AA9 Slope Stability project database, previously identified using ALS data and aerial imagery;
- Assess processes and mechanisms of landsliding;
- Identify possible ground investigation locations; and
- Assess whether assets and infrastructure are likely to be impacted if landslides are reactivated.

The boundary of the study area assessed in this report was provided by BHPB-IC, and is shown as “Longwalls 901-904 Study Area” in Figure 1.

5.2 Landslide Processes and Mechanisms

Landslides within the Longwalls 901 to 904 Study Area are located either on the slopes of the Razorback Range, or on the lower Douglas Park ridge. The processes and mechanisms of landsliding are different according to their location, largely as a function of geology and slope steepness. In general, it was found that the location of landslides identified during the ALS/aerial photograph interpretation was broadly accurate. In places, it was difficult to assess landslide boundaries. Some tentatively identified landslides were removed from the database following field assessment. These tended to be on the lower slopes of the Razorback Range. These landslide areas are discussed below.

5.2.1 Razorback Ridge Landslides

The landslides along the Razorback Ridge appeared to be strongly controlled by the underlying geology. Two distinct sandstone bands and one discontinuous band were identified close to the top of the escarpment. These are probably sandstone layers within the Bringelly Shale Formation. These cliffs were up to approximately 20m in height on the south side of the ridge and approximately 50m in height on the north side of the ridge. Angular bedrock boulders are found throughout the landslide debris and on the spurs. The largest failure blocks were generally located close to the cliff lines.

Landslides were typically very large, complex slide-flow complexes. These were located within bowls separated by spurs. Bedrock outcrops were not observed within the spurs. The topography within the bowls is typically very hummocky, with a jumbled mass of failure blocks. Large “minor” failures have formed minor scarps and lobes which can be over 5m in height. These were back-tilted in places. In contrast, the spurs were relatively smooth, although some evidence of surface instability was observed in places. The toe areas of the landslide complex features were generally characterised by several large, distinct lobe features. However, in places, the flow tracks ran out into smooth alluvial/colluvial valley fill slopes, with no clear toe.

Gullies had cut into the landslide complex surfaces. These could be discontinuous. In places, water had pooled within depressions (often behind back-tilted blocks).

Smaller, discrete landslides were also observed. These tended to be located either above the lower cliff line, or below the landslide complex toes.

A tentative explanation of failure processes and mechanisms is as follows:

- The landslides are probably driven by episodic cliff line retreat with rockfalls from the sandstone band causing unloading of the rock behind and opening of joints. Over time, these enlarge, eventually leading to further rockfall. The resistant, steep sandstone bands have caused prominent steps in the landslide complex profile.
- Failure material from the upper cliff line and slopes can avalanche over the lower cliff lines.
- Slide and slide-flow failures occur in the colluvial material accumulated at the base of the cliff lines.
- In general, the upper section of the landslide complexes is formed by a continuous band of failed material. The failure material then travels around the more stable spurs, funnelling into the bowls.
- Test pit findings indicated that the large spurs at the southern and northern sides of the surface investigation area are bedrock features and the smaller lower spurs between these features are erosional features of the previous landslides. The bedrock on the large spurs was largely obscured by a veneer of colluvium and residual soils covering the surface. Several or the smaller spurs had large breaks in slope, possibly indicative of coalescing landslides and complex backscarps.
- Several discrete fall-avalanche-flow and slide-flows can be observed within the landslide complex features, indicating different phases of activity.
- Distinct multiple flow tracks and toe lobes are also indicative of several flow phases.
- The colluvial landslides are probably triggered by a number of factors, e.g. rockfall from the cliffline above, disturbance of internal drainage, and prolonged or heavy rainfall.
- The landslide complex features are thought to be many thousands of years old. However, periodic activation of individual landslide elements has probably occurred until relatively recently (within the last 100 years).
- Minor, discrete slides and slide-flows are thought to be recent (<100 years old), and tend to occur either just below the upper cliff line, or below the landslide complex features.
- Reactivation is generally triggered by low-frequency, high-magnitude rainfall events, or particularly long periods of prolonged rainfall. This is supported by observations of landslide activity by the landowner of Lot 3/DP 1001897.
- Surface and subsurface erosion (gullying and piping) has caused historic modification of the landslide surfaces, exploiting weaker areas between failure blocks and further emphasising the highly undulating relief. Pooled water and waterlogged ground indicates disrupted surface and subsurface drainage.

5.2.2 Douglas Park Ridge Landslides

The landslides on the Douglas Park ridge were appreciably different to those observed along the Razorback Ridge. Both slide-flow complex features and simple, discrete slide-flow and, less commonly, slide failures were observed. The ground within these features was very hummocky, particularly within the landslide complexes. Large trees tended to be sparse or absent within the body of the landslide complex features. The ground also tended to be waterlogged within the landslides and drier on the intervening ridges.

The major differences between the failures on the Douglas Park ridge and those on the Razorback Ridge are as follows:

- The landslide complexes were appreciably smaller in scale due to the different ridge heights;
- The failure material did not contain large quantities of rock;
- Bedrock exposures were only observed at the head of a few landslides; and
- The landslide toes tended to be indistinct, running out into smooth valley fill.

6 SUBSURFACE INVESTIGATION

On 15 and 16 July 2010, Coffey carried out a test pit assessment of landslide areas on Lot 1/ DP 553170. The investigation focussed on the landslide areas on the lower slopes of the Razorback escarpment to assess the composition of materials within the slide debris and depths of debris where possible. The investigation comprised the excavation of 13 test pits at the approximate locations shown in Figure 4 using a 20t excavator. The engineering logs of the test pits are presented in Appendix C together with explanatory notes. We note that CTP 01 was not excavated due to access difficulties and two pits were excavated close together (CTP11A and CTP11B).

Some test pits were excavated on apparent ridges to confirm that they were not old landslide lobes. These test pits generally encountered weathered shale at relatively shallow depths, confirming that they are bedrock ridges. On the upper part of the southern ridge there was a thin layer of colluvium (likely landslide debris) over the underlying residual soils.

The remaining test pits were excavated within valley areas where there was clearly evidence of previous landslide activity. These test pits encountered variable depths of colluvium exceeding 7m at CTP06, but only 1m at CTP08.

The colluvium was essentially a mix of gravels, cobbles and boulders of varying proportions in a clay matrix. Boulders encountered were generally up to 300mm with some larger rocks up to 1m diameter. The larger rocks within the colluvium were generally sandstone that would have originated from the sandstone cliffs along the top of the escarpment. No groundwater inflows were observed in the test pits, however it is noted that the test pits were excavated following some years of well below average rainfall. Groundwater seepages would normally be expected to occur on these slopes following long periods of rain.

7 LABORATORY TESTING

Samples of the colluvial soils and soils assessed as being close to the interface of the colluviums and the residual soils were taken from the test pits for laboratory testing which comprised direct shear strength tests. The results of the laboratory tests are presented in Appendix D and were used in the SLOPE/W analysis which is discussed in the following section.

Testing was carried out on a relatively small number of samples from the subsurface investigation area, however the range of results obtained allowed a greater degree of confidence in assigning parameters for the various slope conditions analysed.

8 SLOPE/W ANALYSES

In order to assess likely factors of safety (FOS) against sliding within the subsurface investigation area on Lot 1/DP 553170, slope stability analyses were conducted using parameters based on the laboratory test results and the conditions encountered in the test pits. The analyses were carried out on a section through the slope aligned approximately perpendicular to the contours and taking a line of best fit between a number of the test pits. Approximate slope angles were determined from the available contour plans and depths of the soils and assumed rock surface were estimated from the test pit information.

A total of 16 cases were analysed using SLOPE/W by applying different soil parameters, water levels and varying the slope angle analysed by increasing the tilt from mine subsidence effects. Tilt is effectively the change in surface slope resulting from mine subsidence The maximum predicted slope angle induced by mine subsidence from the proposed longwalls, based on a 1m x 1m grid, has been assessed as 0.36 degrees. The Predicted Total Maximum Tilt as the longwall extraction face moves along each panel is 6.34mm per m, or 0.364 degrees which is consistent with the subsidence slope above.

For the SLOPE/W analyses the increase in tilt and subsidence slope was rounded up to 0.4 degrees and in order to assess sensitivity to increasing tilt, the slope was modelled with 1 x predicted tilt angle and at 5 x predicted tilt or 2 degrees added to the natural slope.

The six most applicable analyses of a total of 16 SLOPE/W cases analysed are presented in this report The remainder of cases analysed were outliers or found to be unrealistic, describing slope behaviour beyond practical bounds and therefore in very low or high FOS. These instances were therefore excluded from further analysis. A summary of the six relevant analyses is presented in Table 1 below and the analysis diagrams are presented in Appendix E.

For an active landslide the factor of safety against sliding is less than 1.0. For a temporary or short term slope condition or batter a FOS of 1.3 is normally acceptable and for permanent or long term stability an FOS of 1.5 is acceptable. Factors of Safety for a slope that has previously failed but is presented not active, as is the case in the subsurface investigation area, would be expected to be marginally greater than 1.0 but less than 1.3 as indicated in Table 1 below.

Table 1: Summary of Slope/W Analyses Cases 1 to 4, 7 and 8

Case	C (kPa)	Φ (^{0})	Slope	Water Level Above Toe of Slope(m)	FOSSF
1	4	18	Natural Slopes	0	1.2
2				30	1.0
3			Natural Slope + 0.4 degree Tilt (maximum predicted tilt (MSEC, 2011))	0	1.2
4				30	1.0
7			Natural Slope + 2.0 degree Tilt (5x exaggerated subsidence)	0	1.1
8				30	1.0

Notes:

1. *The soil parameters Cohesion (C) and Angle of Internal Friction (Φ) are based on the results of the subsurface investigation and laboratory testing of the selected soil samples.*
2. *The slopes used in the analysis are based on the natural slope and an increased slope due to tilt from mine subsidence. Additionally an exaggerated tilt of 5 times the predicted tilt was applied to the slope and analysed for Cases 7 and 8.*
3. *The water levels selected for the analysis essentially represented low and very high groundwater levels to assess sensitivity to groundwater. The water level of 30m above toe of slope is highly unlikely and represents an exaggerated level for groundwater. The previous landslides may become active following rain events due to local saturation of the soils where water is temporarily perched within the soil mass at the failure plane.*

The results of the analyses indicate that using the parameters the landslide materials in the trial section area where landsliding has occurred in the past, the FOS against sliding are relatively low, indicating marginal stability and that sliding is largely driven by water level changes in the soil mass, rather than small changes in slope angle or tilt resulting from mine subsidence effects.

The SLOPE/W analyses undertaken relate only to soil slopes where significant landsliding has occurred in the past. Landslides can also occur along the cliffs lines at the top of the escarpment as rock falls. These may be triggered by rainfall and erosion or instantaneous stresses and strains in the rock due to mine subsidence, seismic events or temperature change.

9 LANDSLIDE RISK ASSESSMENT

9.1 Assessment Methodology

The landslide risk assessment conducted for this study involved the following steps:

- Identify the landslide hazards or events that have occurred in the past and may occur in the future;
- Identify the landslide processes occurring, factors contributing to instability, and likely triggers to future instability;
- Assess the time frame over which these landslides occur, and in so doing, assess the likelihood that these landslide hazards or events will occur in the future;
- Assess the potential consequences in terms of potential damage to property;
- Combine the estimates of likelihood and consequence to derive an assessed risk of slope instability in the pre-mining state;
- Review the estimated subsidence effects on the Longwalls 901 to 904 Study Area and the likely surface expression of subsidence;
- Assess how the subsidence will impact on the likelihood or consequences of failure;
- In light of the above, assess the risk of slope instability post-mining.

The slope risk assessment was undertaken in accordance with the methods and principles presented by the Australian Geomechanics Society publication “Practice Note Guidelines for Landslide Risk Management 2007” (AGS2007). Appendix C of AGS2007 presents the qualitative terminology for use in assessing risk to property, which has also been used in this report.

The assessment has addressed landslides identified by Coffey within the Longwalls 901 to 904 Study Area and refers to the identification numbers with which each landslide is identified in the Coffey database. The landslide risk assessment is presented in summary form in Table 2. The risk assessment takes into account the current site surface conditions and potential effects of future mining. Future changes to the surface profile due to building development, site excavations or re-grading are not considered in this risk assessment.

Each of the sites was assessed on the basis of the estimated likelihood and extent of landsliding in relation to property and infrastructure that was able to be identified from aerial photographs and site walkover assessment. Potential elements at risk include residences, associated sheds, pools etc, farm dams and linear infrastructure such as roads and power lines. Some potential elements that may be at risk from landsliding were not included in the assessment, due to the difficulty of identifying the location, extent, and lower cost of replacement of such elements. The elements not considered included farm fences and minor assets not identified in the MSEC (2011) subsidence assessment.

9.2 Mapping of Potential Landslide Activity

The landslides identified by the Coffey study fall into two broad categories, those occurring on the Razorback Range, on the northern half of the Longwalls 901 to 904 Study Area, and those occurring on the lower, Douglas Park Ridge in the eastern part of the Longwalls 901 to 904 Study Area. Mapping of the land in the vicinity of the properties assessed was carried out by a senior geomorphologist from Coffey and Dr Phil Flentje from the University of Wollongong. The work was followed by ground investigations including surface mapping and subsurface investigation of a selected area on Lot 1/DP553170. Evidence of existing or potential landslide activity was identified from aerial photographs and catalogued with reference identification numbers. These identified landslides formed the basis of the risk assessment. The findings of the mapping are outlined in Section 5.

9.3 Elements at risk

In the case of both the Razorback Ridge landslides, they have typically occurred on the upper slopes, well above any development. The visible flow paths and toe lobes do not, in all but a few cases, reach the buildings which are generally confined to the footslopes. The Douglas Park landslides are smaller in scale and are located on steeper slopes on the sides of hills and on side slopes of ridges

The elements at risk of influence from specific landslide events are outlined in the Potential Consequences column of Table 2.

10 MINE SUBSIDENCE EFFECTS ON LANDSLIDE RISK

10.1 Predicted Mine Subsidence

Subsidence predictions for the indicate maximum subsidence of the order of 1m through the central part of the Longwalls 901 to 904 Study Area. Subsidence will take place over a broad subsidence bowl such that incrementally the changes in relief across the area will be minor. In the upper slope areas in which the majority of slope instability occurs, subsidence is expected to be up to 400mm for Longwalls 901 to 904. During the mining of Longwalls 905 and 906 the full subsidence bowl is expected to expand into this area up to a maximum of 1150mm. From the figures provided it appears that tilting or changes in slope angle would be less than 1%, or less than 10mm/m. This is consistent with subsidence predictions on similar longwall mining activity in the area. There are other possible mechanisms that may impact landslide risk due to mine subsidence such as curvature and stresses and strains, however tilt (or slope change) was considered more likely to influence landslide risk than these other mechanisms.

10.2 Factors Affecting Slope Instability

Slope instability is governed by slope angle, soil strength, and concentrations of water within the potentially unstable soil or rock mass. Instability within the Longwalls 901 to 904 Study Area occurs in a variety of forms and incorporates varying proportions of soil, rock, and water.

The types of slope instability identified and the major factors contributing to each are summarised as:

Type 1 - Rock block falls associated with rockmass degradation and cliffline regression due to erosion, and undercutting or softening of low strength bedding planes beneath prominent sandstone blocks;

Type 2 - Translational soil slides occurring over low angle failure planes, typically occurring on low strength relict bedding planes or where water concentrates on the soil/rock interface;

Type 3 - Debris flows associated with downslope movement of material disturbed by translational slides as outlined above;

Type 4 - Mass soil movement in accumulated colluvium triggered by saturation, prolonged waterlogging, erosion, and progressive strength loss of soils;

Seismic events can also influence or trigger landslide activity. Dr Flentje has researched earthquake occurrence in the 50km around the Appin Longwall 901-904 site. These earthquakes have been mainly less than magnitude 4.0 with only a few recorded in the range 4.0 to 5.8. Chowdury et al, (2006) and Chowdury and Flentje, (2007), reviewed selected literature which has examined the relationship between earthquakes and landsliding. The literature indicated that even in areas highly susceptible to slope failure, only a few landslides may occur from an earthquake with magnitude less than 5. The most common landslide types resulting from earthquakes are rock falls, rock slides and fast moving disrupted soil-rock slides. Two earthquakes with magnitude greater than five have been recorded within 50km of the Slope Stability Study Area and Dr Flentje has reported that he was not aware of any records that indicate these earthquakes have triggered any cases of landsliding or slope instability. Seismic activity that could trigger landsliding would be considered as rare based on the recorded history of seismic activity in the region.

Contributing factors to such instability include the presence of soil horizons of low shear strength at adverse orientations relative to the slope, reduction in shear strength by creep movements or other small scale lateral movements within the profile, and concentrations of water that can have the dual effect of reducing soil strength and increasing pore pressures on potential failure planes. Slopes containing any or all of these conditions generally exist with low factors of safety, and failure occurs when a triggering event such as intense rainfall or prolonged wet weather, coupled with ongoing strength reduction in the slope, combine to overcome the available resistance.

The results of laboratory shear strength testing indicate variable strengths in soils on potential failure planes, with one sample revealing zero cohesion and a 14 degree angle of friction. Such low strength materials, if present on bedding planes, could be sensitive to changes in slope angle, and therefore minor tilts could be a contributing factor to future instability in slopes exhibiting the types of sliding that are based on low angle shear planes. Within the Longwalls 901 to 904 Study Area, this would apply to the Type 2 slides (defined above). However, the primary trigger for this type of landsliding will be rainfall and water ingress into the failure plane and the existing slide debris. Increased water ingress may result through tensions cracks resulting from movements.

10.3 Expected Impact of Mining on Slope Instability

As discussed above, the subsidence effects will take place over a broad area, and due to the depth of mining, and localised changes in slope, will be minor. It is anticipated that surface expression of systematic subsidence in the form of cracking or similar, would be minor. However, non systematic movements such as down slope movements can result in increased tension and cracking at the tops of ridges. On the basis of the types of sliding present and the potential impacts of subsidence on the profile, Table 2 addresses the potential increased risk of slope stability associated with the expected mine subsidence impacts. In evaluating the potential influence of mine subsidence on slope stability, Coffey considered that the following mine subsidence effects could potentially influence the risk of landslide under conditions similar to those present within the study area:

- Tilting – there is the potential for minor tilts associated with mine subsidence to alter the angle of potential slide planes. In situations where sliding occurs on low angle slide planes, such as Type 2 slides, sliding can be triggered where tilts increase the angle of the slide planes in the down-slope direction. At sites within the Longwalls 901 to 904 Study Area, Type 2 sliding is likely to be occurring on the soil-rock interface or on relict bedding planes. The mine subsidence movements predicted indicate tilts are likely to be less than 10mm/m at the sites of potential instability within the Longwalls 901 to 904 Study Area. These tilt movements acting on potential failure planes within the Longwalls 901 to 904 Study Area are generally not expected to be significant, although low shear strength on some bedding planes could make these sensitive to some movement in combination with other contributing factors such as undercutting, or prolonged rainfall events;
- Strength Reduction – subsidence movements can reduce the strength of a slope profile by introducing cracking that reduces the tensile resistance of a slope to failure. Also, in sedimentary sequences bedded at low angles, differential movement along low angle bedding planes, (which can occur during relaxation of the ground towards a subsidence bowl), can introduce shearing along the plane. These shear movements reduce the available shear strength of the plane and can contribute to slope failure. The expected subsidence effects on the instability identified within this study are minor, and are not expected to produce significant cracking or differential lateral movements.
- Water concentration – cracking associated with mine subsidence can allow ingress of water into a slope. This can potentially introduce water to slide planes within the soil or weathered rock horizons that can assist in triggering instability. The estimated effects from systematic subsidence movements on the surface within this Longwalls 901 to 904 Study Area are unlikely to produce cracking of significant dimension that would allow significant ingress of water into the slopes or to failure planes where there have been previous landslides. However, where non-systematic (down slope) movements occur there is potential for increased tension and cracking at the tops of slopes which, if not mitigated, could increase water infiltration and associated pore water pressures.

As shown in Table 2, it is considered generally unlikely that the additional influence of mine subsidence will instigate new landslides or increase landslide activity within the study area. The most likely trigger event for landslide activity on the hillsides at all of these sites (other than oversteepening of the slope by manmade activities) will be significant rainfall events e.g. intense or prolonged rain.

The influence of landslide activity is not expected to contribute to increased consequences should failure occur. Therefore the influence on landslide risk will be due to increases (if any) in the likelihood of instability. Table 2 summarises these predicted effects.

10.4 Terrain Sensitivity

In order to assess which areas may be sensitive to changes in slope conditions resulting from existing conditions in combination with possible changes during and following longwall mining in the study area, Coffey and Dr Flentje have considered a range of factors that may contribute to terrain sensitivity over the hillside areas. The sensitivity analysis was based on the outcomes of this study and Dr Flentje's work on landslide susceptibility within the study area and included:-

- Landslide Inventory
- Pre-mining susceptibility
- Existing 10m ALS DEM derived groundslope
- Predicted Subsidence after the Mining of LW904; and
- Predicted Maximum Tilt during and after the mining of Longwall 904

As a result of this sensitivity analysis, plans of the Longwalls 901 to 904 Study Area and surrounds were produced by Dr Flentje to identify by colours red, orange and green hillside areas indicating high, medium and low sensitive to the above factors. The sensitivity analysis indicates that the medium and high sensitivity areas occur mainly in vacant farmland or unoccupied areas and in localised areas around the perimeter or just outside of the Longwalls 901 to 904 Study Area as shown in Figures 5 and 6.

The outcomes of this terrain sensitivity analysis provides a tool or method by which existing property can be targeted for more detailed assessment by onground observations and in some cases by subsurface investigation. This also allows future monitoring of structures to be focussed on the areas of higher sensitivity. This approach to assessing likely influences of future mining on slope instability and risk to property due to landslide may be applied to other areas of the larger Slope Stability Study Area.

11 RECOMMENDATIONS

11.1 Assessment of Property in Study Area

Based on the terrain sensitivity analysis carried out for the current Longwalls 901 to 904 study area Coffey recommend that properties in hillside areas where the sensitivity is considered medium or high (and where the properties are close to these areas) be assessed by an experienced geotechnical engineer. From our initial site reconnaissance residential dwellings and associated structures that are within or close to these areas of sensitivity are mainly located as follows:-

- Along the top of the Razorback escarpment in Donald Range Road and off Top Range Road;
- Off Menangle Road where it crosses the Menangle Ridge;
- Off the southern end of Carroll's Road; and
- Properties on the sloping parts of McWilliam Drive.

Coffey recommend that a review of the hillside conditions around structures on these properties be carried out prior to mining commencing and on completion of the longwall mining activities, or where any significant change to the site conditions may occur that could influence the stability of the slopes and performance of the existing buildings.

11.2 Ongoing Maintenance of Existing Sites

Properties in hillside areas or close to steep hillside require ongoing maintenance of drainage and water storage in particular to ensure that water is not directed onto slopes where there is a risk of landslide. This includes regular clearing of pipes, drainage paths and pits, maintenance of septic tanks and effluent irrigation systems, management of roof water and water storage tank overflows and repairs to damaged structures. Maintenance of slopes and watercourse banks to minimise erosion should also be carried out regularly. Mitigation of any subsidence cracks by infilling and re-profiling is recommended where appropriate to minimise the ingress of water into the groundwater system.

11.3 Monitoring of Landslide Risk Areas

There are a number of factors that trigger and contribute to landslide activity as discussed in Section 10.2. In order to assess if increased landslide activity is likely to occur in close proximity to buildings in some of the terrain sensitive areas, following the commencement of longwall mining and subsequent mine subsidence, landslide monitoring may need to be implemented to allow potential effects on buildings to be assessed. Methods of assessing ground movement due to landslide include the following:-

- Site observations by an experienced geotechnical engineer familiar with landslide behaviour;
- Survey monitoring of onground survey markers and fixed surface features including buildings, concrete pavements, trees and other fixed points;
- Installation of piezometers to monitor groundwater within and/or downhill of identified landslides that present an increased risk to property. These would normally be located within the slide area and between the toe of the landslide where the property (buildings) is located downhill or between the head of the slide and property where the property is located uphill. The inclinometer casing is installed in boreholes drilled through the soil mass and socketed into rock. Groundwater levels in the piezometers would be monitored by data loggers with regular downloads of recorded information, or alternatively by real time monitoring before and after the commencement of mining. Groundwater levels could then be plotted against rainfall and mine subsidence to assess whether landslide activity is increasing and presenting a risk to property; and
- Monitoring of landslide movement by inclinometer. This would involve the installation of inclinometer casing in boreholes within the landslide and between the toe of the landslide and buildings downhill of the slide or between the head of the slide and buildings where uphill of the slide. Inclinometers would be monitored at regular intervals before the commencement of mining and during the anticipated period of subsidence. In conjunction with the above monitoring methods this will provide information on the rate of movement and depth of the slide for active slides.

