Metallurgical Coal

DENDROBIUM AREA 3B

SUBSIDENCE MANAGEMENT PLAN

Volume 1 – Written Report

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Table of Contents

Tables

Figures

Attachments

A. SUBSIDENCE REPORT (MSEC, 2012)

B. SURFACEWATER AND SHALLOW GROUNDWATER (ECOENGINEERS, 2012)

C. GROUNDWATER (COFFEY GEOTECHNICS, 2012)

D. TERRESTRIAL ECOLOGY (NICHE ENVIRONMENT AND HERITAGE, 2012)

E. AQUATIC ECOLOGY (CARDNO ECOLOGY LAB, 2012)

F. CULTURAL HERITAGE (BIOSIS, 2012)

G. COMMUNITY CONSULTATION DOCUMENTS

H. RISK ASSESSMENT

1 INTRODUCTION

1.1 BACKGROUND

Dendrobium Mine is located within the NSW Southern Coalfield approximately 15 km west of Wollongong (ref **Figure 1.1**). The Mine is one of three operating underground mines managed by BHP Billiton Illawarra Coal (BHPBIC) south of Sydney, the other two mines being Appin Colliery and West Cliff Colliery. The Mine currently produces high quality coking coal from the Wongawilli Seam.

The mining operations are divided into three areas, Area 1, 2 and 3. To date, extraction of the Wongawilli Seam has occurred in Areas 1, 2 and is currently proceeding in Longwall 7 of Area 3A. BHPBIC now plans to continue its underground mining operations into Area 3B.

The original Development Consent (DA 60-03-2001) for the Mine was granted by the Department of Planning (then DUAP now DP&I) on 20 November 2001.

In 2007, BHPBIC applied to modify the consent and the footprint of Area 3. This assessment was prepared by Cardno and submitted as a s75w modification (MOD 6) to the 2001 Consent. Conditional Approval for Area 3 was granted on 8 December 2008 (referred to hereafter as the Area 3 Modification).

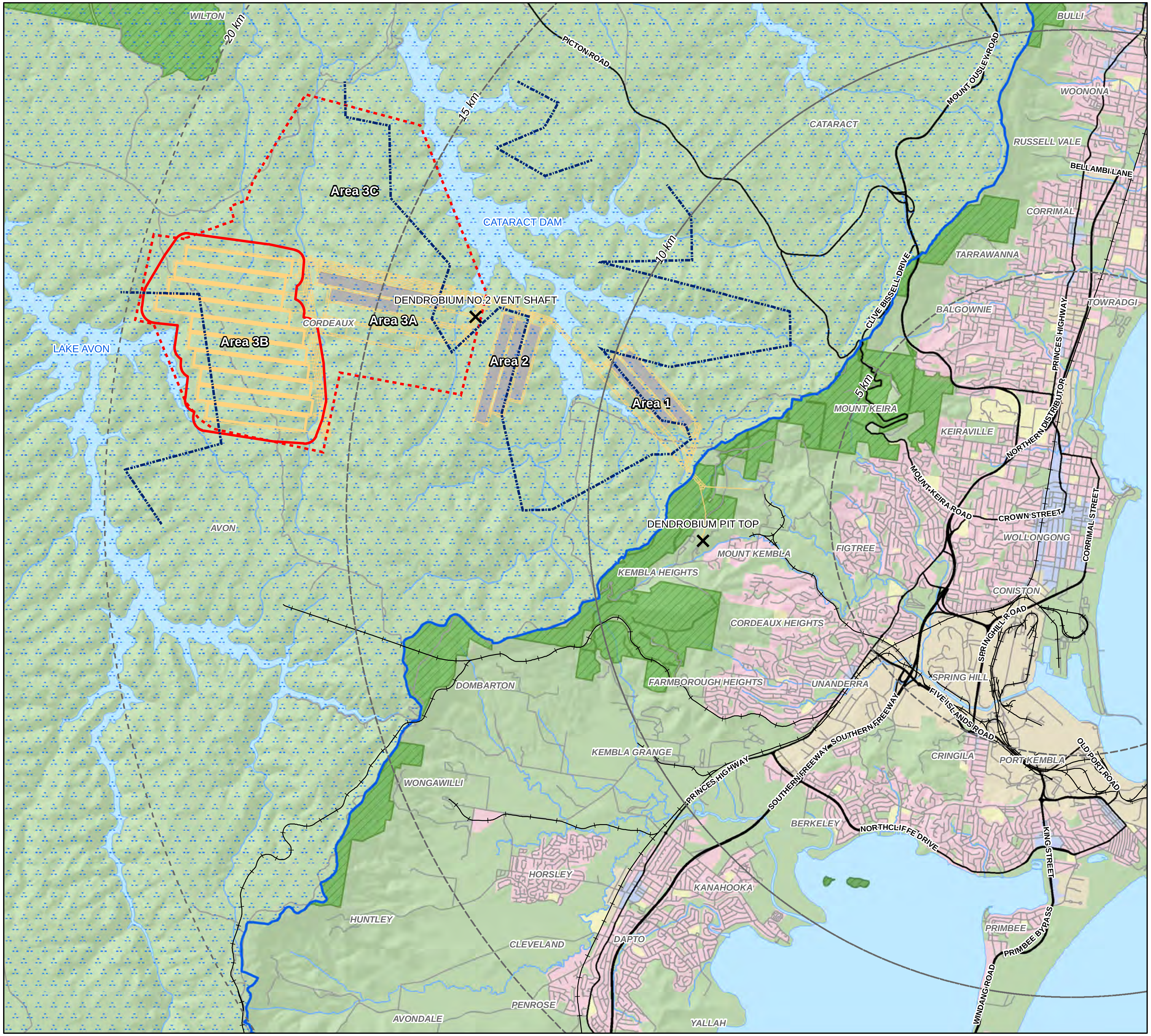
At this time the final longwall layouts for Dendrobium Areas 3B and 3C were subject to the results of additional exploration. It is a condition of the Area 3 Modification that BHPBIC gains SMP Approval from the Department of Trade and Investment, Regional Infrastructure and Services (DITRIS) prior to the commencement of mining in Area 3B.