Table 3 below provides a summary of the likely monitoring methods that would apply to the various landslide risk categories before and after commencement of subsidence. The recommended timing of this landslide monitoring is provided following Table 3.

Table 3- Monitoring Methods Relating to Terrain Sensitivity Before and After Mine Subsidence Commencement

Terrain Sensitivity	Method of Monitoring Landslide Movement or Potential Landslide Movement			
	Observations by Experienced Engineer and Photographic Records	On ground Survey	Piezometers to Monitor Groundwater	Slope Inclinometers
Low	Yes (incidental)	No	No	No
Moderate	Yes	Yes	No	No
High	Yes	Yes	Possible	Possible

Timing of Landslide Monitoring

The recommended timing of landslide monitoring for each of the categories of risk to property (as shown in Table 3) is as follows:-

1. **Low Terrain Sensitivity** (Monitoring by Visual Assessment)
   - 6 months before commencement of mining;
   - 6 months after completion of mining.
2. **Moderate Terrain Sensitivity** (Monitoring by Visual Assessment and onground survey)
   - 6 to 12 months before commencement of mining;
   - 3 monthly during active mining;
   - 6 months after completion of mining.
3. **High Terrain Sensitivity** (Monitoring by Visual Assessment, onground survey, piezometer and slope inclinometer)
   - 12 months before commencement of mining for visual and onground survey;
   - Monthly for visual during active mining;
   - 3 monthly for ground survey active mining;
   - Installation of piezometer with data logger (remotely accessed) prior to commencement of mining. Monthly readings of piezometer prior to mining commencing. Weekly readings of piezometer during major active mining and on completion of mining; and
   - Use of down borehole inclinometer installed 12 months prior to mining, subject to trigger (visual assessment or onground survey shows landslide movement or high piezometer reading).

11.4 Slope Stabilisation Measures

11.4.1 Pre-Emptive Measures

There are a number of pre-emptive slope stabilisation measures that may be undertaken in landslide areas to reduce the risk to property prior to mining commencing. These measures include:-

- The installation of subsoil drains;
- Regrading of slopes and sealing of tension cracks in active landslides;
- Provision of surface water cut-off drains above landslides and potential landslides;
- Provision of shear piles through slide zone; and
- Improvements to vegetation including slashing of thick matted grass and planting of suitable trees.

11.4.2 Measures to Reduce Risk to Property During Landslide Activity

Risk mitigation measures may be implemented during or following mining to reduce the risk to property resulting from landslide. The primary trigger for implementation of these measures will be observations from experienced geotechnical engineers or geologists, or where landslide monitoring instrumentation during mining activity shows that movement of a landslide has commenced for a previously dormant slide or soils slope or monitoring shows ongoing or increasing landslide activity. These risk mitigation measures will be dependent on the type of landslide movement and the actual slope conditions and landuse and may include some or all of the following:-

- Removal or re-shaping of the soil slope to reduce loads within the sliding mass;
- Provision of toe support and associated drainage to support the soil mass depending on the scale of the landslide;
- Diverting overland flows around the slide area and providing localised drainage improvements e.g. Repair leaking drains or re-direct drains that may discharge into landslide areas, or improvements to septic seepaway systems;
- Redirect stock where tracks are disturbing slope or creating flow paths in landslide areas; and
- Restrict grazing in areas where landslide activity is indicated by monitoring.

12 LIMITATIONS

The findings of this report are the result of discrete/specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site.

Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Important information about your **Coffey** Report

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment.
Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Tables

TABLE 2 - LANDSLIDE RISK ASSESSMENT - RISK TO EXISTING PROPERTY - APPIN AREA LONGWALLS 901 TO 904 STUDY AREA

			PRE-MINING				POST MINING	
LOCATION OF RESIDENCE	COFFEY STUDY IDENTIFICATION No.	GEOTECHNICAL LANDSLIDE HAZARD	LIKELIHOOD OF LANDSLIDE EVENT OCCURING	CONSEQUENCES TO PROPERTY		ASSESSED RISK TO PROPERTY	LIKELIHOOD	ASSESSED RISK TO PROPERTY
Lot 3 DP1133989	1295	Localised south-facing slide-flow above creek. Possible toe erosion contributing factor	Likely	Likely to come to rest on slopes above developed areas	Insignificant	**Low**	Likely	**Low**
	1296	Large complex of multiple ancient relict debris slide-flows on south side of Razorback Range - localised re-activation of some sections may occur	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1296	Cliffline regression associated with the above	Unlikely	Houses close to cliff. Ongoing regression will eventually reach property.	Minor	**Low**	Possible	**Moderate**
	1297	Ancient relict debris slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1298	Ancient relict debris slide-flow complex	Possible	Likely to come to rest on slopes above developed areas - may impact dam	Minor	**Moderate**	Possible	**Moderate**
	1299	Ancient relict debris slide-flow complex	Possible	Likely to come to rest on slopes above developed areas - may impact dam	Minor	**Moderate**	Possible	**Moderate**
	1300	Ancient relict debris slide-flow complex	Possible	Likely to come to rest on slopes above developed areas - may impact dam	Minor	**Moderate**	Possible	**Moderate**
	1301	Multiple ancient relict debris slide-flows	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1302	Large complex of multiple ancient relict debris slide-flows on south side of Razorback Range - localised re-activation of some sections may occur	Possible	Likely to come to rest on slopes above developed areas - may impact dam	Insignificant	**Very Low**	Possible	**Very Low**
	1560	Slide-flow complex on lower spur	Unlikely	May encroach on dam. Some debris may reach large shed complex	Minor	**Low**	Possible	Moderate
	1582	Colluvial re-activation lower slope	Possible	Localised failure in gully	Insignificant	**Very Low**	Possible	**Very Low**
Lot 1 DP553170	1303	Large complex of multiple ancient relict debris slide-flows on south side of Razorback Range - localised re-activation of some sections may occur	Possible	Likely to come to rest on slopes above developed areas - some debris may reach residence and cause minor damage	Minor	**Moderate**	Possible	**Moderate**
	1581	Colluvial re-activation lower slope	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
Lot 900 DP1072947	1304	Large complex of multiple ancient relict debris slide-flows on south side of Razorback Range - localised re-activation of some sections may occur	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1305	Large complex of multiple ancient relict debris slide-flows on south side of Razorback Range - localised re-activation of some sections may occur	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**

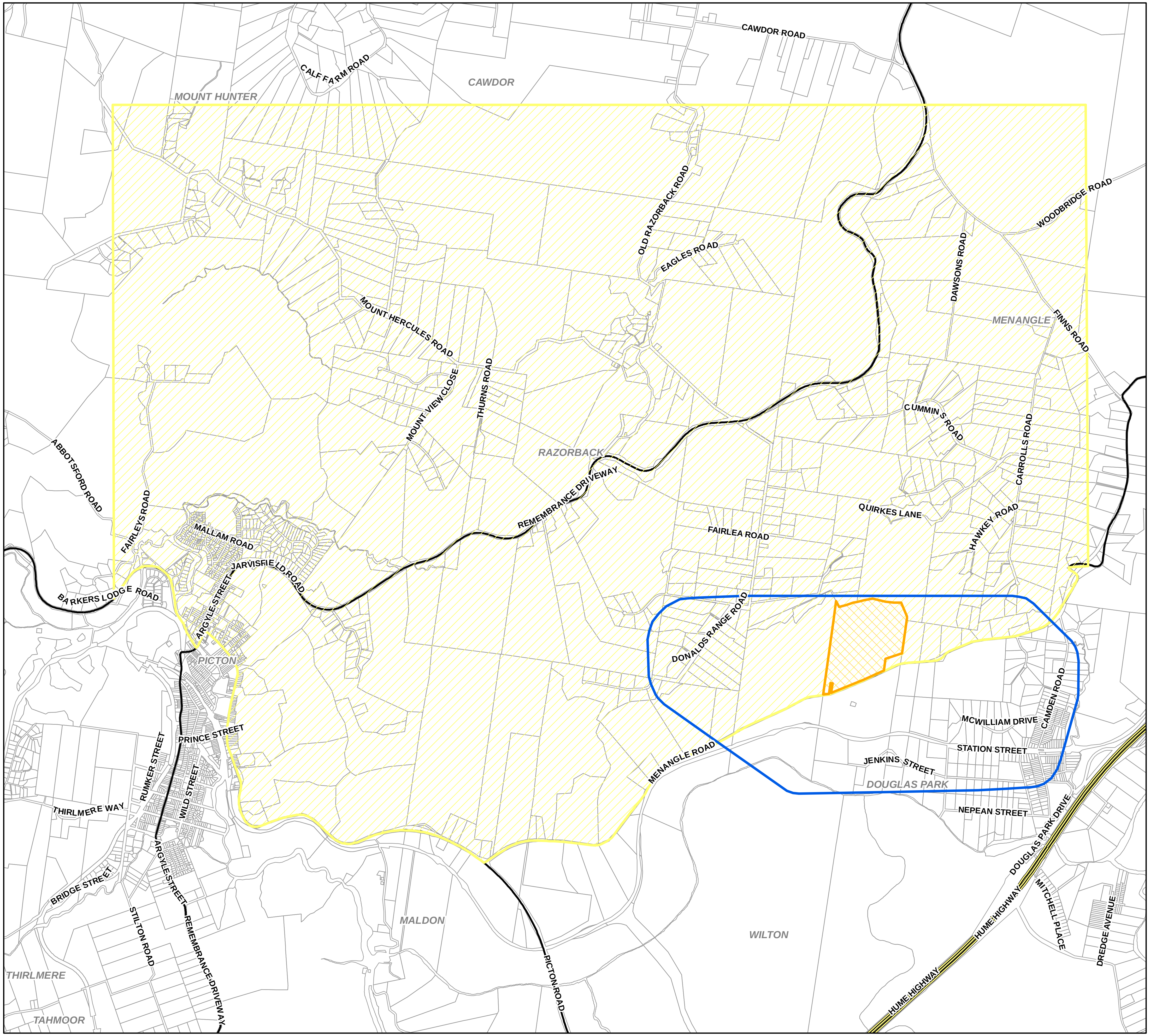
TABLE 2 - LANDSLIDE RISK ASSESSMENT - RISK TO EXISTING PROPERTY - APPIN AREA LONGWALLS 901 TO 904 STUDY AREA

			PRE-MINING				POST MINING	
LOCATION OF RESIDENCE	COFFEY STUDY IDENTIFICATION No.	GEOTECHNICAL LANDSLIDE HAZARD	LIKELIHOOD OF LANDSLIDE EVENT OCCURING	CONSEQUENCES TO PROPERTY		ASSESSED RISK TO PROPERTY	LIKELIHOOD	ASSESSED RISK TO PROPERTY
Lot 32 DP833584	1292	Creep, minor localised sliding	Possible	Unlikely to reach developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1293	Large complex of multiple ancient relict debris slide-flows on south side of Razorback Range - localised re-activation of some sections may occur	Possible	Debris likely to come to rest on slopes above development - may be some minor encroachment	Minor	**Moderate**	Possible	**Moderate**
	1294	Large complex of multiple ancient relict debris slide-flows on south side of Razorback Range - localised re-activation of some sections may occur	Possible	May encorach slightly onto shed area or dam	Minor	**Moderate**	Possible	**Moderate**
	1531	Creep, minor localised sliding	Possible	Unlikely to reach developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1532	Localised colluvial slide-flow in head of gully	Possible	Unlikely to reach developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1561	Localised colluvial slide-flow in head of gully	Possible	Unlikely to reach developed areas	Insignificant	**Very Low**	Possible	**Very Low**
Unknown properties	1304	Large complex of multiple ancient relict debris slide-flows on south side of Razorback Range - localised re-activation of some sections may occur	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1500	Slide flow complex on upper slope of Douglas Park Ridge	Unlikely	May undercut peripheral area below existing residence	Minor	**Low**	Possible	Moderate
	1504	Creep with periodic localised slide-flow	Possible	May undercut peripheral area below existing residence	Minor	**Moderate**	Possible	**Moderate**
	1505	Creep with periodic localised slide-flow	Possible	May undercut peripheral area below existing residence	Minor	**Moderate**	Possible	**Moderate**
	1507	Slide-flow complex on lower spur	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1518	Slide-flow complex on lower spur	Unlikely	May undercut peripheral area below existing residence	Minor	**Low**	Possible	Moderate
	1519	Slide-flow complex on lower spur	Unlikely	Debris may encroach on developed residential site or associated sheds	Minor	**Low**	Possible	Moderate
	1520	Slide-flow complex on lower spur	Unlikely	May undercut peripheral area below existing residence	Minor	**Low**	Possible	Moderate
	1523	Slide-flow complex on lower spur						
	1526	Slide-flow complex on lower spur						

TABLE 2 - LANDSLIDE RISK ASSESSMENT - RISK TO EXISTING PROPERTY - APPIN AREA LONGWALLS 901 TO 904 STUDY AREA

			PRE-MINING				POST MINING	
LOCATION OF RESIDENCE	COFFEY STUDY IDENTIFICATION No.	GEOTECHNICAL LANDSLIDE HAZARD	LIKELIHOOD OF LANDSLIDE EVENT OCCURING	CONSEQUENCES TO PROPERTY		ASSESSED RISK TO PROPERTY	LIKELIHOOD	ASSESSED RISK TO PROPERTY
Lot 200 DP746432	1306	Slide-flow complex	Unlikely	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Unlikely	**Very Low**
	1498	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1499	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1501	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1502	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1503	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1506	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas. May potentially encroach on road causing temporary partial blockage until cleaned up	Minor	**Moderate**	Possible	**Moderate**
	1508	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1509	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1510	Slide-flow complex	Unlikely	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Unlikely	**Very Low**
	1511	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1512	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1513	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1514	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**
	1515	Slide-flow complex	Unlikely	Debris may reach dam	Minor	**Low**	Unlikely	**Low**
	1516	Slide-flow complex	Unlikely	Could possibly reach dam, but would only be extremities of flow - low volume	Insignificant	**Very Low**	Unlikely	**Very Low**
	1517	Slide-flow complex	Unlikely	May undercut periphery of existing residence or reach dam below	Medium	**Low**	Unlikely	**Low**
	1525	Slide-flow complex	Possible	Likely to come to rest on slopes above developed areas	Insignificant	**Very Low**	Possible	**Very Low**

Figures



bhpbilliton
ILLAWARRA COAL

Locality Plan

APPIN AREA 9
SLOPE STABILTY ASSESSMENT

Legend

- Motorway (LPI)
- Arterial Road (LPI)
- ☐ Cadastre (LPI, 2011)
- ▨ Slope Stability Study Area (7,492 ha)
- ▨ Subsurface Investigation Area (67 ha)
- ☐ Longwalls 901-904 Study Area (897 ha)

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PROJECT: LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS APPIN AREA 9 PROPOSED LONGWALLS RAZORBACK RANGE DOUGLAS PARK NSW
TITLE: STUDY AREA FOR LONGWALLS 901 TO 904 AND SLOPE STABILITY STUDY AREA
PROJECT NO: GEOTWOLL02834AA-AG
FIGURE NO: 1

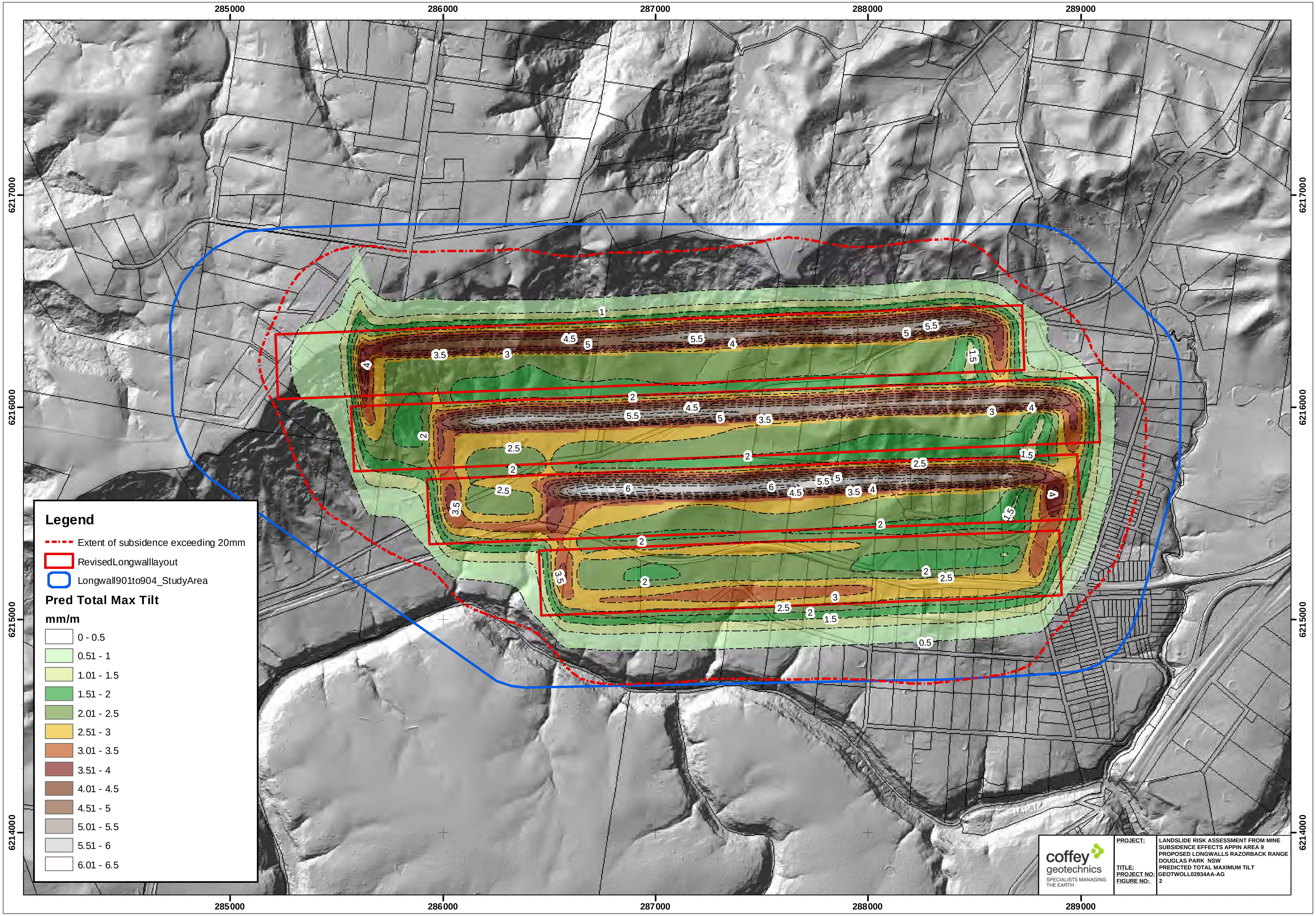
N
W E
S

Scale 1:40,000 (at A3)

Metres
0 250 500 1,000 1,500 2,000

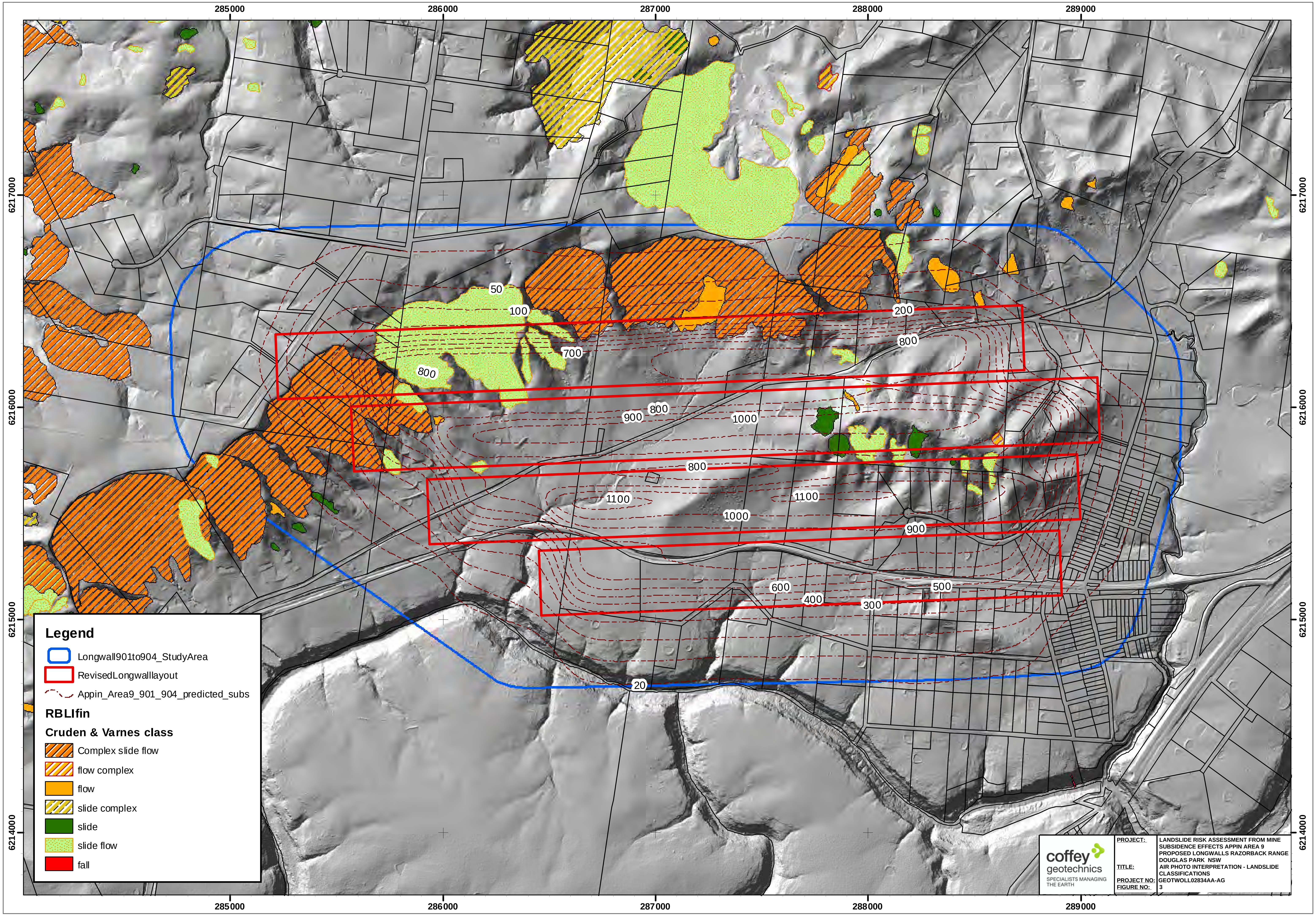
Cardno

Map Produced by Cardno Wollongong
Date: 05 December 2011
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF: 109012-02
1812_AccessInformation.mxd 01



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PROJECT:	LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS APPIN AREA 9 PROPOSED LONGWALLS RAZORBACK RANGE DOUGLAS PARK NSW
TITLE:	PREDICTED TOTAL MAXIMUM TILT
PROJECT NO:	GEOTWOLL02834AA-AG
FIGURE NO:	2



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PROJECT:	LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS APPIN AREA 9 PROPOSED LONGWALLS RAZORBACK RANGE DOUGLAS PARK NSW
TITLE:	AIR PHOTO INTERPRETATION - LANDSLIDE CLASSIFICATIONS
PROJECT NO:	GEOTWOLL02834AA-AG
FIGURE NO:	3

revision	description	drawn	approved	date

drawn	**RBJ**
approved	**JPT**
date	**12/07/11**
scale	**N.T. S.**
original size	**A3**

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

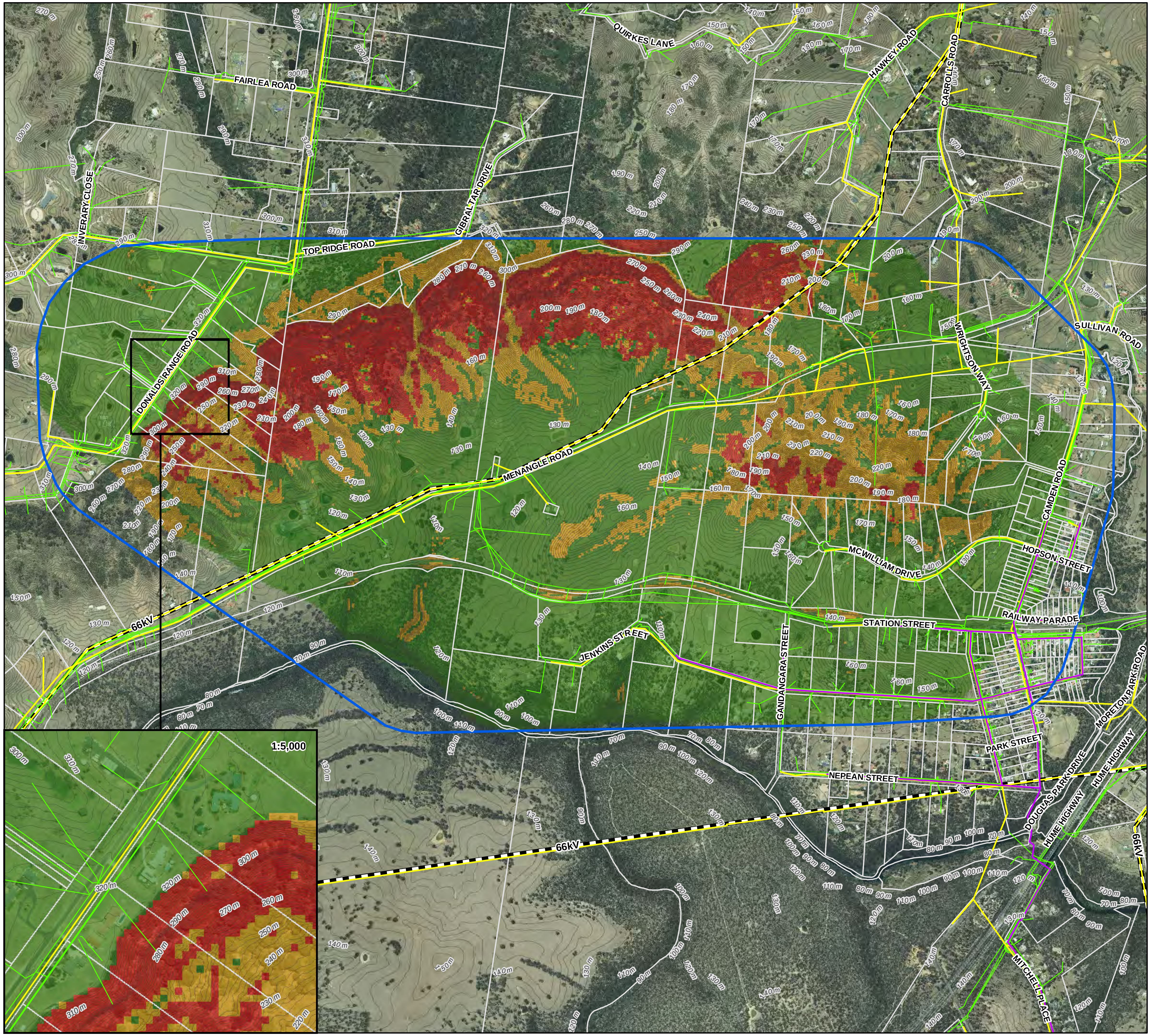
client: **CARDNO**

project: **LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS APPIN AREA 9 PROPOSED LONGWALLS RAZORBACK RANGE DOUGLAS PARK NSW**

title: **SUBSURFACE INVESTIGATION – LOT 1 DP553170 TEST PIT LOCATIONS**

project no:**GEOTWOLL02834AA-AG**

Figure no: 4



bhpbilliton
ILLAWARRA COAL

Terrain Sensitivity

APPIN AREA 9
SLOPE STABILITY ASSESSMENT

Legend

- ▭ Longwalls 901-904 Study Area
- — 2m Contours (BHPBIC)
- — Telecommunications Infrastructure (MSEC)
- — Electrical Infrastructure (MSEC)
- — Water Infrastructure (MSEC)
- ▬ Electricity Transmission Line (LPMA)
- ▭ Cadastre (LPMA, 2009)

Terrain Sensitivity

- 🟩 Low
- 🟨 Medium
- 🟥 High

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PROJECT:	LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS APPIN AREA 9 PROPOSED LONGWALLS RAZORBACK RANGE DOUGLAS PARK NSW
TITLE:	TERRAIN SENSITIVITY - APPIN LONGWALLS 901 TO 904 STUDY AREA (FACILITY)
PROJECT NO:	GEOTWOLL02834AA-AG
FIGURE NO:	5

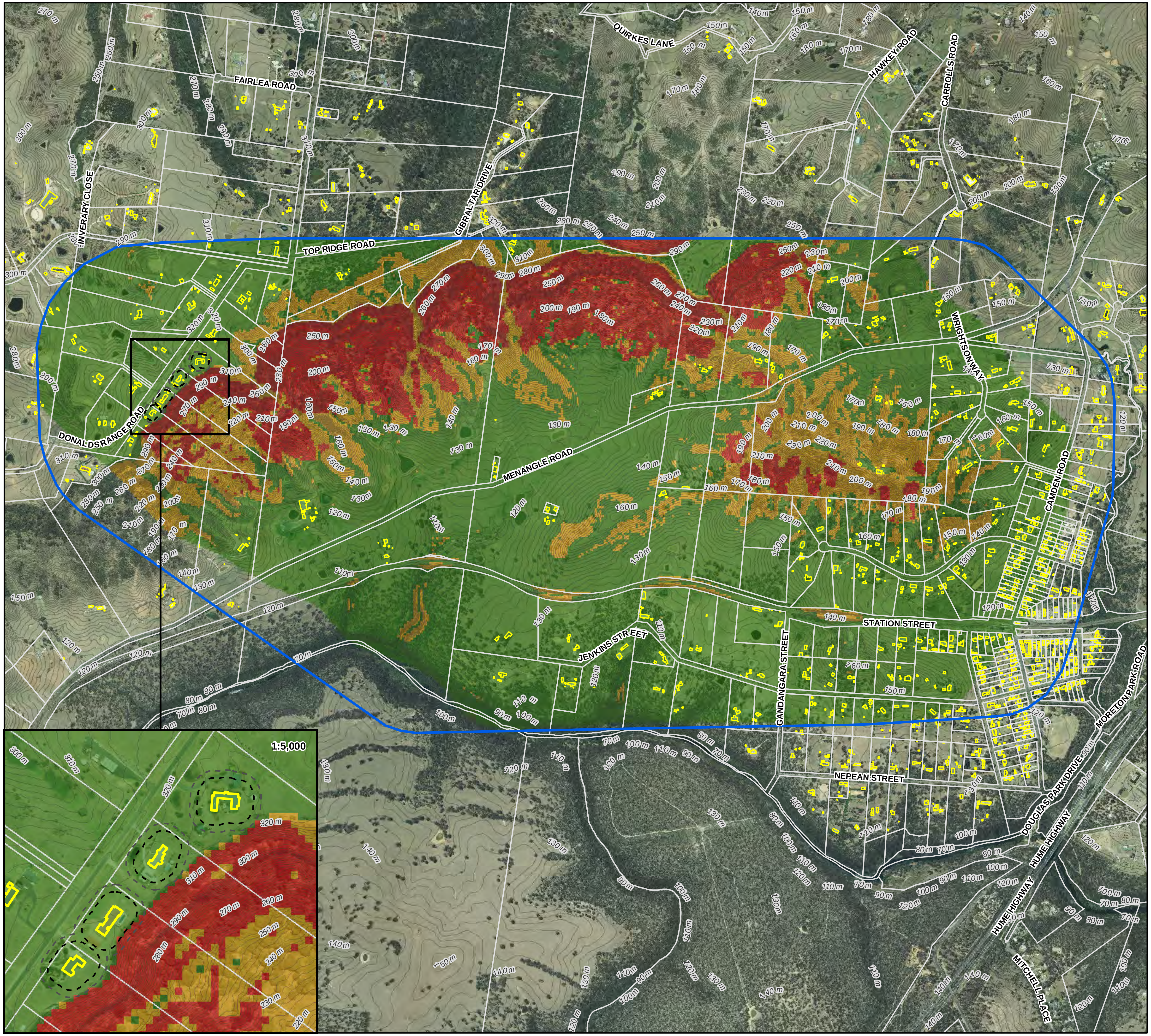
Scale 1:16,000 (at A3)

Metres
0 200 400 600 800 1,000

Cardno

Map Produced by Cardno Wollongong
Date: 31/03/2011
Coordinate System: GDA 1994 MGA Zone 56
Project: 109012-02
Map: 1811_TerrainSensitivity_Facilities.mxd 02

Aerial imagery from BHPBIC (2009)



bhpbilliton
ILLAWARRA COAL

Terrain Sensitivity

APPIN AREA 9
SLOPE STABILITY ASSESSMENT

Legend

- ▭ Longwalls 901-904 Study Area
- — 2m Contours (BHPBIC)
- — Building Structures (MSEC)
- ⬚ 30m Buffer from Houses
- ⬚ 20m Buffer from Houses
- ▭ Cadastre (LPMA, 2009)

Terrain Sensitivity

- 🟩 Low
- 🟧 Medium
- 🟥 High

N
W E
S

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PROJECT:	LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS APPIN AREA 9 PROPOSED LONGWALLS RAZORBACK RANGE DOUGLAS PARK NSW
TITLE:	TERRAIN SENSITIVITY - APPIN LONGWALLS 901 TO 904 STUDY AREA (BUILDING)
PROJECT NO:	GEOTWOLL02834AA-AG
FIGURE NO:	6

Scale 1:16,000 (at A3)

Metres
0 200 400 600 800 1,000

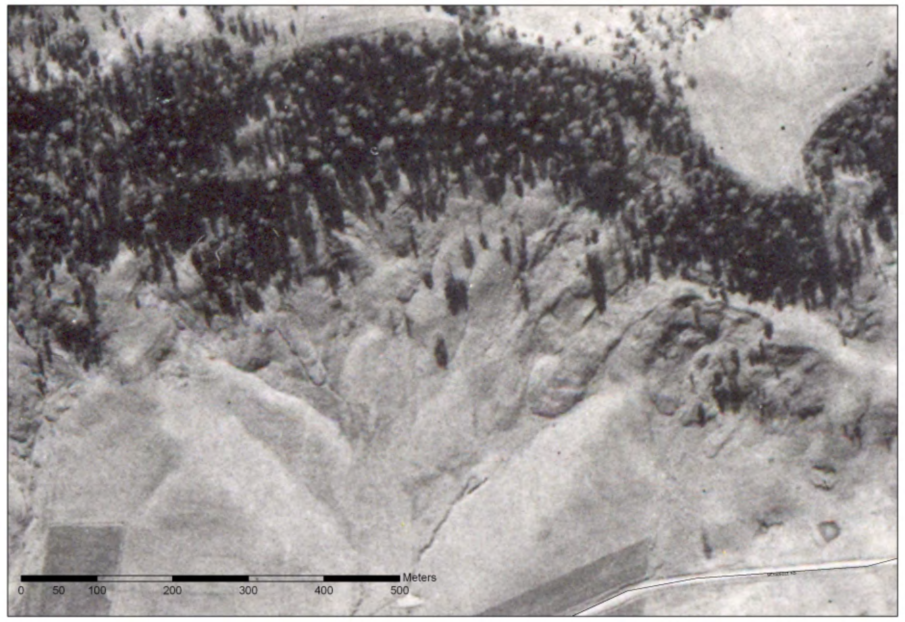
Cardno

Map Produced by Cardno Wollongong
Date: 31/03/2011
Coordinate System: GDA 1994 MGA Zone 56
Project: 109012-02
Map: 1808_TerrainSensitivity_Buildings.mxd 03

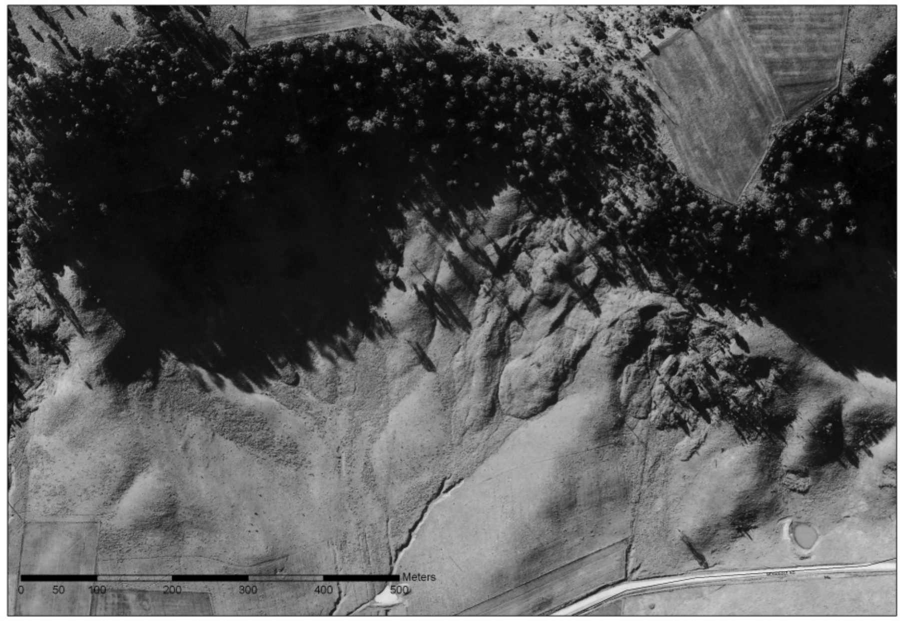
Aerial imagery from BHPBIC (2009)

Appendix A

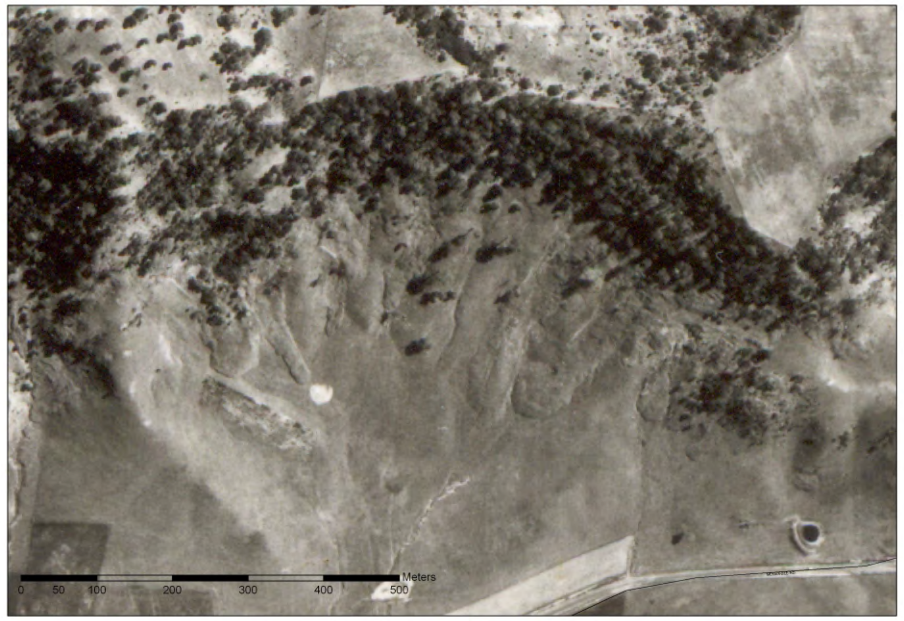
Air Photo Interpretation – Examples 1 to 3



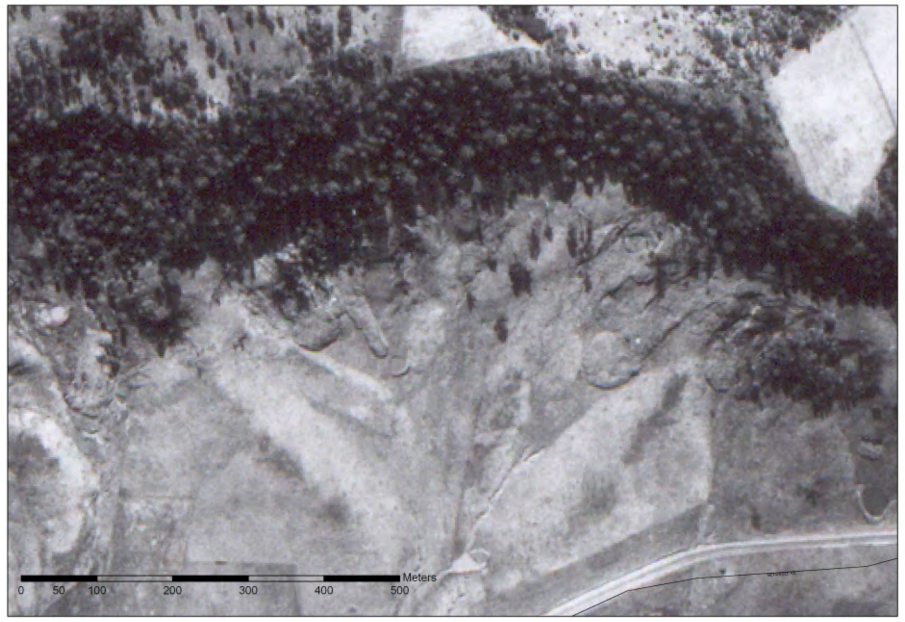
1955



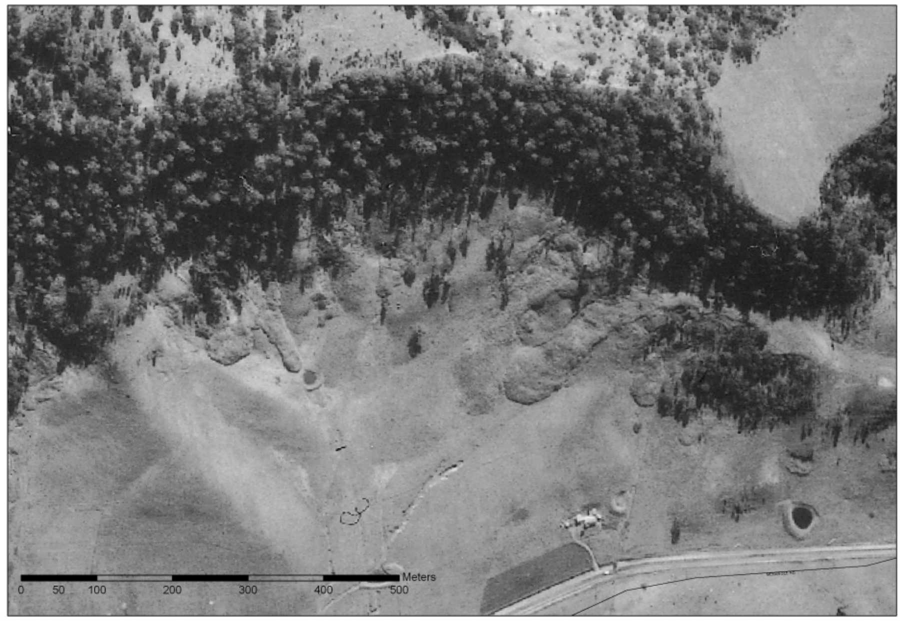
1961



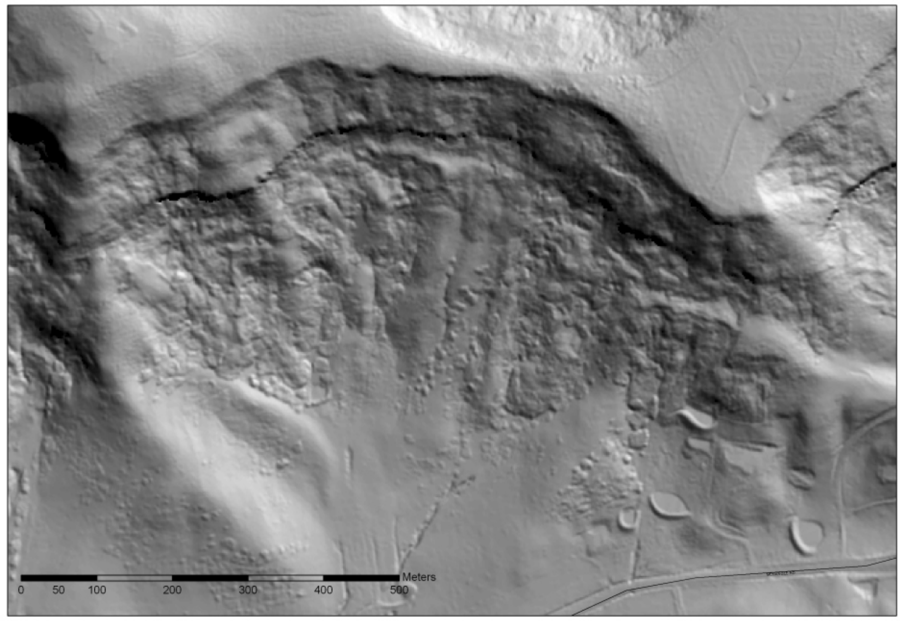
1966



1969



1971

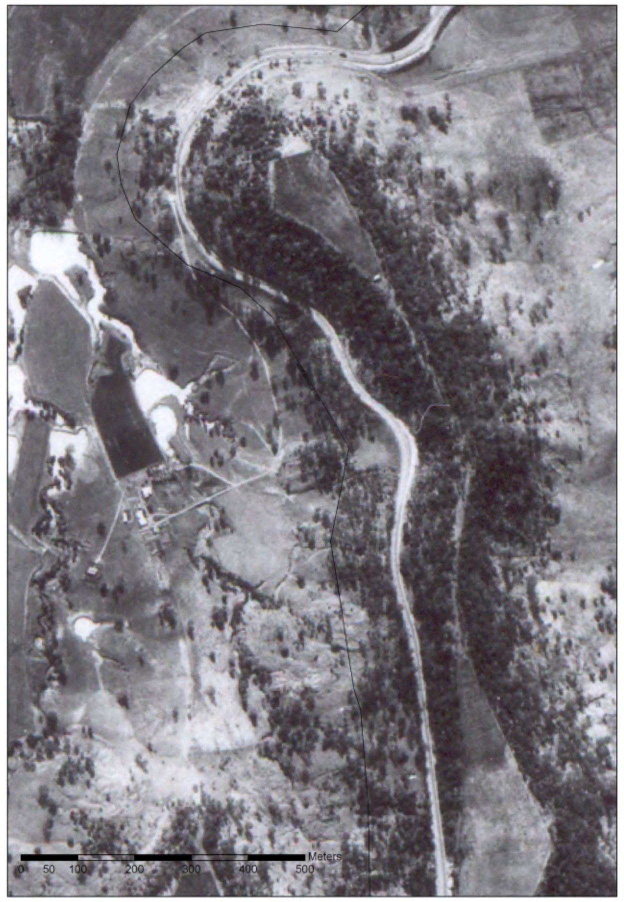


2008 DEM from ALS Data

Aerial Photograph

Example of change in landslide morphology, 1955 - 2008
north of Menangle Road, Razorback

1966

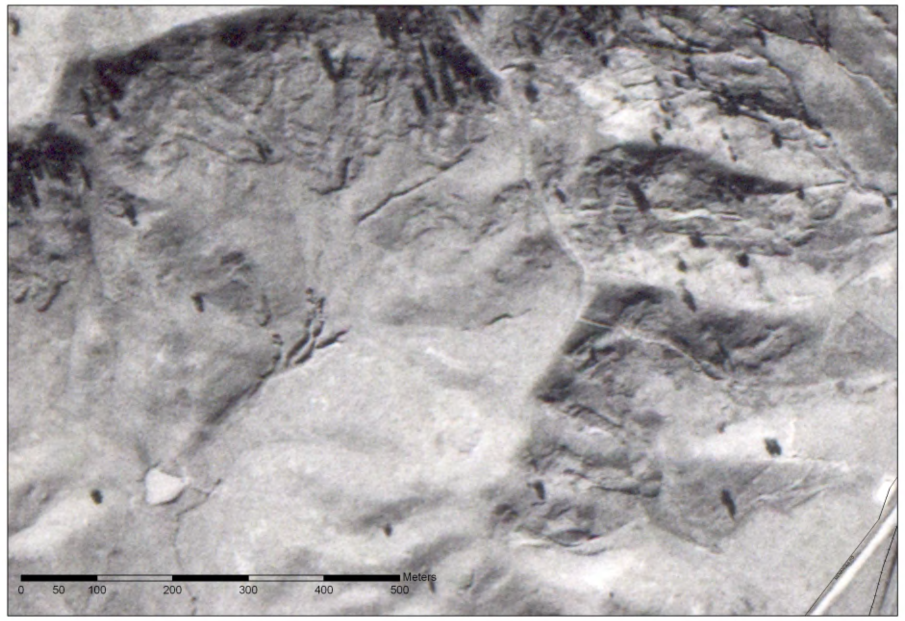


1969

1979

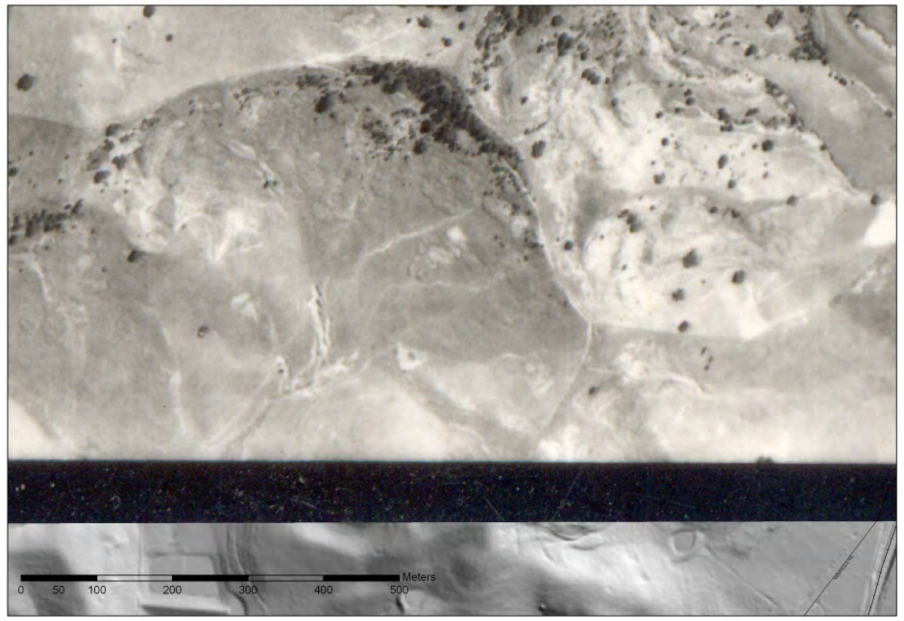
2008

Example of change in landslide morphology, 1966 - 2008
Remembrance Drive, Razorback

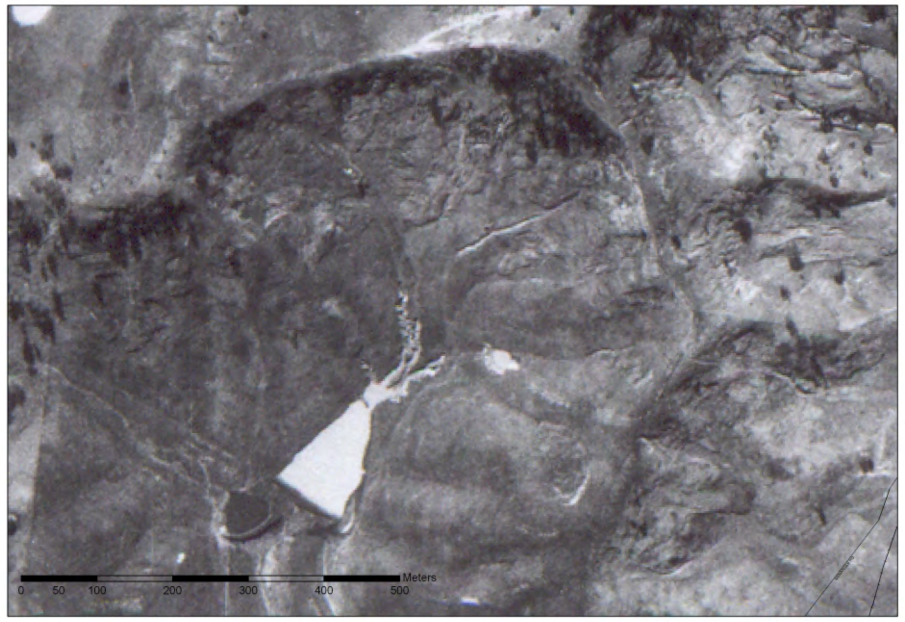


1955

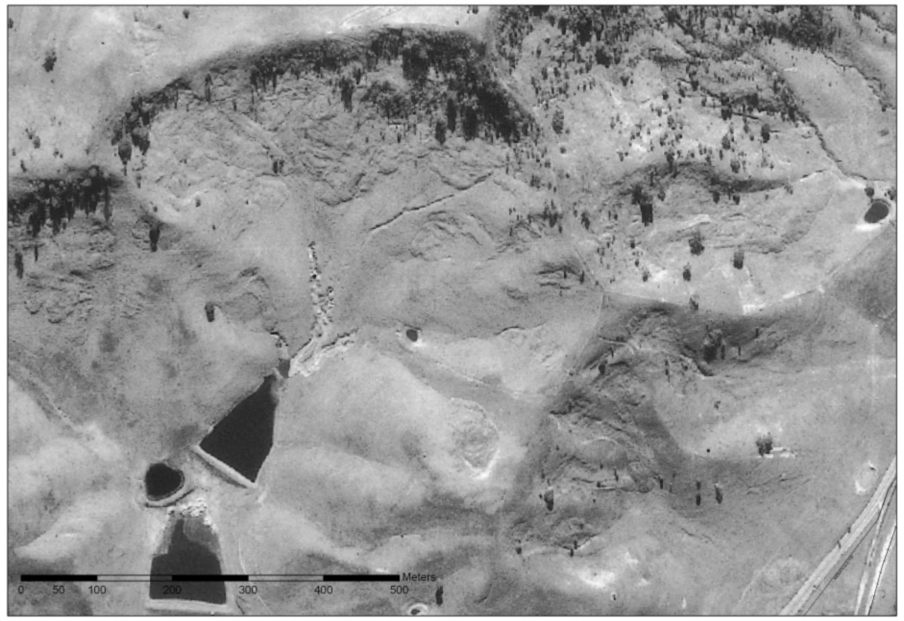
1961



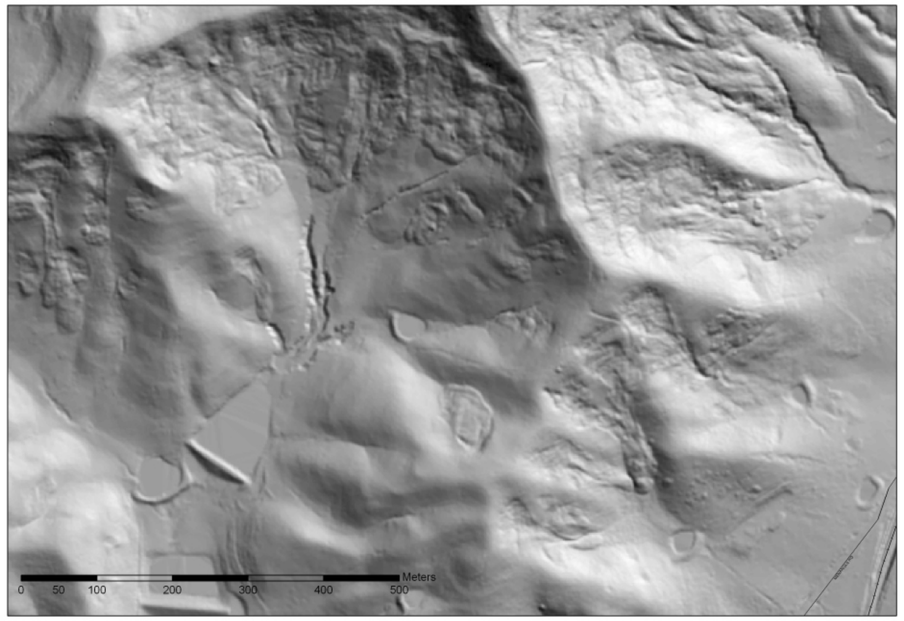
1966



1969

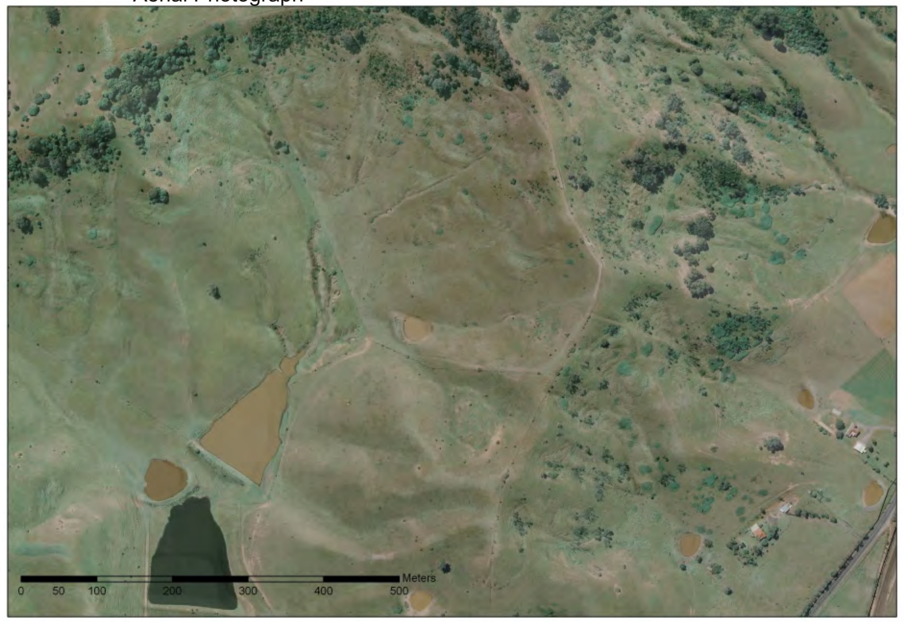


1979



2008 DEM from ALS Data

Aerial Photograph



Example of change in landslide morphology, 1955 - 2008
north of Menangle Road, Razorback

Appendix B

Site Photos, Subsurface Investigation Area

Deep Test Pit In Colluvium Soils Near Toe Of Landslide

Large Boulders on Surface Part of Colluvium on Lower Part of Landslide

Gentle to Moderate Undulating Slopes on Lower Part of Landslide

View to Southwest Looking Across Numerous Landslides on Slopes Below Tree Covered Escarpment

Note Landslide Lobes on Hillside

Broad Gently Sloping Valley With Undulating Slopes Over Landslide Affected Area

revision	description	drawn	approved	date

drawn	NA
approved	JPT
date	12/07/2011
scale	N.T. S.
original size	A3

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client: **CARDNO**

project: **LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS APPIN AREA 9 PROPOSED LONGWALLS RAZORBACK RANGE DOUGLAS PARK NSW**

title: **SITE PHOTOS, SUBSURFACE INVESTIGATION AREA- LOT 1 DP553170**

project no:GEOTWOLL02834AA-AG

APPENDIX B

Appendix C

Test Pit Logs with Explanatory Notes

Soil Description Explanation Sheet (1 of 2)

DEFINITION:

In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME

Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

MOISTURE CONDITION

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH s_u (kPa)	FIELD GUIDE
Very Soft	<12	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	–	Crumbles or powders when scraped by thumbnail.

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: <5% Fine grained soils: <15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 - 12% Fine grained soils: 15 - 30%

SOIL STRUCTURE

ZONING		CEMENTING	
Layers	Continuous across exposure or sample.	Weakly cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water.
Pockets	Irregular inclusions of different material.		

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian soil	Deposited by wind.
Alluvial soil	Deposited by streams and rivers.
Colluvial soil	Deposited on slopes (transported downslope by gravity).
Fill	Man made deposit. Fill may be significantly more variable between tested locations than naturally occurring soils.
Lacustrine soil	Deposited by lakes.
Marine soil	Deposited in ocean basins, bays, beaches and estuaries.

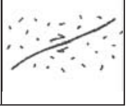
Soil Description Explanation Sheet (2 of 2)

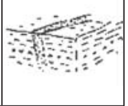
SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 60 mm and basing fractions on estimated mass)						**USC**	**PRIMARY NAME**
COARSE GRAINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.36 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.		GW	GRAVEL
				Predominantly one size or a range of sizes with more intermediate sizes missing.		GP	GRAVEL
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)		GM	SILTY GRAVEL
				Plastic fines (for identification procedures see CL below)		GC	CLAYEY GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.36 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes		SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing.		SP	SAND
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).		SM	SILTY SAND
				Plastic fines (for identification procedures see CL below).		SC	CLAYEY SAND
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm			IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.				
			DRY STRENGTH	**DILATANCY**	**TOUGHNESS**		
		SILTS & CLAYS Liquid limit less than 50	None to Low	Quick to slow	None	ML	SILT
			Medium to High	None	Medium	CL	CLAY
			Low to medium	Slow to very slow	Low	OL	ORGANIC SILT
		SILTS & CLAYS Liquid limit greater than 50	Low to medium	Slow to very slow	Low to medium	MH	SILT
			High	None	High	CH	CLAY
			Medium to High	None	Low to medium	OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS			Readily identified by colour, odour, spongy feel and frequently by fibrous texture.			Pt	PEAT

- Low plasticity – Liquid Limit w_L less than 35%.
- Medium plasticity – w_L between 35% and 50%.
- High plasticity – w_L greater than 50%.

COMMON DEFECTS IN SOIL

TERM	**DEFINITION**	**DIAGRAM**
PARTING	A surface or crack across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
JOINT	A surface or crack across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed. The term 'fissure' may be used for irregular joints <0.2 m in length.	
SHEARED ZONE	Zone in clayey soil with roughly parallel near planar, curved or undulating boundaries containing closely spaced, smooth or slickensided, curved intersecting joints which divide the mass into lenticular or wedge shaped blocks.	
SHEARED SURFACE	A near planar curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	

TERM	**DEFINITION**	**DIAGRAM**
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter	
TUBE CAST	Roughly cylindrical elongated body of soil different from the mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	
INFILLED SEAM	Sheet or wall like body of soil substance or mass with roughly planar to irregular near parallel boundaries which cuts through a soil mass. Formed by infilling of open joints.	

Rock Description Explanation Sheet (1 of 2)

The descriptive terms used by Coffey are given below. They are broadly consistent with Australian Standard AS1726-1993.

DEFINITIONS:	Rock substance, defect and mass are defined as follows:
Rock Substance	In engineering terms roch substance is any naturally occurring aggregate of minerals and organic material which cannot be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Effectively homogenous material, may be isotropic or anisotropic.
Defect	Discontinuity or break in the continuity of a substance or substances.
Mass	Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

SUBSTANCE DESCRIPTIVE TERMS:

ROCK NAME	Simple rock names are used rather than precise geological classification.
PARTICLE SIZE	Grain size terms for sandstone are:
Coarse grained	Mainly 0.6mm to 2mm
Medium grained	Mainly 0.2mm to 0.6mm
Fine grained	Mainly 0.06mm (just visible) to 0.2mm
FABRIC	Terms for layering of penetrative fabric (eg. bedding, cleavage etc.) are:
Massive	No layering or penetrative fabric.
Indistinct	Layering or fabric just visible. Little effect on properties.
Distinct	Layering or fabric is easily visible. Rock breaks more easily parallel to layering of fabric.

CLASSIFICATION OF WEATHERING PRODUCTS

Term	Abbreviation	Definition
Residual Soil	**RS**	Soil derived from the weathering of rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely Weathered Material	**XW**	Material is weathered to such an extent that it has soil properties, ie, it either disintegrates or can be remoulded in water. Original rock fabric still visible.
Highly Weathered Rock	**HW**	Rock strength is changed by weathering. The whole of the rock substance is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Some minerals are decomposed to clay minerals. Porosity may be increased by leaching or may be decreased due to the deposition of minerals in pores.
Moderately Weathered Rock	**MW**	The whole of the rock substance is discoloured, usually by iron staining or bleaching , to the extent that the colour of the fresh rock is no longer recognisable.
Slightly Weathered Rock	**SW**	Rock substance affected by weathering to the extent that partial staining or partial discolouration of the rock substance (usually by limonite) has taken place. The colour and texture of the fresh rock is recognisable; strength properties are essentially those of the fresh rock substance.
Fresh Rock	**FR**	Rock substance unaffected by weathering.

Notes on Weathering:

1. AS1726 suggests the term "Distinctly Weathered" (DW) to cover the range of substance weathering conditions between XW and SW. For projects where it is not practical to delineate between HW and MW or it is judged that there is no advantage in making such a distinction. DW may be used with the definition given in AS1726.
2. Where physical and chemical changes were caused by hot gasses and liquids associated with igneous rocks, the term "altered" may be substituted for "weathering" to give the abbreviations XA, HA, MA, SA and DA.

ROCK SUBSTANCE STRENGTH TERMS

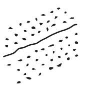
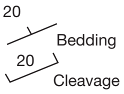
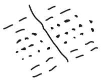
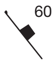
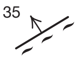
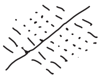
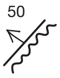
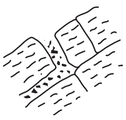
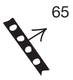
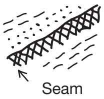
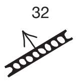
Term	Abbreviation	Point Load Index, $I_{s(50)}$ (MPa)	Field Guide
Very Low	**VL**	Less than 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with a knife; pieces up to 30mm thick can be broken by finger pressure.
Low	**L**	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show with firm bows of a pick point; has a dull sound under hammer. Pieces of core 150mm long by 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium	**M**	0.3 to 1.0	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
High	**H**	1 to 3	A piece of core 150mm long by 50mm can not be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.
Very High	**VH**	3 to 10	Hand specimen breaks after more than one blow of a pick; rock rings under hammer.
Extremely High	**EH**	More than 10	Specimen requires many blows with geological pick to break; rock rings under hammer.

Notes on Rock Substance Strength:

1. In anisotropic rocks the field guide to strength applies to the strength perpendicular to the anisotropy. High strength anisotropic rocks may break readily parallel to the planar anisotropy.
2. The term "extremely low" is not used as a rock substance strength term. While the term is used in AS1726-1993, the field guide therein makes it clear that materials in that strength range are soils in engineering terms.
3. The unconfined compressive strength for isotropic rocks (and anisotropic rocks which fall across the planar anisotropy) is typically 10 to 25 times the point load index $I_{s(50)}$. The ratio may vary for different rock types. Lower strength rocks often have lower ratios than higher strength rocks.

Rock Description Explanation Sheet (2 of 2)

COMMON DEFECTS IN ROCK MASSES

Term	Definition	Diagram	Map Symbol	Graphic Log (Note 1)
Parting	A surface or crack across which the rock has little or no tensile strength. Parallel or sub parallel to layering (eg bedding) or a planar anisotropy in the rock substance (eg, cleavage). May be open or closed.			
Joint	A surface or crack across which the rock has little or no tensile strength. but which is not parallel or sub parallel to layering or planar anisotropy in the rock substance. May be open or closed.			
Sheared Zone (Note 3)	Zone of rock substance with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge shaped blocks.			
Sheared Surface (Note 3)	A near planar, curved or undulating surface which is usually smooth, polished or slickensided.			
Crushed Seam (Note 3)	Seam with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock substance which may be more weathered than the host rock. The seam has soil properties.			
Infilled Seam	Seam of soil substance usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint, infilled seams less than 1mm thick may be described as veneer or coating on joint surface.			
Extremely Weathered Seam	Seam of soil substance, often with gradational boundaries. Formad by weathering of the rock substance in place.			

DEFECT SHAPE

DEFECT SHAPE	TERMS
Planar	The defect does not vary in orientation
Curved	The defect has a gradual change in orientation
Undulating	The defect has a wavy surface
Stepped	The defect has one or more well defined steps
Irregular	The defect has many sharp changes of orientation

Note: The assessment of defect shape is partly influenced by the scale of the observation.

ROUGHNESS TERMS

Slickensided	Grooved or striated surface, usually polished
Polished	Shiny smooth surface
Smooth	Smooth to touch. Few or no surface irregularities
Rough	Many small surface irregularities (amplitude generally less than 1mm). Feels like fine to coarse sand paper.
Very Rough	Many large surface irregularities (amplitude generally more than 1mm). Feels like, or coarser than very coarse sand paper.

COATING TERMS

Clean	No visible coating
Stained	No visible coating but surfaces are discoloured
Veneer	A visible coating of soil or mineral, too thin to measure; may be patchy
Coating	A visible coating up to 1mm thick. Thicker soil material is usually described using appropriate defect terms (eg, infilled seam). Thicker rock strength material is usually described as a vein.

BLOCK SHAPE TERMS

Blocky	Approximately equidimensional
Tabular	Thickness much less than length or width
Columnar	Height much greate than cross section

Notes on Defects:

1. Usually borehole logs show the true dip of defects and face sketches and sections the apparent dip.
2. Partings and joints are not usually shown on the graphic log unless considered significant.
3. Sheared zones, sheared surfaces and crushed seams are faults in geological terms.

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**CTP 02**
Sheet	1 of 1
Project No:	**GEOTWOLL02834AA**
Client:	**CARDNO (NSW) PTY LTD**
Principal:	**BHP BILLITON/ILLAWARRA COAL**
Project:	**SUBSURFACE INVESTIGATION - LOT 1 DP553170**
Test pit location:	**REFER TO FIGURE 4**
Date started:	**15.7.2010**
Date completed:	**15.7.2010**
Logged by:	**CA**
Checked by:	**JPT**

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	286824 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	4m long 0.7m wide			Northing:	6216335 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NONE OBSERVED					ML	**TOPSOIL; Clayey SILT:** Medium plasticity, orange/brown, with some fine to medium grained sand, and a trace of sub-rounded/sub-angular gravel and roots.	<Wp	St		TOPSOIL Boulders up to 400mm in diameter observed on surface
						0.5		CL	**CLAY:** Medium plasticity, pale brown, with some fine to coarse grained sub-angular sandstone gravel and fine to medium grained sand. Trace of slightly weathered sandstone cobbles and boulders up to 300mm in diameter.		VSt		COLLUVIUM
						1.0		CL	**Gravelly CLAY:** Medium plasticity, pale brown to pale orange, fine to coarse grained angular shale gravel, and a trace of sand.		VSt/H		RESIDUAL/EXTREMELY WEATHERED MATERIAL
						1.5			**SHALE:** Pale brown/grey, low strength				HIGHLY WEATHERED SHALE
						2.0 2.5			Test pit CTP 02 terminated at 1.9m				CTP 02 Terminated at 1.9m on slow progress

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*CTP 03*
Sheet	1 of 1
Project No:	*GEOTWOLL02834AA*

Client:	*CARDNO (NSW) PTY LTD*
Principal:	*BHP BILLITON/ILLAWARRA COAL*
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*
Test pit location:	*REFER TO FIGURE 4*
Date started:	*15.7.2010*
Date completed:	*15.7.2010*
Logged by:	*CA*
Checked by:	*JPT*

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	286902 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	3m long 0.8m wide			Northing:	6216269 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	**notes** samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro- meter kPa 100 200 300 400	**structure and additional observations**
E		N	NONE OBSERVED					ML	**TOPSOIL; Clayey SILT:** Medium to high plasticity, brown, with some fine to medium grained sand and some roots. Trace of fine to coarse grained sub-rounded to sub-angular shale gravel.	<Wp	St		TOPSOIL
				D		0.5		CL/CH	**CLAY:** Medium to high plasticity, orange, with some silt and trace fine to coarse grained angular shale gravel. Trace fine to medium grained sand.	Wp	St/VSt	×	COLLUVIUM AND/OR POSSIBLE SLOPEWASH
						1.0		GC	**Clayey GRAVEL/Gravelly CLAY:** Fine to coarse grained angular shale, pale brown to grey with medium plasticity clay, and some fine grained sand.	<Wp	H	× ×	RESIDUAL/EXTREMELY WEATHERED MATERIAL
						1.5			**SHALE:** Pale brown to grey, low strength				HIGHLY/MODERATELY WEATHERED SHALE
						2.0 2.5			Test pit CTP 03 terminated at 1.9m				CTP 03 Terminated at 1.90m on slow to very slow progress

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4

no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	CTP 04
Sheet	1 of 1
Project No:	GEOTWOLL02834AA
Client:	CARDNO (NSW) PTY LTD
Principal:	BHP BILLITON/ILLAWARRA COAL
Project:	SUBSURFACE INVESTIGATION - LOT 1 DP553170
Test pit location:	REFER TO FIGURE 4
Date started:	15.7.2010
Date completed:	15.7.2010
Logged by:	CA
Checked by:	JPT

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287016 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	4m long 0.7m wide			Northing:	6216348 m	datum:	HAND HELD GPS

excavation information / material substance

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
E		N	NONE OBSERVED					ML	**TOPSOIL; Clayey SILT:** Medium plasticity, brown, with some fine to medium grained sand and roots, and a trace of fine to coarse grained sub-rounded to sub-angular gravel.	<Wp	VSt		TOPSOIL No cobbles or boulders observed on surface
						0.5		CL/CH	**CLAY:** Medium to high plasticity, orange, with some fine to coarse grained sub-angular shale gravel, and a trace of decaying roots.	Wp	VSt/H		RESIDUAL SOIL
						1.0		CL	**Gravelly CLAY:** Low plasticity, pale orange/brown with pale grey to red/brown pockets, fine to coarse grained sub-angular shale gravel, and a trace of fine grained sand.	<Wp	H		EXTREMELY WEATHERED MATERIAL
						1.5			**SHALE:** Grey with iron stained orange/brown pockets, medium strength.				HIGHLY/MODERATELY WEATHERED SHALE
						2.0 2.5			Test pit CTP 04 terminated at 1.6m				CTP 04 Terminated at 1.60m on very slow progress

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**CTP 05**
Sheet	1 of 2
Project No:	**GEOTWOLL02834AA**
Client:	**CARDNO (NSW) PTY LTD**
Principal:	**BHP BILLITON/ILLAWARRA COAL**
Project:	**SUBSURFACE INVESTIGATION - LOT 1 DP553170**
Test pit location:	**REFER TO FIGURE 4**
Date started:	**15.7.2010**
Date completed:	**15.7.2010**
Logged by:	**CA**
Checked by:	**JPT**

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287114 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	8m long 0.7m wide			Northing:	6216380 m	datum:	HAND HELD GPS

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NONE OBSERVED				ML	**TOPSOIL; Clayey SILT:** Medium plasticity, brown, with some fine roots and fine grained sand. Trace of fine to medium grained sub-rounded to sub-angular shale gravel.	Wp	St		TOPSOIL
				D			CL/CH	**CLAY:** Medium to high plasticity, orange, with some silt, and a trace of fine grained sand, roots and fine to medium grained sub-angular shale gravel.		VSt		COLLUVIUM AND/OR POSSIBLE SLOPEWASH
						0.5	CL	**CLAY:** Medium plasticity, pale brown/pale orange, with a trace of fine roots and fine to coarse grained sub-angular shale gravel.	<Wp/Wp	H	600 600	
				Bs		1.0	CL/CH	**CLAY:** Medium to high plasticity, orange to pale orange/brown mottled red/brown, black and grey, trace/some fine to coarse grained sub-angular highly weathered shale and sandstone gravel. Approximately 10 highly weathered medium strength sandstone (fine to coarse grained) cobbles observed in this material unit.	<Wp			CONSOLIDATED COLLUVIUM
						1.5						At 1.5m front of 20t excavator lifting off ground
						2.0						
						2.5						

Sketch

method		support		notes, samples, tests		classification symbols and soil description	consistency/density index	
N	natural exposure	S shoring	N nil	U_{50}	undisturbed sample 50mm diameter	based on unified classification system	VS	very soft
X	existing excavation			U_{63}	undisturbed sample 63mm diameter		S	soft
BH	backhoe bucket	**penetration** 1 2 3 4		D	disturbed sample		F	firm
B	bulldozer blade	no resistance ranging to refusal		V	vane shear (kPa)		St	stiff
R	ripper			Bs	bulk sample	**moisture**	VSt	very stiff
E	excavator			E	environmental sample	D dry	H	hard
		water		R	refusal	M moist	Fb	friable
		water level on date shown				W wet	VL	very loose
						Wp plastic limit	L	loose
						W_L liquid limit	MD	medium dense
		water inflow					D	dense
		water outflow					VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*CTP 05*
Sheet	2 of 2
Project No:	*GEOTWOLL02834AA*
Client:	*CARDNO (NSW) PTY LTD*
Principal:	*BHP BILLITON/ILLAWARRA COAL*
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*
Test pit location:	*REFER TO FIGURE 4*
Date started:	*15.7.2010*
Date completed:	*15.7.2010*
Logged by:	*CA*
Checked by:	*JPT*

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287114 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	8m long 0.7m wide			Northing:	6216380 m	datum:	HAND HELD GPS

excavation information | **material substance**

method	penetration 1 2 3	support	water	**notes** samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
E		N					▨		**CLAY:** Medium to high plasticity, orange to pale orange/brown mottled red/brown, black and grey, trace/some fine to coarse grained sub-angular highly weathered shale and sandstone gravel. *(continued)* Approximately 10 highly weathered medium strength sandstone (fine to coarse grained) cobbles observed in this material unit.	<Wp	H		CONSOLIDATED COLLUVIUM
						3.0							COLLUVIUM
			NONE OBSERVED	Bs		3.5							
						4.0							
						4.5							CTP 05 Terminated at 4.90m on slow progress on full excavator reach
						5.0			Test pit CTP 05 terminated at 4.9m				

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

- water level on date shown
- ► water inflow
- ◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **CTP 06**
Sheet 1 of 3
Project No: **GEOTWOLL02834AA**

Client:	**CARDNO (NSW) PTY LTD**	Date started:	**16.7.2010**
Principal:	**BHP BILLITON/ILLAWARRA COAL**	Date completed:	**16.7.2010**
Project:	**SUBSURFACE INVESTIGATION - LOT 1 DP553170**	Logged by:	**CA**
Test pit location:	**REFER TO FIGURE 4**	Checked by:	**JPT**

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287000 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	6m long 0.8m wide			Northing:	6216408 m	datum:	HAND HELD GPS

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NONE OBSERVED			0.5 1.0		CL	**Gravelly CLAY:** Medium plasticity, pale orange/pale brown mottled grey, yellow and black, with a trace of roots and sub-angular highly weathered to slightly weathered low to high strength sandstone cobbles and boulders up to 1.50m in diameter.	Wp/>Wp	VSt		COLLUVIUM Large sub-angular boulders up to 1.5m in diameter observed on ground surface and within this unit
				Bs								×	
						1.5 2.0 2.5						×	

Sketch

method
N natural exposure
X existing excavation
BH backhoe bucket
B bulldozer blade
R ripper
E excavator

support
S shoring N nil

penetration
1 2 3 4
no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description
based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **CTP 06**

Sheet 2 of 3

Project No: **GEOTWOLL02834AA**

Client:	*CARDNO (NSW) PTY LTD*	Date started:	*16.7.2010*
Principal:	*BHP BILLITON/ILLAWARRA COAL*	Date completed:	*16.7.2010*
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*	Logged by:	*CA*
Test pit location:	*REFER TO FIGURE 4*	Checked by:	*JPT*

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287000 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	6m long 0.8m wide			Northing:	6216408 m	datum:	HAND HELD GPS

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NONE OBSERVED							Wp/>Wp	VSt		COLLUVIUM
				Bs		3.0		CL	**CLAY:** Medium plasticity, dark grey/black mottled orange/brown, with some fine to medium grained sand, and a trace of fine grained angular gravel and fine decaying roots.	<Wp/Wp	VSt/H		ORGANIC LAYER: POSSIBLY A REMENANT TOPSOIL?
						3.5		CL	**Sandy CLAY:** Medium plasticity, mottled grey, brown, orange and red/brown, with some fine to coarse grained sub-angular sandstone gravel, and a trace of sandstone sub-angular cobbles.	<Wp	H	600	COLLUVIUM
						4.0							
						4.5							
						5.0							

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **CTP 06**
Sheet 3 of 3
Project No: **GEOTWOLL02834AA**

Client:	*CARDNO (NSW) PTY LTD*	Date started:	*16.7.2010*
Principal:	*BHP BILLITON/ILLAWARRA COAL*	Date completed:	*16.7.2010*
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*	Logged by:	*CA*
Test pit location:	*REFER TO FIGURE 4*	Checked by:	*JPT*

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287000 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	6m long 0.8m wide			Northing:	6216408 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
E		N	NONE OBSERVED			5.5 6.0 6.5 7.0	▨		**Sandy CLAY:** Medium plasticity, mottled grey, brown, orange and red/brown, with some fine to coarse grained sub-angular sandstone gravel, and a trace of sandstone sub-angular cobbles. *(continued)*	<Wp	H		COLLUVIUM
						7.5			Test pit CTP 06 terminated at 7m				CTP 06 Terminated at 7.0m on slow progress at excvavator arm maximum reach

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*CTP 07*
Sheet	1 of 2
Project No:	*GEOTWOLL02834AA*
Client:	*CARDNO (NSW) PTY LTD*
Principal:	*BHP BILLITON/ILLAWARRA COAL*
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*
Test pit location:	*REFER TO FIGURE 4*
Date started:	*15.7.2010*
Date completed:	*15.7.2010*
Logged by:	*CA*
Checked by:	*JPT*

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287132 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	10m long 1m wide			Northing:	6216425 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NONE OBSERVED					ML	**TOPSOIL; Clayey SILT:** High plasticity, brown, with some roots, and a trace of fine to coarse grained sub-rounded to sub-angular sandstone gravel.	Wp	F/St		TOPSOIL POSSIBLE SLOPEWASH Large sandstone boulders observed on surface greater than 1.5m in diameter
				D				CL/CH	**CLAY:** Medium to high plasticity, orange mottled pale yellow/pale brown, with a trace of fine roots and fine to medium grained pale orange/brown sub-angular to angular sandy shale and sandstone gravel.				
						0.5						×	P.P Not Insitu
								GL	**Gravelly CLAY/Clayey GRAVEL:** Fine to coarse grained sandstone gravel, pale orange/pale brown, medium plasticity clay, with a trace of cobbles.	D	VD		
						1.0		CL/CH	**CLAY:** Medium to high plasticity, orange to orange/brown mottled red, brown, black and grey, with some fine to coarse grained pale orange/brown sub-angular to angular highly weathered sandstone gravel, and a trace of highly to moderately weathered medium to high strength sandstone cobbles.	<Wp	H		COLLUVIUM
												×	P.P Not Insitu High to very high strength sandstone boulder >1.0m in diameter observed at 1.3m
				Bs		1.5							
						2.0							
						2.5							

Sketch

method		support		notes, samples, tests		classification symbols and soil description	consistency/density index	
N	natural exposure	S shoring	N nil	U_{50}	undisturbed sample 50mm diameter	based on unified classification system	VS	very soft
X	existing excavation			U_{63}	undisturbed sample 63mm diameter		S	soft
BH	backhoe bucket	**penetration** 1 2 3 4	no resistance ranging to refusal	D	disturbed sample		F	firm
B	bulldozer blade			V	vane shear (kPa)		St	stiff
R	ripper			Bs	bulk sample	**moisture**	VSt	very stiff
E	excavator			E	environmental sample	D dry	H	hard
		water		R	refusal	M moist	Fb	friable
		▼	water level on date shown			W wet	VL	very loose
						Wp plastic limit	L	loose
						W_L liquid limit	MD	medium dense
		►	water inflow				D	dense
		◄	water outflow				VD	very dense

Engineering Log - Excavation

Excavation No.	**CTP 07**
Sheet	2 of 2
Project No:	**GEOTWOLL02834AA**
Client:	**CARDNO (NSW) PTY LTD**
Principal:	**BHP BILLITON/ILLAWARRA COAL**
Project:	**SUBSURFACE INVESTIGATION - LOT 1 DP553170**
Test pit location:	**REFER TO FIGURE 4**
Date started:	**15.7.2010**
Date completed:	**15.7.2010**
Logged by:	**CA**
Checked by:	**JPT**

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287132 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	10m long 1m wide			Northing:	6216425 m	datum:	HAND HELD GPS

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NONE OBSERVED				▨		**CLAY:** Medium to high plasticity, orange to orange/brown mottled red, brown, black and grey, with some fine to coarse grained pale orange/brown sub-angular to angular highly weathered sandstone gravel, and a trace of highly to moderately *(continued)* weathered medium to high strength sandstone cobbles, 1 boulder >1.0m in diameter observed at 1.30m.	<Wp	H		COLLUVIUM
						3.0							
						3.5							
						4.0							
						4.5							
				Bs									
						5.0							CTP 07 Terminated at 5.0m on slow progress

Test pit CTP 07 terminated at 5m

Sketch

method		support		notes, samples, tests		classification symbols and soil description	consistency/density index	
N	natural exposure	S shoring	N nil	U_{50}	undisturbed sample 50mm diameter	based on unified classification system	VS	very soft
X	existing excavation			U_{63}	undisturbed sample 63mm diameter		S	soft
BH	backhoe bucket	**penetration**		D	disturbed sample		F	firm
B	bulldozer blade	1 2 3 4	no resistance ranging to refusal	V	vane shear (kPa)		St	stiff
R	ripper			Bs	bulk sample	**moisture**	VSt	very stiff
E	excavator			E	environmental sample	D dry	H	hard
		water		R	refusal	M moist	Fb	friable
		▼	water level on date shown			W wet	VL	very loose
						Wp plastic limit	L	loose
						W_L liquid limit	MD	medium dense
		►	water inflow				D	dense
		◄	water outflow				VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*CTP 08*
Sheet	1 of 1
Project No:	*GEOTWOLL02834AA*
Client:	*CARDNO (NSW) PTY LTD*
Principal:	*BHP BILLITON/ILLAWARRA COAL*
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*
Test pit location:	*REFER TO FIGURE 4*
Date started:	*16.7.2010*
Date completed:	*16.7.2010*
Logged by:	*CA*
Checked by:	*JPT*

equipment type and model:	20 TONNE HITACHI	Pit Orientation: N/A	Easting: 287101 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	3m long 0.8m wide		Northing: 6216289 m	datum:	HAND HELD GPS

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NONE OBSERVED					ML	**TOPSOIL; Clayey SILT:** Medium to high plasticity, brown, with some fine roots, and a trace of fine grained gravel.	Wp	St		TOPSOIL
						0.5		CL/CH	**CLAY:** Medium to high plasticity, orange, with a trace of fine roots, silt and fine grained sand.	Wp	VSt		COLLUVIUM Large sandstone boulders approximately 1.0m in diameter observed on surface.
						1.0		CL	**CLAY:** Medium plasticity, pale yellow/pale brown, with some silt and fine to coarse grained angular grey to iron stained red/brown shale gravel. Trace of roots.	<Wp	H		RESIDUAL/EXTREMELY WEATHERED MATERIAL
									SHALE: Grey, with some iron stained red/brown pockets, low strength.				HIGHLY WEATHERED SHALE
						1.5			Test pit CTP 08 terminated at 1.3m				CTP 08 Terminated at 1.30m on very slow progress
						2.0							
						2.5							

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4

no resistance ranging to refusal

water

water level on date shown

water inflow

water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	*CTP09*
Sheet	1 of 2
Project No:	*GEOTWOLL02834AA*
Client:	*CARDNO (NSW) PTY LTD*
Principal:	*BHP BILLITON/ILLAWARRA COAL*
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*
Test pit location:	*REFER TO FIGURE 4*
Date started:	*16.7.2010*
Date completed:	*16.7.2010*
Logged by:	*CA*
Checked by:	*JPT*

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287212 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	4.5m long 0.8m wide			Northing:	6216408 m	datum:	HAND HELD GPS

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
E		N	NOT OBSERVED					ML	**TOPSOIL; Clayey SILT:** Medium plasticity, brown, with some fine roots, and a trace of fine to medium grained sub-angular sandstone gravel.	Wp	VSt		TOPSOIL Sandstone boulders observed on surface approximately 500mm in diameter.
						0.5 1.0 1.5 2.0		CL	**Gravelly CLAY:** Medium plasticity, brown/pale orange mottled red/brown, grey and black, fine to coarse grained angular sandstone gravel, with some fine to medium grained sand and roots. Trace of sub-angular sandstone cobbles and boulders up to 1.2m in diameter	<Wp	VSt/H		COLLUVIUM
						2.5		CL/CH	**CLAY:** Medium to high plasticity, brown mottled red/brown, grey, black and orange, with some fine to medium grained sand and with a trace of fine to coarse grained sub-angular sandstone gravel and cobbles.		H		No boulders observed beyond 2.0m depth below surface level.

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Engineering Log - Excavation

Excavation No.	**CTP09**
Sheet	2 of 2
Project No:	**GEOTWOLL02834AA**
Client:	**CARDNO (NSW) PTY LTD**
Principal:	**BHP BILLITON/ILLAWARRA COAL**
Project:	**SUBSURFACE INVESTIGATION - LOT 1 DP553170**
Test pit location:	**REFER TO FIGURE 4**
Date started:	**16.7.2010**
Date completed:	**16.7.2010**
Logged by:	**CA**
Checked by:	**JPT**

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287212 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	4.5m long 0.8m wide			Northing:	6216408 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NOT OBSERVED			3.0 3.5 4.0			**CLAY:** Medium to high plasticity, brown mottled red/brown, grey, black and orange, with some fine to medium grained sand and with a trace of fine to coarse grained sub-angular sandstone gravel and cobbles. *(continued)*	<Wp	H		COLLUVIUM
						4.5		GC	**Gravelly CLAY/ Clayey GRAVEL;** Fine to coarse grained angular shale, grey, brown/grey and orange pockets, medium plasticity clay.	D			EXTREMELY WEATHERED MATERIAL WITH SOME HIGHLY WEATHERED SHALE GRAVEL
						5.0			Test pit CTP09 terminated at 4.5m				CTP09 terminated at 4.5m on very slow progress

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Client:	*CARDNO (NSW) PTY LTD*	Excavation No.	***CTP10***
Principal:	*BHP BILLITON/ILLAWARRA COAL*	Sheet	1 of 1
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*	Project No:	***GEOTWOLL02834AA***
Test pit location:	*REFER TO FIGURE 4*	Date started:	***16.7.2010***
		Date completed:	***16.7.2010***
		Logged by:	***CA***
		Checked by:	***JPT***

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287252 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	4.5m long 0.8m wide			Northing:	6216392 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
E			NOT OBSERVED					ML	**TOPSOIL; Clayey SILT:** Medium plasticity, brown, with some fine roots	Wp	St		TOPSOIL
						0.5		CL/CH	**CLAY:** Medium to high plasticity, orange mottled pale yellow/pale brown, with some fine grained sand.	Wp	VSt		RESIDUAL SOIL: POSSIBLE SLOPEWASH
						1.0 1.5		CL	**Gravelly CLAY:** Medium plasticity, pale yellow/pale brown, fine to coarse grained angular shale gravel, with some sand.	<Wp	H		EXTREMELY WEATHERED MATERIAL
									SHALE: Grey, with some fine to medium grained sand, low to medium strength..				HIGHLY WEATHERED SHALE, WITH SOME MODERATELY WEATHERED LAYERS
						2.0 2.5			Test pit CTP10 terminated at 1.9m				CTP10 Terminated at 1.9m on very slow progress.

Sketch

method	
N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support
S shoring N nil

penetration
1 2 3 4 no resistance ranging to refusal

water
▼ water level on date shown
► water inflow
◄ water outflow

notes, samples, tests	
U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description
based on unified classification system

moisture	
D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index	
VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**CTP11A**
Sheet	1 of 2
Project No:	**GEOTWOLL02834AA**
Client:	**CARDNO (NSW) PTY LTD**
Principal:	**BHP BILLITON/ILLAWARRA COAL**
Project:	**SUBSURFACE INVESTIGATION - LOT 1 DP553170**
Test pit location:	**REFER TO FIGURE 4**
Date started:	**16.5.2010**
Date completed:	**16.5.2010**
Logged by:	**CA**
Checked by:	**JPT**

equipment type and model: 20 TONNE HITACHI Pit Orientation: N/A Easting: 287319 m R.L. Surface: NOT MEASURED

excavation dimensions: 5m long 0.8m wide Northing: 6216409 m datum: HAND HELD GPS

excavation information						material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
E		N	NOT OBSERVED					CL	**TOPSOIL:Clayey SILT:** Medium plasticity, brown, with some fine roots and fine grained sand, and a trace of fine to coarse grained sandstone gravel.	Wp	VSt		TOPSOIL/COLLUVIUM Large boulders up to 2.0m in diameter observed on surface.
						0.5 1.0 1.5 2.0 2.5		CL/CH	**CLAY:** Medium to high plasticity, orange/brown, with some fine to coarse grained sub-angular sandstone gravel, and a trace of roots and sub-angular sandstone cobbles (fine grained, orange/brown). Approximately 8 highly weathered, medium strength, sub-angular sandstone boulders up to 500mm in diameter observed throughout this material unit.	Wp	VSt		COLLUVIUM

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

water level on date shown

water inflow

water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**CTP11A**
Sheet	2 of 2
Project No:	**GEOTWOLL02834AA**

Client:	**CARDNO (NSW) PTY LTD**	Date started:	**16.5.2010**
Principal:	**BHP BILLITON/ILLAWARRA COAL**	Date completed:	**16.5.2010**
Project:	**SUBSURFACE INVESTIGATION - LOT 1 DP553170**	Logged by:	**CA**
Test pit location:	**REFER TO FIGURE 4**	Checked by:	**JPT**

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287319 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	5m long 0.8m wide			Northing:	6216409 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
E		N	NOT OBSERVED			3.0 3.5 4.0	▨		**CLAY:** Medium to high plasticity, orange/brown, with some fine to coarse grained sub-angular sandstone gravel, and a trace of roots and sub-angular sandstone cobbles (fine grained, orange/brown). *(continued)* Approximately 8 highly weathered, medium strength, sub-angular sandstone boulders up to 500mm in diameter observed throughout this material unit.	Wp	VSt		COLLUVIUM
						4.5 5.0			Test pit CTP11A terminated at 4m				CTP11A Terminated at 4.0m on steady to slow progress

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4

no resistance ranging to refusal

water

water level on date shown

water inflow

water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Engineering Log - Excavation

Excavation No.	**CTP11B**
Sheet	1 of 2
Project No:	**GEOTWOLL02834AA**
Client:	**CARDNO (NSW) PTY LTD**
Principal:	**BHP BILLITON/ILLAWARRA COAL**
Project:	**SUBSURFACE INVESTIGATION - LOT 1 DP553170**
Test pit location:	**REFER TO FIGURE 4**
Date started:	**16.7.2010**
Date completed:	**16.7.2010**
Logged by:	**CA**
Checked by:	**JPT**

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287317 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	8m long 1m wide			Northing:	6216325 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
E			NOT OBSERVED					ML	**TOPSOIL; CLAY/ Clayey SILT:** Medium to high plasticity, dark brown mottled orange/brown with some fine roots and some fine to coarse grained sub-angular sandstone gravel and cobbles.	Wp	VSt		TOPSOIL/COLLUVIUM, Boulders up to 1.0m in diameter observed on surface
								CL/CH	**Clay:** Medium to high plasticity, orange/brown, with some fine grained sand and a trace of roots. Trace fine to coarse grained sub-angular sandstone gravel and cobbles.	Wp	VSt/H		COLLUVIUM
						0.5							
						1.0							
						1.5							
						2.0				<Wp	H		
						2.5							

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No. **CTP11B**

Sheet 2 of 2

Project No: **GEOTWOLL02834AA**

Client: ***CARDNO (NSW) PTY LTD***

Principal: ***BHP BILLITON/ILLAWARRA COAL***

Project: ***SUBSURFACE INVESTIGATION - LOT 1 DP553170***

Test pit location: ***REFER TO FIGURE 4***

Date started: ***16.7.2010***

Date completed: ***16.7.2010***

Logged by: ***CA***

Checked by: ***JPT***

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287317 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	8m long 1m wide			Northing:	6216325 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	**notes** samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
E			NOT OBSERVED				▨		**Clay:** Medium to high plasticity, orange/brown, with some fine grained sand and a trace of roots. Trace fine to coarse grained sub-angular sandstone gravel and cobbles. *(continued)*	<Wp	H		COLLUVIUM
						3.0	▨						
						3.5	▨						
						4.0	▨		At 4.0M a trace of fIne to coarse grained highly weathered very low strengtH shale.				
						4.5	▨						
									Test pit CTP11B terminated at 4.5m				CTP11B Terminated at 4.50m on steady progress
						5.0							

Sketch

method

N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4 no resistance ranging to refusal

water

▼ water level on date shown

► water inflow

◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	**CTP12**
Sheet	1 of 1
Project No:	*GEOTWOLL02834AA*
Client:	*CARDNO (NSW) PTY LTD*
Principal:	*BHP BILLITON/ILLAWARRA COAL*
Project:	*SUBSURFACE INVESTIGATION - LOT 1 DP553170*
Test pit location:	*REFER TO FIGURE 4*
Date started:	*16.7.2010*
Date completed:	*16.7.2010*
Logged by:	*CA*
Checked by:	*JPT*

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287467 m
R.L. Surface:	NOT MEASURED			Northing:	6216359 m
excavation dimensions:	4m long 0.8m wide			datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	**notes** samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
E			NOT OBSERVED					CL	**TOPSOIL; CLAY:** Medium plasticity, brown, with some fine roots and a trace of fine to medium grained angular shale gravel.	<Wp	VSt		TOPSOIL
						0.5		CL	**CLAY:** Medium to high plasticity, orange, with some silt, and a trace of fine roots, fine grained sand and fine to coarse grained angular shale gravel.	>Wp/Wp	VSt/H		RESIDUAL SOIL
						1.0 1.5			**Clayey GRAVEL:** Fine to coarse grained, grey to pale brown, highly weathered low strength shale gravel and medium plasticity clay.	D	VD		EXTREMELY WEATHERED MATERIAL
									SHALE: Iron stained, red/brown to grey, with some fine grained sand, low strength.				HIGHLY WEATHERED SHALE
						2.0 2.5			Test pit CTP12 terminated at 1.9m				CTP12 Terminated at 1.90m on very slow progress

Sketch

method	
N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support
S shoring N nil

penetration
1 2 3 4
no resistance ranging to refusal

water
▼ water level on date shown
► water inflow
◄ water outflow

notes, samples, tests	
U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description
based on unified classification system

moisture	
D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index	
VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Excavation

Excavation No.	***CTP13***
Sheet	1 of 1
Project No:	***GEOTWOLL02834AA***
Date started:	***16.7.2010***
Date completed:	***16.7.2010***
Logged by:	***CA***
Checked by:	***JPT***

Client:	***CARDNO (NSW) PTY LTD***
Principal:	***BHP BILLITON/ILLAWARRA COAL***
Project:	***SUBSURFACE INVESTIGATION - LOT 1 DP553170***
Test pit location:	***REFER TO FIGURE 4***

equipment type and model:	20 TONNE HITACHI	Pit Orientation:	N/A	Easting:	287422 m	R.L. Surface:	NOT MEASURED
excavation dimensions:	3m long 0.8m wide			Northing:	6216271 m	datum:	HAND HELD GPS

excavation information							material substance						
method	penetration 1 2 3	support	water	**notes** samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
E			NOT OBSERVED					ML	**TOPSOIL: Clayey SILT:** Brown, with some fine roots.	<Wp	St		TOPSOIL
						0.5		CL	**CLAY:** Medium plasticity, pale yellow/pale brown, with some silt and a trace of fine roots.	<Wp	H		RESIDUAL SOIL
						1.0		GC	**Gravelly CLAY:** Medium plasticity, pale yellow/pale brown, fine to coarse grained angular shale, highly weathered low strength shale gravel.	<Wp	H		EXTREMELY WEATHERED MATERIAL
						1.5			**SHALE:** Grey with some orange/brown iron stained pockets and some extremely weathered clay, layers, very low to low strength.				HIGHLY WEATHERED SHALE
						2.0 2.5			Test pit CTP13 terminated at 1.9m				CTP13 Termineted at 1.90m on very slow progress

Sketch

method	
N	natural exposure
X	existing excavation
BH	backhoe bucket
B	bulldozer blade
R	ripper
E	excavator

support

S shoring N nil

penetration

1 2 3 4

no resistance ranging to refusal

water

water level on date shown

water inflow

water outflow

notes, samples, tests	
U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description

based on unified classification system

moisture	
D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index	
VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

Appendix D

Laboratory Test Results

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Unit 2/4 Kellogg Road Glendenning, NSW 2761
ph: (61 2) 9421 3800 Fax: (61 2) 9421 3899
ABN: 92 114 364 046

test results - direct shear test

client: ***COFFEY GEOTECHNICS PTY LTD. (GEOTWOLL02834AA)***
job no: ***INFOGLEN00696AA***
principal: ***CARDNO FORBES RIGBY***
laboratory: ***Glendenning***
project: ***LANDSLIDE RISK ASSESSMENT***
report date: ***23-Aug-10***
location: ***LOT 1 DP553170 - RAZORBACK RIDGE***
test report: ***IOLT 4091***
test procedure: *AS1289.6.2.2*
test date: *17/08/10 to 19/08/10*

Sample Identification	***STAGE TYPE***	***CORRECTED NORMAL STRESS (kPa)***	***CORRECTED SHEAR STRESS (kPa)***
CTP05 (3.50 to 3.70m) Glendenning Lab No. (GLEN10S - 05852)	*Peak*	*41.5*	*21.6*
	Peak	*84.6*	*48.0*
	Peak	*167.1*	*80.9*

Notes:

1. *3 X Single Individual Recompacted Specimens*
2. *Specimens Remoulded to 95% of Standard Maximum Dry Density and at Optimum Moisture Content*
3. *Box Dimensions (mm) : 70.75 x 70.90 x 44.5*
4. *- 6.7mm Material Tested*
5. *Sample received on the 30/07/10*

remarks:

NATA Accredited Laboratory
No 431

Date: 23rd August, 2010

Approved Signatory: ***Alex Munoz***
Senior Technical Officer

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Unit 2/4 Kellogg Road Glendenning NSW 2761
ph: (61 2) 9421 3800 Fax: (61 2) 9421 3899
ABN 92 114 364 046

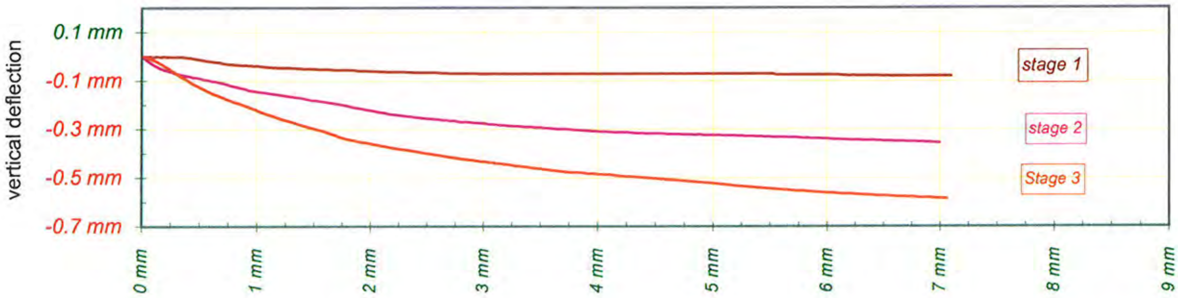
direct shear test

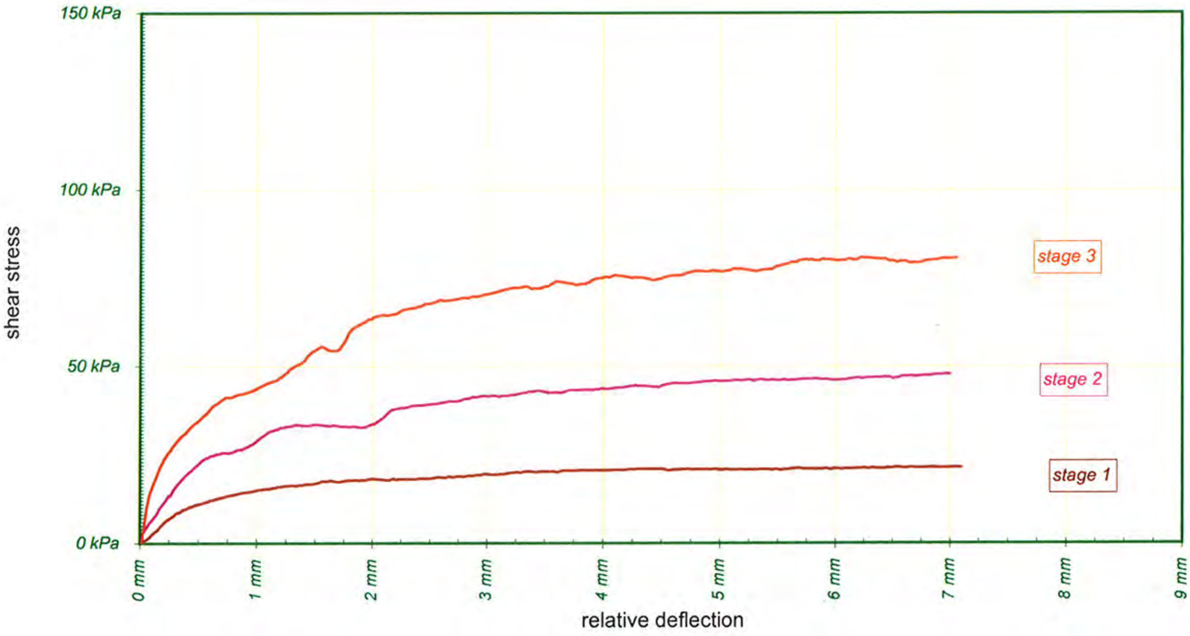
client: *COFFEY GEOTECHNICS PTY LTD (GEOTWOLL02834AA)*
principal: *CARDNO FORBES RIGBY*
project: *LANDSLIDE RISK ASSESSMENT*
location: *LOT 1 DP553170 - RAZORBACK RIDGE*

job no : ***INFOGLEN696AA***
laboratory : *Lane Cove West*
report date : *23 Aug 2010*
test report : *IOLT4091*

test procedure: *AS1289.6.2.2*
test type: *PEAK SHEAR STRESS*
test dates: *17th to 19th August, 2010*

laboratory sample no: *GLEN10S - 05852*
client Sample Nunber *CTP05 3.5 to 3.7m*
material classification: *-6.7mm Material Tested*
Borehole No ***CTP05***
Depth: ***3.50 to 3.70m***





shear rate: *0.005 mm/min*
Average Dry Density: *1.72t/m³*
Average Moisture Content: *15.2%*
Initial Moisture Content: *13.80 %*

notes: *1. 3 X Single Individual Recompacted Specimens.*
2. Box Dimensions (mm):- 70.75 x 70.90 x 44.5

SYD-R1-002 2005

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/national standards.

NATA Accredited Laboratory
No 431

Approved Signatory:
Alex Munoz
Senior Technical Officer

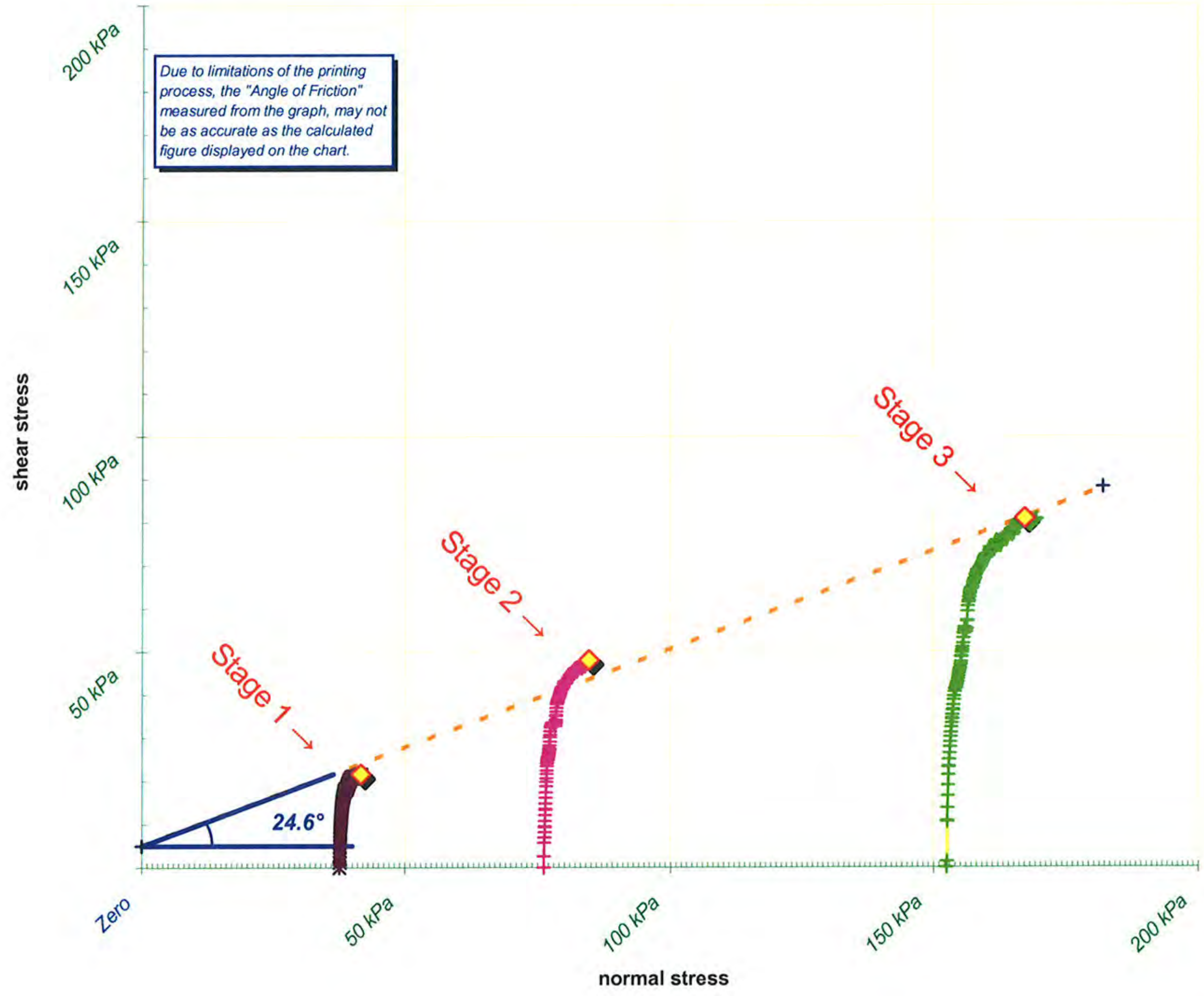
Date: ***23 Aug 2010***

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Unit 2/4 Kellogg Road Glendenning NSW 2761
ph: (61 2) 9421 3800 Fax: (61 2) 9421 3899
ABN 92 114 364 046

direct shear test

client:	COFFEY GEOTECHNICS PTY LTD (GEOTWOLL02834AA)	job no :	**INFOGLEN696AA**
principal:	CARDNO FORBES RIGBY	laboratory :	Lane Cove West
project:	LANDSLIDE RISK ASSESSMENT	report date :	23 Aug 2010
location:	LOT 1 DP553170 - RAZORBACK RIDGE	test report :	IOLT4091
test procedure:	**AS 1289.6.2.2**	test date :	17th to 19th August, 2010
test type:	**Peak shear Stress**		
laboratory sample no:	GLEN10S - 05852	borehole no :	**CTP05**
cleint Sample Nunber	CTP05 3.5 to 3.7m	Depth:	**3.50 to 3.70m**
material classification:	-6.7mm Material Tested		



shear rate:	0.005 mm/min	cohesion:	5.0 kPa
Average Dry Density:	1.72t/m³	angle of friction:	24.6°
Average Moisture Content:	15.2%		
type of test:	Saturated Consolidated Drained		

note: 1. 3 X Single Individual Recompacted Specimens.
2. Box Dimensions (mm):- 70.75 x 70.90 x 44.5

SYD-R2-002 2005

F:\2. Laboratory\1-INFOGLEN Jobs\INFOGLEN 00696AA - Razorback Ridge\[CTP07.xls]Report 1

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/national standards.

NATA Accredited Laboratory
No 431
Approved Signatory:
Alex Munoz
Senior Technical Officer

Date: **23 Aug 2010**

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Unit 2/4 Kellogg Road Glendenning, NSW 2761
ph: (61 2) 9421 3800 Fax: (61 2) 9421 3899
ABN: 92 114 364 046

test results - direct shear test

client:	***COFFEY GEOTECHNICS PTY LTD. (GEOTWOLL02834AA)***	job no:	***INFOGLEN00696AA***
principal:	***CARDNO FORBES RIGBY***	laboratory:	***Glendenning***
project:	***LANDSLIDE RISK ASSESSMENT***	report date:	***23-Aug-10***
location:	***LOT 1 DP553170 - RAZORBACK RIDGE***	test report:	***IOLT 4092***
test procedure:	*AS1289.6.2.2*	test date:	*17/08/10 to 20/08/10*

Sample Identification	***STAGE TYPE***	***CORRECTED NORMAL STRESS (kPa)***	***CORRECTED SHEAR STRESS (kPa)***
CTP07 (4.50 to 4.70m) Glendenning Lab No. (GLEN10S - 05853)	*Peak*	*56.6*	*25.7*
	Peak	*112.7*	*36.7*
	Peak	*223.3*	*79.3*

Notes:

1. *3 X Single Individual Recompacted Specimens*
2. *Specimens Remoulded to 95% of Standard Maximum Dry Density and at Optimum Moisture Content*
3. *Box Dimensions (mm) : 71.55 x 71.35 x 44.15*
4. *- 6.7mm Material Tested*
5. *Sample received on the 30/07/10*

remarks:

F:\2. Laboratory\1-INFOGLEN Jobs\INFOGLEN 00696AA - Razorback Ridge\[CTP07.xls]Repo

NATA Accredited Laboratory
No 431

Date: 23rd August, 2010

Approved Signatory: ***Alex Munoz***
Senior Technical Officer

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Unit 2/4 Kellogg Road Glendenning NSW 2761
ph: (61 2) 9421 3800 Fax: (61 2) 9421 3899
ABN 92 114 364 046

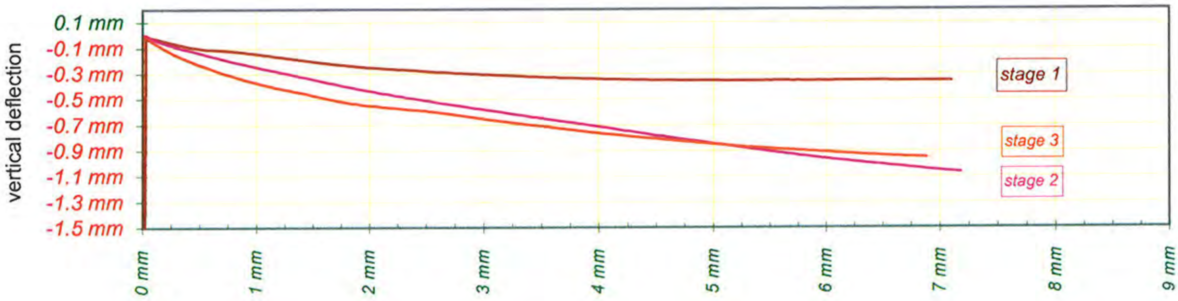
direct shear test

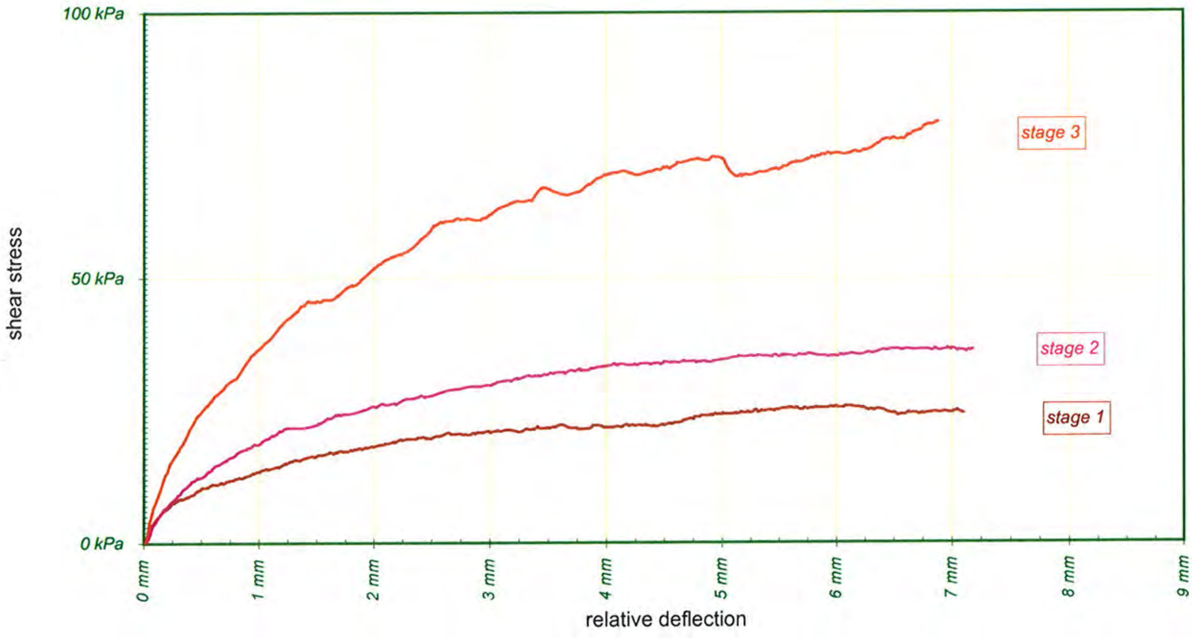
client: COFFEY GEOTECHNICS PTY LTD (GEOTWOLL02834AA)
principal: CARDNO FORBES RIGBY
project: LANDSLIDE RISK ASSESSMENT
location: LOT 1 DP553170 - RAZORBACK RIDGE

job no : INFOGLEN696AA
laboratory : Lane Cove West
report date : 23 Aug 2010
test report : IOLT4092

test procedure: AS1289.6.2.2
test type: PEAK SHEAR STRESS
test dates: 17th to 20th August, 2010

laboratory sample no: GLEN10S - 05853
client Sample Nunber CTP07 4.50 to 4.70m
material classification: -6.7mm Material Tested
borehole no : CTP07
Depth: 4.50 to 4.70m





shear rate: 0.006 mm/min
Average Dry Density: 1.68t/m³
Average Moisture Content: 16.4%
Initial Moisture Content: 13.80 %

notes: 1. 3 X Single Individual Recompacted Specimens.
2. Box Dimensions (mm):- 71.55 x 71.35 x 44.15

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/national standards.

NATA Accredited Laboratory
No 431
Approved Signatory:
Alex Munoz
Senior Technical Officer

Date: 23 Aug 2010

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

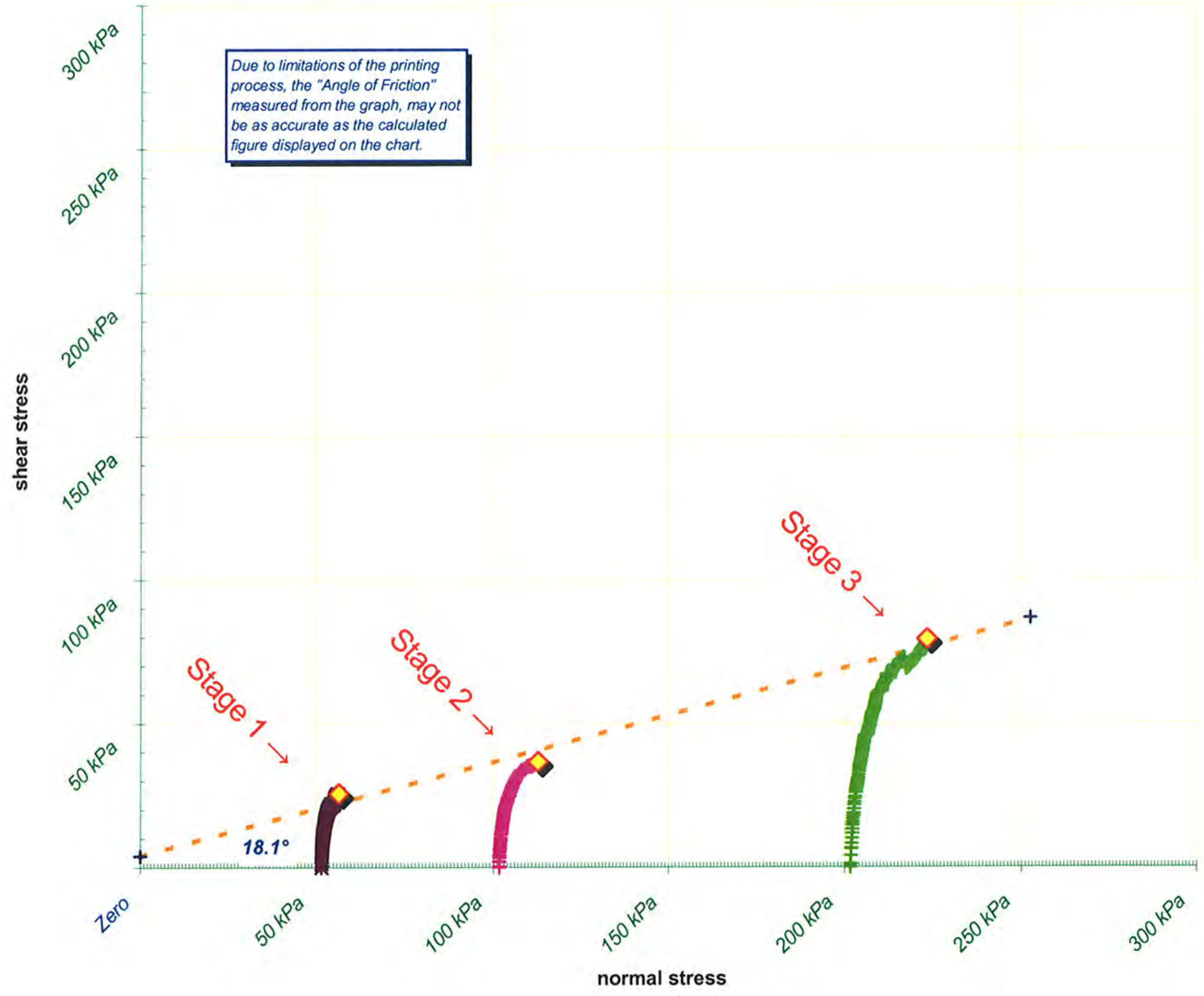
Unit 2/4 Kellogg Road Glendenning NSW 2761
ph: (61 2) 9421 3800 Fax: (61 2) 9421 3899
ABN 92 114 364 046

direct shear test

client: COFFEY GEOTECHNICS PTY LTD (GEOTWOLL02834AA)
principal: CARDNO FORBES RIGBY
project: LANDSLIDE RISK ASSESSMENT
location: LOT 1 DP553170 - RAZORBACK RIDGE
job no : **INFOGLEN696AA**
laboratory : Lane Cove West
report date : 23 Aug 2010
test report : IOLT4092

test procedure: **AS 1289.6.2.2**
test type: **Peak shear Stress**
test date : 17th to 20th August, 2010

laboratory sample no: GLEN10S - 05853
cleint Sample Nunber CTP07 4.50 to 4.70m
material classification: -6.7mm Material Tested
borehole no : **CTP07**
Depth: **4.50 to 4.70m**



shear rate: 0.006 mm/min
Average Dry Density: 1.68t/m³
Average Moisture Content: 16.4%
type of test: Saturated Consolidated Drained
cohesion: 4.0 kPa
angle of friction: 18.1°

note: 1. 3 X Single Individual Recompacted Specimens.
2. Box Dimensions (mm):- 71.55 x 71.35 x 44.15

SYD-R2-002 2005

F:\2. Laboratory\1-INFOGLEN Jobs\INFOGLEN 00696AA - Razorback Ridge\[CTP07.xls]Report 1

NATA ACCREDITED FOR TECHNICAL COMPETENCE

This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/national standards.

NATA Accredited Laboratory
No 431

Approved Signatory:
Alex Munoz
Senior Technical Officer

Date: **23 Aug 2010**

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Unit 2/4 Kellogg Road Glendenning, NSW 2761
ph: (61 2) 9421 3800 Fax: (61 2) 9421 3899
ABN: 92 114 364 046

test results - direct shear test

client:	**COFFEY GEOTECHNICS PTY LTD. (GEOTWOLL02834AA)**	job no:	**INFOGLEN00696AA**
principal:	**CARDNO FORBES RIGBY**	laboratory:	**Glendenning**
project:	**LANDSLIDE RISK ASSESSMENT**	report date:	**25-Aug-10**
location:	**LOT 1 DP553170 - RAZORBACK RIDGE**	test report:	**IOLT 4099**
test procedure:	*AS1289.6.2.2*	test date:	*19/08/10 to 25/08/10*

Sample Identification	**STAGE TYPE**	**CORRECTED NORMAL STRESS (kPa)**	**CORRECTED SHEAR STRESS (kPa)**
CTP11A *(1.30 to 1.60m)* *Glendenning Lab No.* *(GLEN10S - 05854)*	*Peak*	*37.9*	*3.4*
	Peak	*83.9*	*21.3*
	Peak	*160.3*	*43.0*

Notes:
1. *3 X Single Individual Recompacted Specimens*
2. *Specimens Remoulded to 95% of Standard Maximum Dry Density and at Optimum Moisture Content*
3. *Box Dimensions (mm) : 70.75 x 70.90 x 44.5*
4. *- 6.7mm Material Tested*
5. *Sample received on the 30/07/10*

remarks:

NATA Accredited Laboratory
No 431

Date: 25th August, 2010

Approved Signatory: ***Alex Munoz***
Senior Technical Officer

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Unit 2/4 Kellogg Road Glendenning NSW 2761
ph: (61 2) 9421 3800 Fax: (61 2) 9421 3899
ABN 92 114 364 046

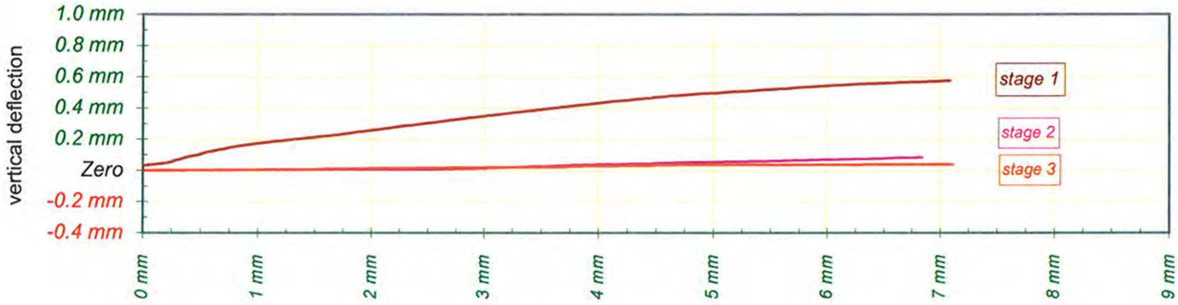
direct shear test

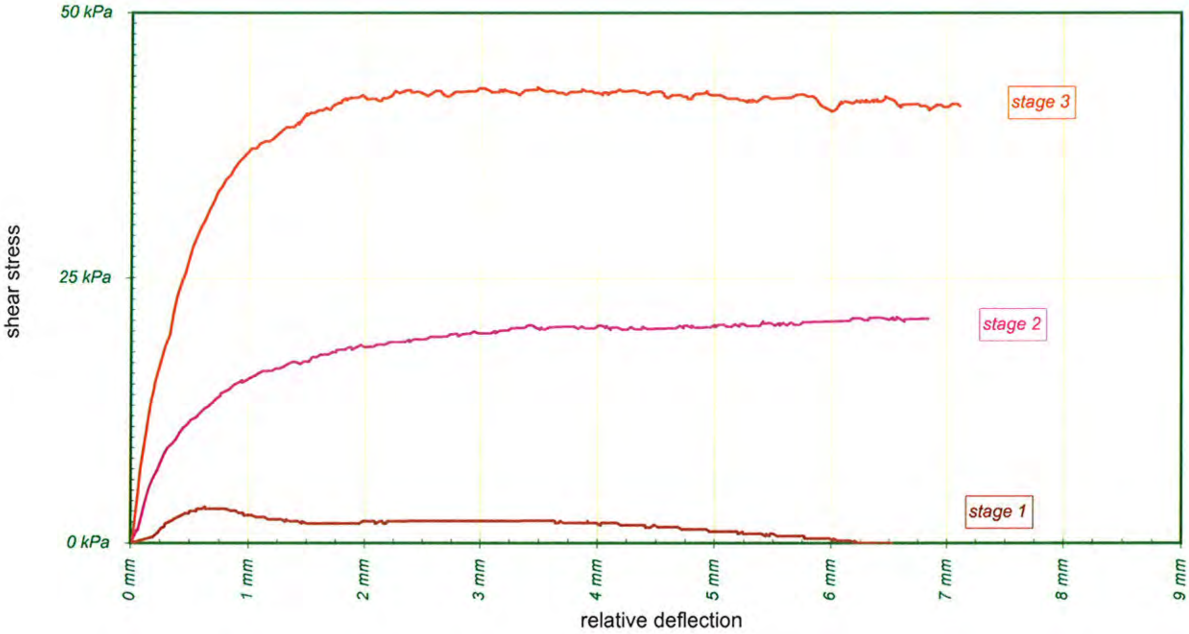
client: *COFFEY GEOTECHNICS PTY LTD (GEOTWOLL02834AA)*
principal: *CARDNO FORBES RIGBY*
project: ***LANDSLIDE RISK ASSESSMENT***
location: ***LOT 1 DP553170*** *- RAZORBACK RIDGE*

job no : ***INFOGLEN576AA***
laboratory : *Lane Cove West*
report date : *25 Aug 2010*
test report : *IOLT4099*

test procedure: ***AS1289.6.2.2***
test type: ***Peak Shear Stress***
test dates: *19th to 25th August, 2010*

laboratory sample no: *GLEN10S - 05854*
client Sample Number *CTP11A 1.30 to 1.60m*
material classification: *-6.7mm Material Tested*
Borehole No ***CTP11A***
Depth: *1.30 to 1.60m*





shear rate: *0.005 mm/min*
Average Dry Density: *1.74t/m³*
Average Moisture Content: *14.8%*
Initial Moisture Content: *16.0 %*
notes: *1. 3 X Single Individual Recompacted Specimens.*
2. Box Dimensions (mm):- 70.75 x 70.90 x 44.5

SYD-R1-002 2005

F:\2. Laboratory\1-INFOGLEN Jobs\INFOGLEN 00696AA - Razorback Ridge\[CTP11a.xls]Data Entry

NATA ACCREDITED FOR TECHNICAL COMPETENCE

This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/national standards.

NATA Accredited Laboratory
No 431
Approved Signatory:
Alex Munoz
Senior Technical Officer

Date: ***25 Aug 2010***

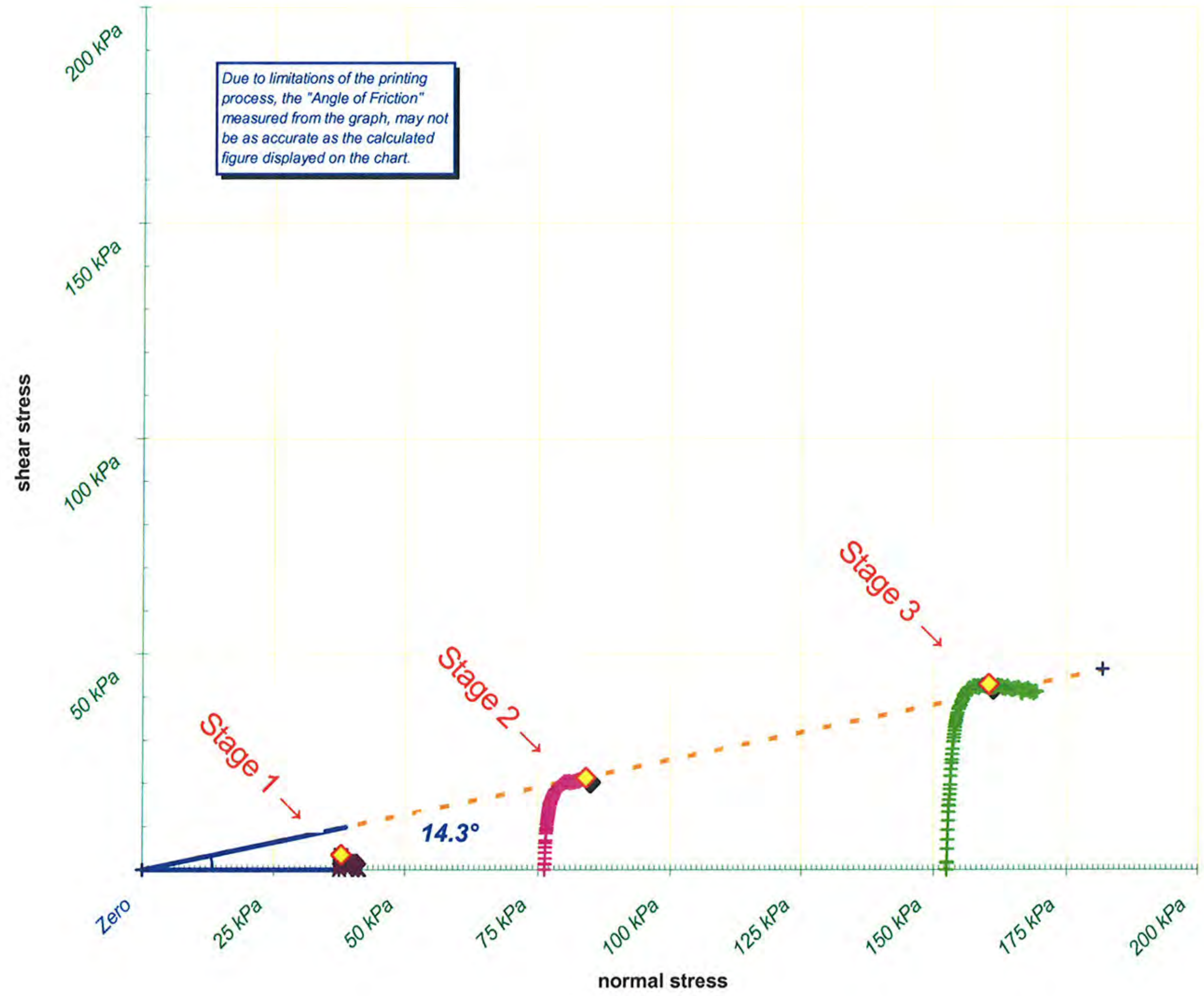
direct shear test

client: COFFEY GEOTECHNICS PTY LTD (GEOTWOLL02834AA)
principal: CARDNO FORBES RIGBY
project: LANDSLIDE RISK ASSESSMENT
location: LOT 1 DP553170 - RAZORBACK RIDGE

job no : **INFOGLEN576AA**
laboratory : Lane Cove West
report date : 25 Aug 2010
test report : IOLT4099

test procedure: **AS 1289.6.2.2**
test type: **Peak shear Stress**
test date : 19th to 25th August, 2010

laboratory sample no: GLEN10S - 05854
cleint Sample Number CTP11A 1.30 to 1.60m
material classification: -6.7mm Material Tested
borehole no : **CTP11A**
Depth: 1.30 to 1.60m



shear rate: 0.005 mm/min
Average Dry Density: 1.74t/m³
Average Moisture Content: 14.8%
type of test: Saturated Consolidated Drained

cohesion: 0.0 kPa
angle of friction: 14.3°

note: 1. 3 X Single Individual Recompacted Specimens.
2. Box Dimensions (mm):- 70.75 x 70.90 x 44.5

NATA ACCREDITED FOR TECHNICAL COMPETENCE

This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/national standards.

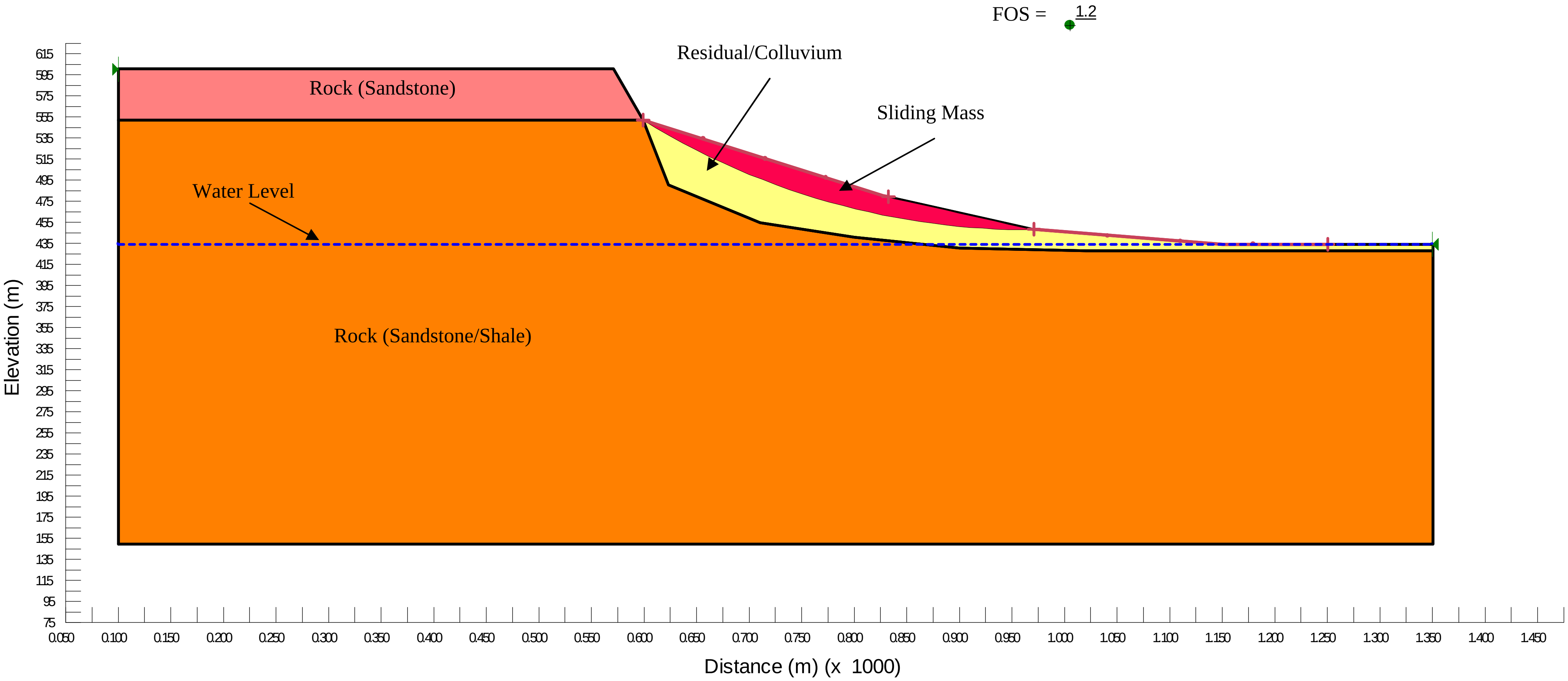
NATA Accredited Laboratory
No 431

Approved Signatory:
Alex Munoz
Senior Technical Officer

Date: **25 Aug 2010**

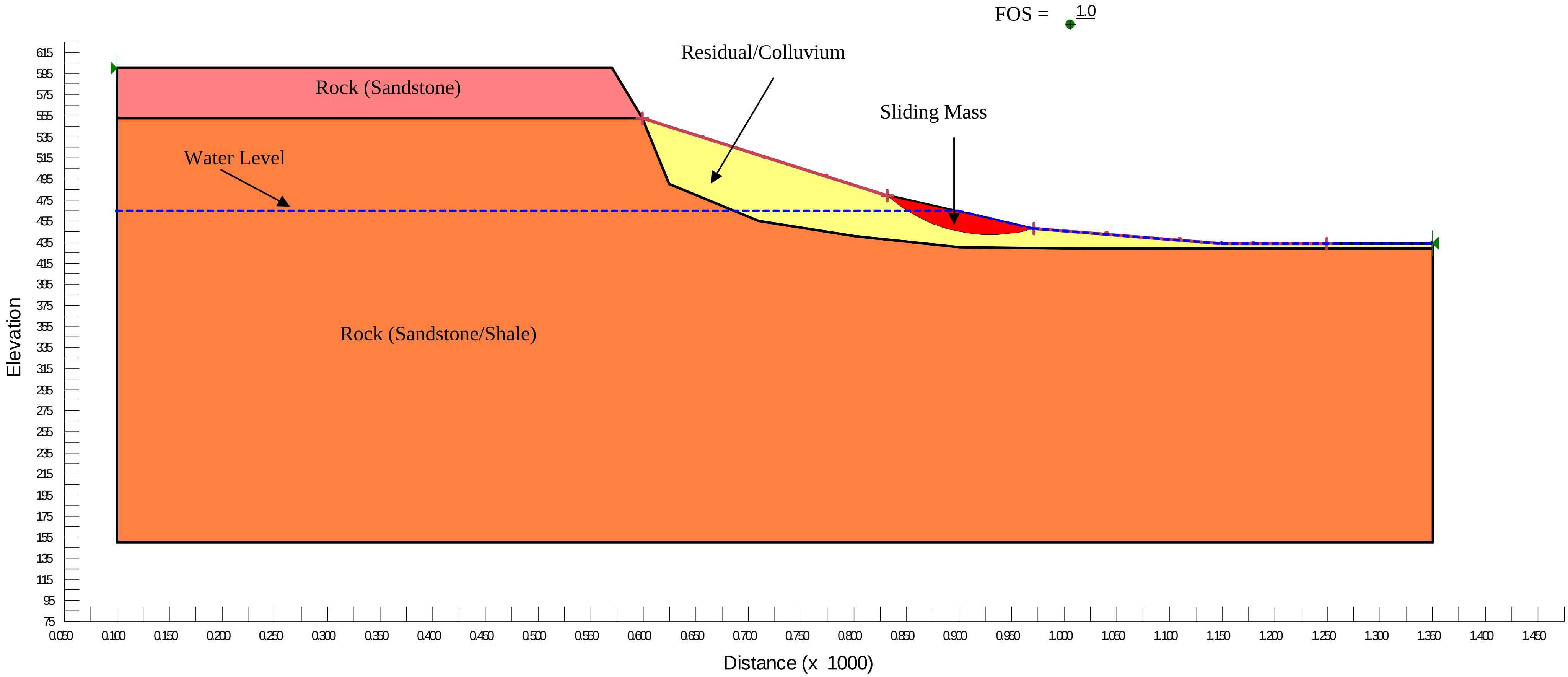
Appendix E

SLOPE/W Analyses



drawn	**KK**	client:	**CARDO (NSW) PTY LTD**
approved	**JT**	project:	**LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS** **Appin Area 9 Proposed Longwalls, Douglas Park NSW**
date	**10/01/2011**	title:	**Case 1: Natural Slope with water Table at Toe of Slope**
scale	**N/A**	project no: **GEOTWOLL02834AA-AG**	figure no: **FIGURE 1**
original size	**A4**		

coffey geotechnics
SPECIALISTS MANAGING THE EARTH



drawn	**KK**
approved	**JT**
date	**10/01/2011**
scale	**N/A**
original size	**A4**

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

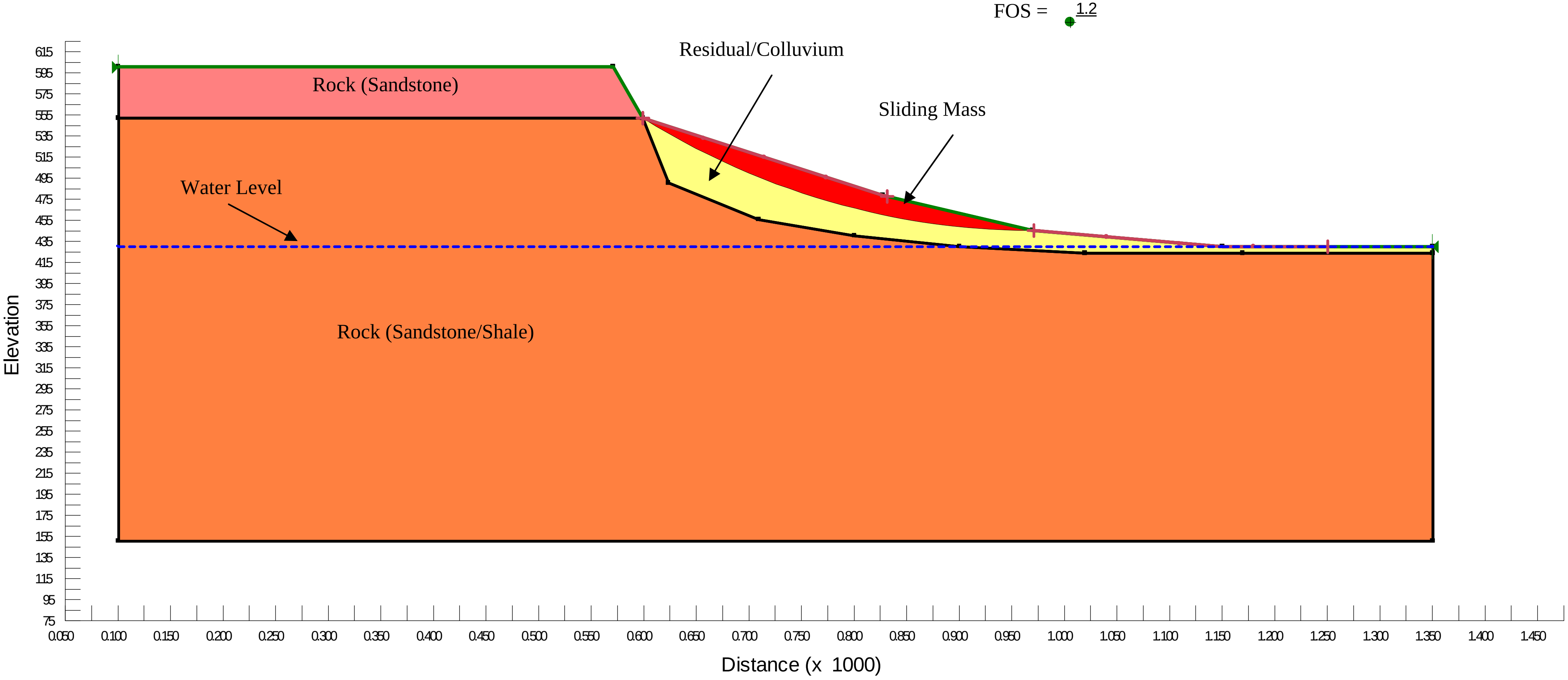
client: **CARDO (NSW) PTY LTD**

project: **LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS**
Appin Area 9 Proposed Longwalls, Douglas Park NSW

title: **Case 2: Natural Slope with Water Table at 30 m above Toe of Slope**

project no: **GEOTWOLL02834AA-AG**

figure no: **FIGURE 2**



drawn	**KK**
approved	**JT**
date	**10/01/2011**
scale	**N/A**
original size	**A4**

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

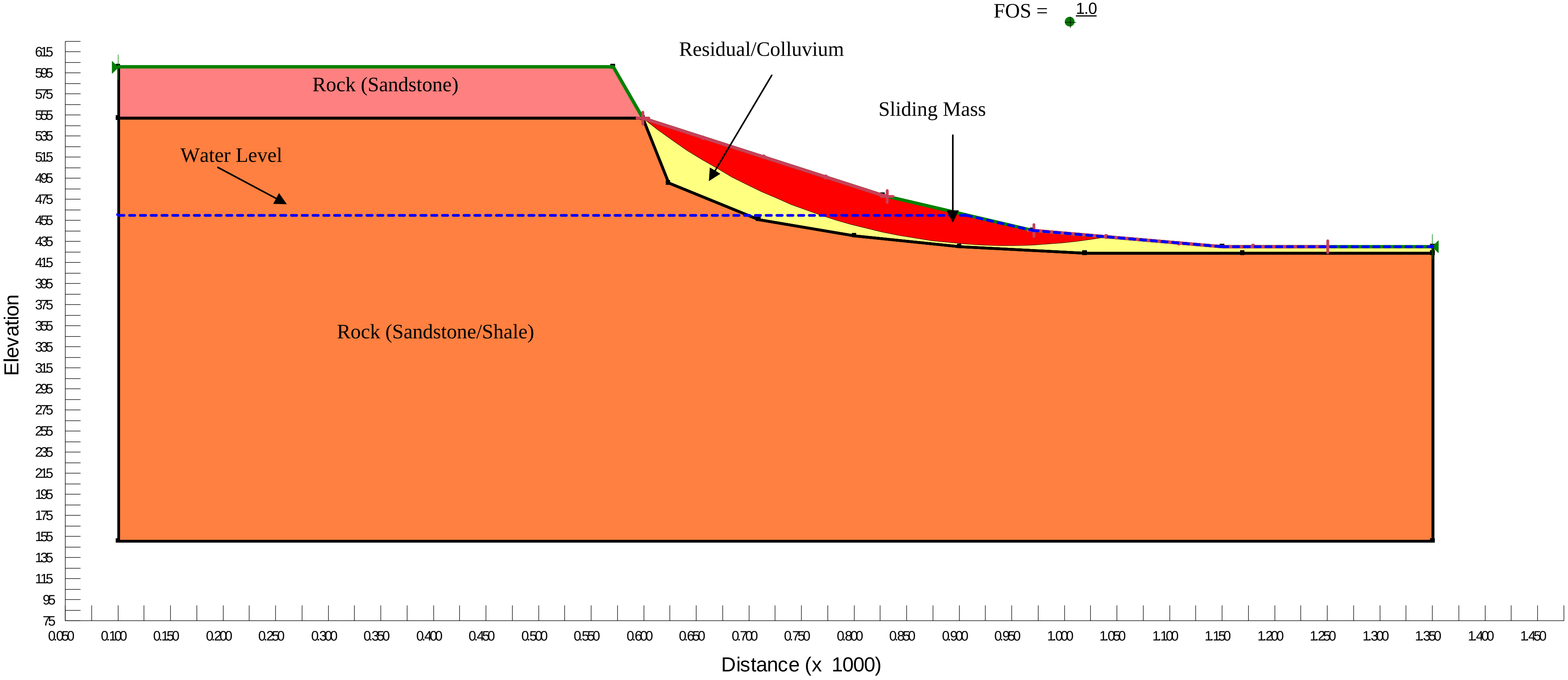
client: **CARDO (NSW) PTY LTD**

project: **LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS**
Appin Area 9 Proposed Longwalls, Douglas Park NSW

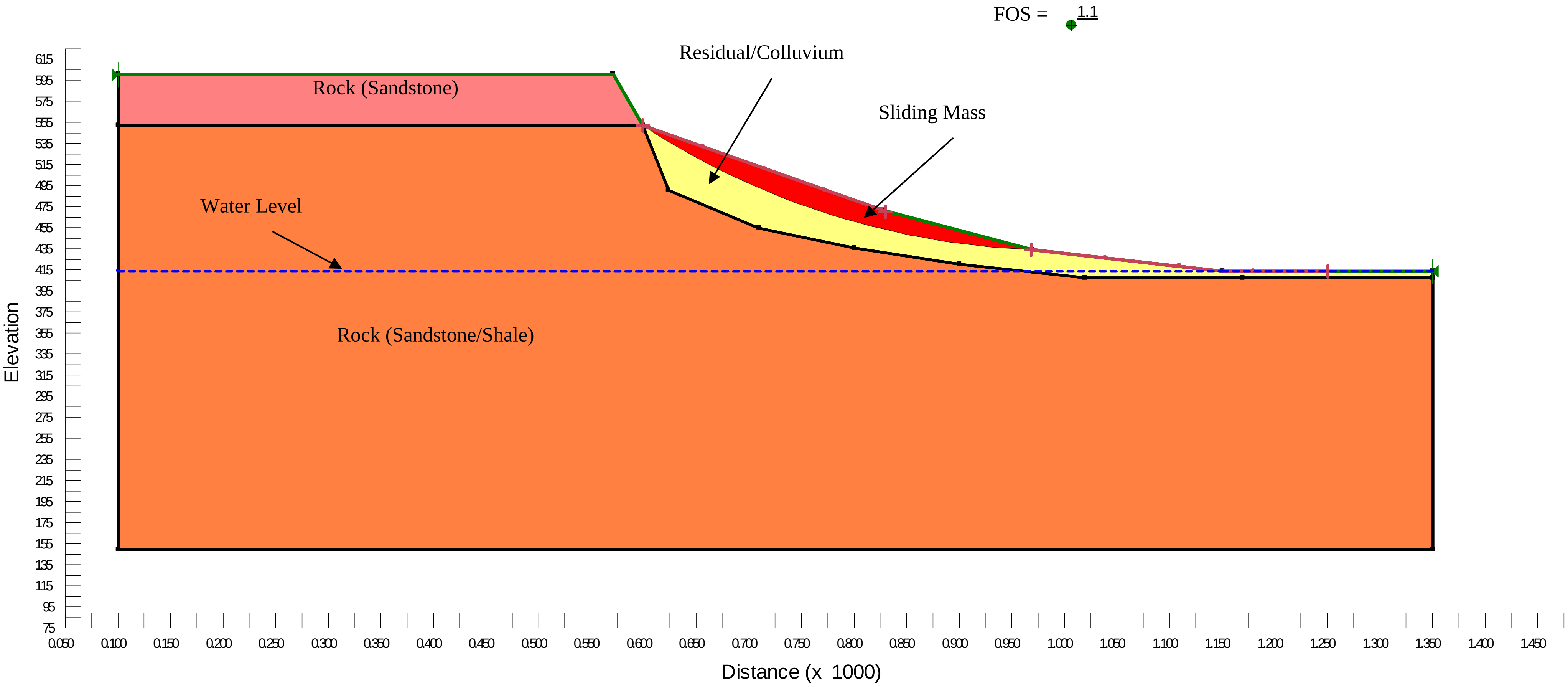
title: **Case 3: Natural Slope+0.4 degree Tilt with Water at Toe of Slope**

project no: **GEOTWOLL02834AA-AG**

figure no: **FIGURE 3**



drawn	KK	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	CARDO (NSW) PTY LTD
approved	JT		project:	LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS Appin Area 9 Proposed Longwalls, Douglas Park NSW
date	10/01/2011			
scale	N/A		title:	Case 4: Natural Slope+ 0.4 Degree Tilt with Water Table at 30 m above Toe of Slope
original size	A4		project no: GEOTWOLL02834AA-AG	figure no: FIGURE 4



drawn	KK
approved	JT
date	10/01/2011
scale	N/A
original size	A4

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

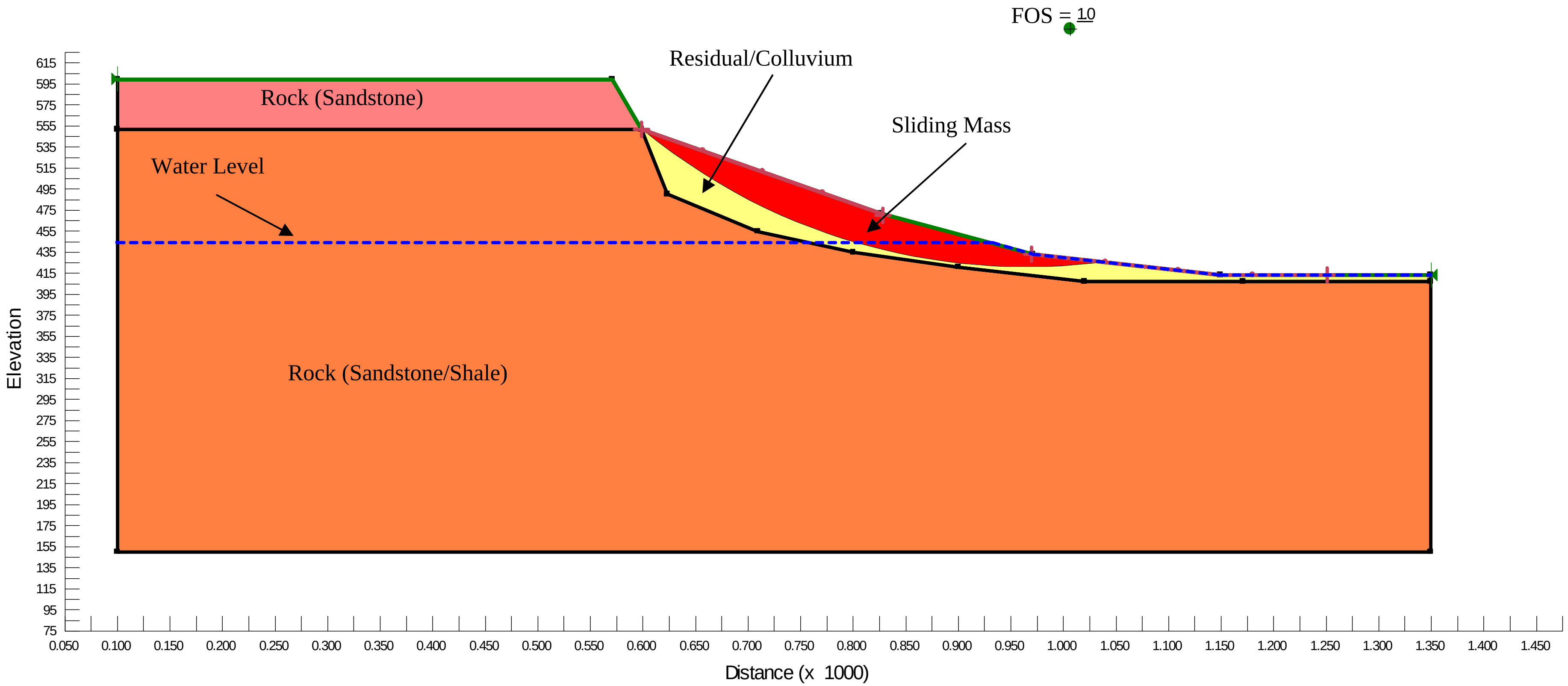
client: **CARDO (NSW) PTY LTD**

project: **LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS**
Appin Area 9 Proposed Longwalls, Douglas Park NSW

title: **Case 7: Natural Slope+ 2.0 Degrees Tilt with Water Table at Toe of Slope**

project no: **GEOTWOLL02834AA-AG**

figure no: **FIGURE 5**



drawn	KK
approved	JT
date	10/01/2011
scale	N/A
original size	A4

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client:	**CARDO (NSW) PTY LTD**
project:	**LANDSLIDE RISK ASSESSMENT FROM MINE SUBSIDENCE EFFECTS** **Appin Area 9 Proposed Longwalls, Douglas Park NSW**
title:	**Case 8: Natural Slope+ 2.0 Degrees Tilt with Water Table at 30 m above Toe of Slope**
project no:	**GEOTWOLL02834AA-AG**
figure no:	**FIGURE 6**

Appendix F

Landslide Risk Management, 2007, Appendix C

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	Notional Boundary					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	Notional Boundary			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	1: CATASTROPHIC 200%	2: MAJOR 60%	3: MEDIUM 20%	4: MINOR 5%	5: INSIGNIFICANT 0.5%
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or L (5)
B - LIKELY	10^{-2}	VH	VH	H	M	L
C - POSSIBLE	10^{-3}	VH	H	M	M	VL
D - UNLIKELY	10^{-4}	H	M	L	L	VL
E - RARE	10^{-5}	M	L	L	VL	VL
F - BARELY CREDIBLE	10^{-6}	L	VL	VL	VL	VL

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Appendix G

Important Information about Appendix C of Landslide Risk Management, 2007

Landslide Risk Management

Important Information about AGS 2007 Appendix C (1 of 2)

INTRODUCTION

This sheet provides important information on the following Appendix **C** which has been copied from "Practice note guidelines for landslide risk management 2007". The "Practice Note" and accompanying "Commentary" (References 1 & 2, hereafter referred to as AGS2007) are part of a series of documents on landslide risk management prepared on behalf of, and endorsed by, the Australian Geomechanics Society. These documents were primarily prepared to apply to residential or similar development.

It should be noted that AGS2007 define landslides as "the movement of a mass of rock, debris or earth down a slope". This definition includes falls, topples, slides, spreads and flows from both natural and artificial slopes.

LANDSLIDE LIKELIHOOD ASSESSMENT

The assessment of the likelihood of landsliding requires evidence-based judgements.

Judging how often and how much an existing landslide will move is difficult. Judging the likelihood of a new landslide occurring is even harder. Records of past landslides can provide some information on what has happened, but are invariably incomplete and often provide little or no guidance on less frequent events that may occur. Often judgements have to be made about the likelihood of infrequent events with serious consequences, with little or no help from historical records. Slope models, which reflect evidence-based knowledge of how a slope was formed, how it behaved in the past and how it might behave in the future, are used to support judgements about what might happen. Because of the difficulties in assessing landslide likelihood, different assessors may make different judgements when presented with the same information.

The likelihood terms in Appendix C can be taken to imply that it is possible to distinguish between low probability events (e.g. between events having a probability of 1 in 10,000 and 1 in 100,000). In many circumstances it will not be possible to develop defensibly realistic judgements to do so, and so joint terms need to be used (e.g. Likely or Possible). For further discussion on landslide likelihood and other matters see References 3, 4 and 5.

CONSEQUENCES OF LANDSLIDES

There can be direct (e.g. property damage, injury / loss of life) and indirect (e.g. litigation, loss of business confidence) consequences of a landslide. The assessment of the importance (seriousness) of the consequences is a value judgement best made by those most affected (e.g. client, owner, regulator, public). The main role of the expert is usually to understand and explain what and who might be affected, and what damage or injury might occur.

Appendix C implies that we can anticipate total cost (direct and indirect) of landslide damage to about half an order of magnitude (e.g. the difference between $30,000 and $100,000). This involves predicting the location, size, travel distance and speed of a landslide, the response of a building (often before it has been built), the nature and the extent of damage, repair costs as well as indirect consequences such as legal costs, accommodation etc. There can be other direct and indirect consequences of a landslide which can be difficult to anticipate, let alone quantify and cost. The situation is analogous to the cost of work place accidents where the hidden costs can range from less than one to more than 20 times the visible direct costs (Reference 5).

In many circumstances it will not be possible to develop defensibly realistic judgements to enable use of a single consequence descriptor from Appendix C, and so joint terms need to be used (e.g. Minor or Medium). In our experience, explicit descriptions of potential consequences (e.g. rocks up to 0.5m across may fall on a parked car) help those affected to make their own judgements about the seriousness of the consequences.

RISK MATRIX

The main purpose of a risk matrix is to help rank risks, set priorities and help the decision making process. The risk terms should be regarded only as a guide to the relative level of risk as they are the product of an evidence-based quantitative judgement of likelihood and a value judgement about consequences, both of which involve considerable uncertainty. Different assessors may arrive at different judgements on the risk level.

Using Appendix C, many existing houses on sloping land will be assessed to have a Moderate Risk.

Landslide Risk Management

Important Information about AGS 2007 Appendix C (2 of 2)

RISK LEVEL IMPLICATIONS

In general, it is the responsibility of the client and/or owner and/or regulatory authority and/or others who may be affected to decide whether to accept or treat the risk. The risk assessor and/or other advisers may assist by making risk comparisons, discussing treatment options, explaining the risk management process, advising how others have reacted to risk in similar situations, and making recommendations. Attitudes to risk vary widely and risk evaluation often involves considering more than just property damage (e.g. environmental effects, public reaction, political consequences, business confidence etc).

The risk level implications in Appendix C represent a very specific example and are unlikely to be generally applicable. In our experience the typical response of regulators to assessed risk is as follows:

Assessed risk	**Typical response of client/ owner/ regulator/ person affected**
Very High, High [1]	Treats seriously. Usually requires action to reduce risk. Will generally avoid development.
Moderate	May accept risk. Usually looks for ways to reduce risk if reasonably practicable.
Low, Very Low [1]	Usually regards risk as acceptable. May reduce risk if reasonably practicable.

1 The distinctions between Very High and High and between Low and Very Low risks are usually used to help set priorities.

REFERENCES

1. AGS (2007). "Practice note guidelines for landslide risk management 2007". Australian Geomechanics, Vol. 42, No. 1, pp 63-114.
2. AGS (2007). "Commentary on practice note guidelines for landslide risk management 2007". Australian Geomechanics, Vol. 42, No. 1, pp 115-158.
3. Baynes, F.J., Lee I.K. and Stewart, I.E., (2002). "A study of the accuracy and precision of some landslide risk analyses." Australian Geomechanics, Vol. 37, No. 2, pp 149-156.
4. Baynes, et. al., (2007). "Concerns about the Practice Note Guidelines for Landslide Risk Management 2007." Letter to the editor, Australian Geomechanics, Vol. 2, No. 4, pp 63-114.
5. Moon, A.T., and Wilson, R,A., (2004). "Will it happen? – Quantitative judgements of landslide likelihood". Proceedings of the Australia New Zealand conference on Geomechnics, Centre of continuing education, University of Auckland, Vol. 2, pp 754-760.

Appendix H

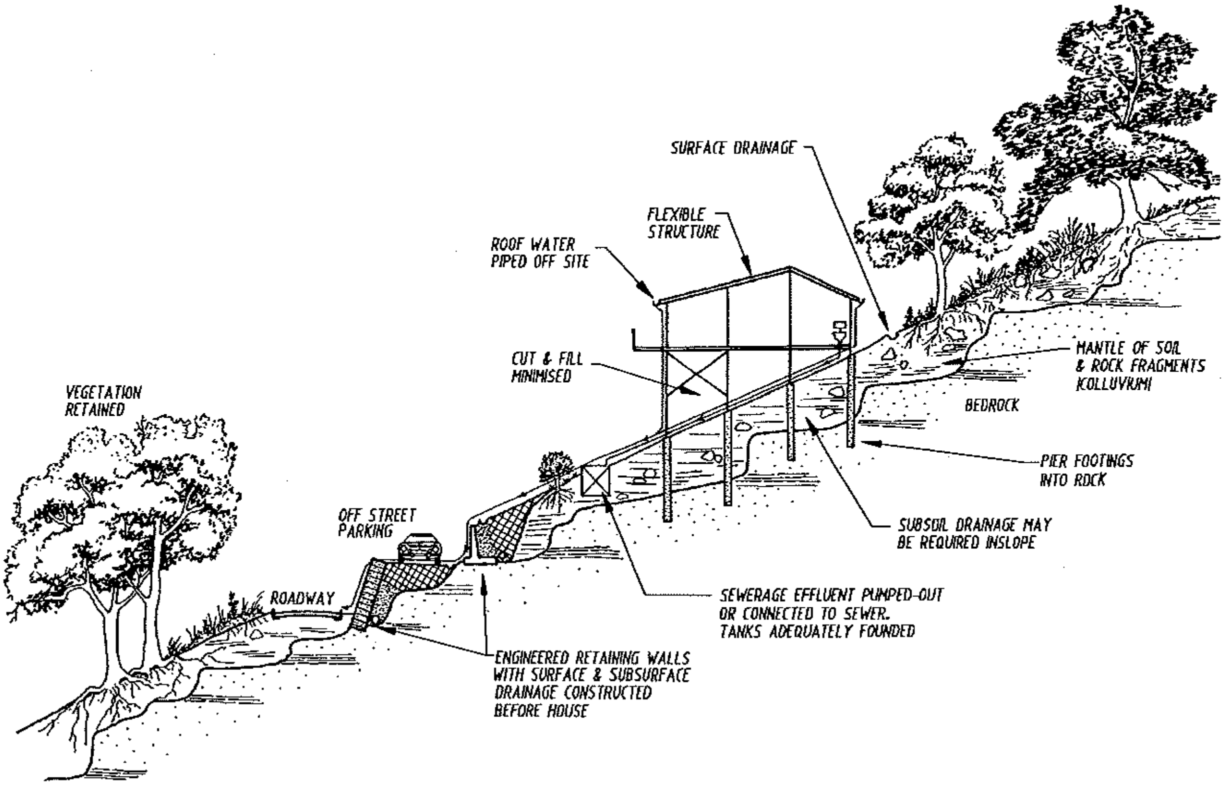
Examples of Good Hillside Practice

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

Information published by Australian Geomechanics Society (2000). 'Landslide Risk Management Concepts and Guidelines'. Australian Geomechanics Vol 35, p49-92.

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE

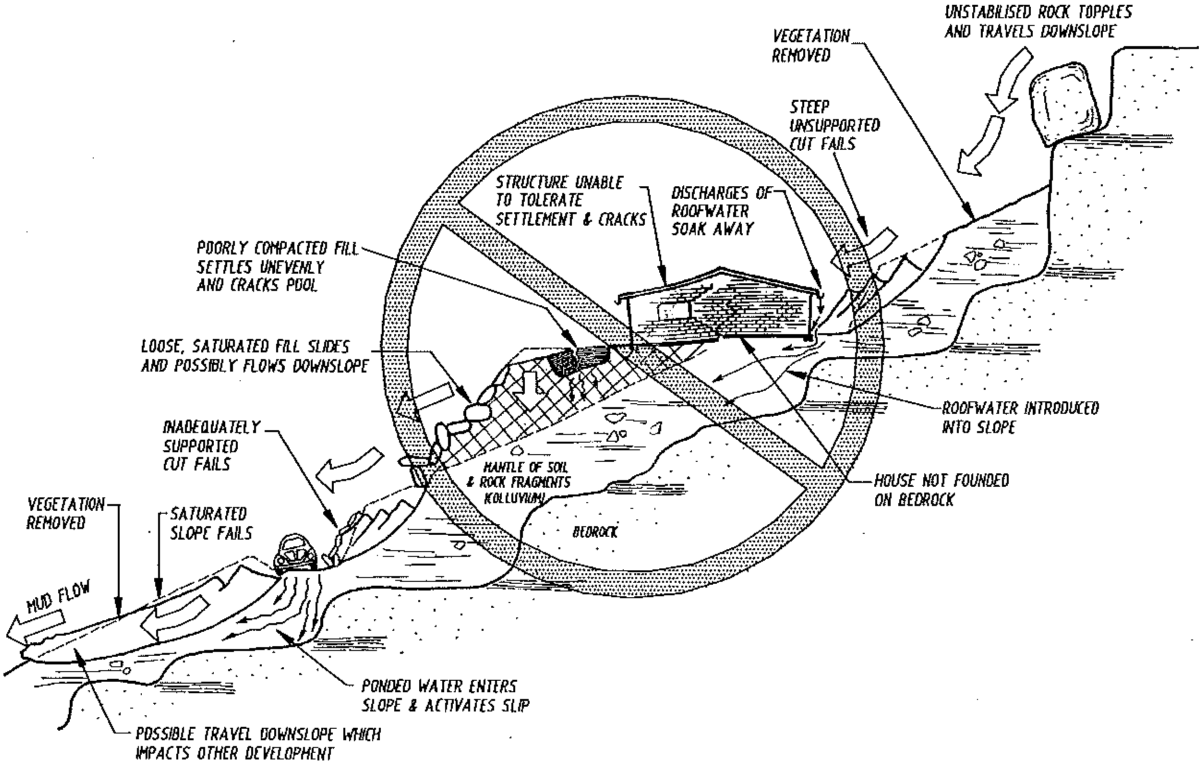


FIGURE 2: ILLUSTRATIONS OF GOOD AND POOR HILLSIDE PRACTICE

This figure is an extract form LANDSLIDE RISK MANAGEMENT CONCEPTS AND GUIDELINES as presented in *Australian Geomechanics*, Vol 35, No 1, 2000 which discusses the matter more fully.