In accordance with the conditions of the Area 3 Modification, SMP approval is now sought for Area 3B.

It is noted that a number of government restructures have occurred since the original Development Consent for the Mine was granted in 2001. As mentioned above, SMP approval was formerly assessed by the Department of Primary Industries (DPI). The Department of Primary Industries (DPI) was also formerly known as the Department of Primary Industries and Minerals (DPIM), under which the *Guideline for Applications for Subsidence Management Approvals* (DPIM, 2003) were developed.

At the time of writing the Mine must seek SMP approval from the Division of Resources and Energy (DRE) a component of the newly formed Department of Trade and Investment, Regional Infrastructure and Services (DITRIS).

From here on in, for the purposes of clarity, all references to the government department formerly known as the DPI, responsible for the assessment of the SMP will be referred to as the DRE.



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Locality Plan

DENDROBIUM AREA 3B SMP

Legend

- Mining Infrastructure
- Railway
- Major Roads
- Local Roads
- Major Watercourses
- SMP Area 3B (1,199 ha)
- Longwall Layout (MSEC)
- Maximum Footprint Area 3 (MSEC)
- Outlines of Longwalls 9 to 18 (MSEC)
- DSC Notification Zone (MSEC)
- NPWS Reserve
- Major Waterbodies
- Distance from Wollongong CBD
- Special Water Catchment Areas (SCA)
- Dendrobium Goaf (Illawarra Coal, Oct 2011)

Land Use (ABS)

- Other
- Commercial
- Education
- Industrial
- Residential

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FIGURE 1.1

1:75,000 Scale at A3

Metres
0 1,000 2,000 3,000 4,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-21
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1002_LocalityPlan.mxd 02

Data supplied by LPI (2009/2011) unless otherwise stated

1.2 THE APPLICANT

Dendrobium Mine is owned and operated by Dendrobium Coal, part of Illawarra Coal Holdings, which is a wholly owned subsidiary of BHP Billiton. BHPBIC operates three mines in the Illawarra region, Appin, West Cliff and Dendrobium, producing premium quality hard coking coal for the Steelworks in Port Kembla and Whyalla and overseas export.

1.3 PRIOR APPROVALS

BHPBIC hold the following approvals which are of relevance to this SMP Application:

- Development Consent for the Dendrobium Mine (DA 60-03-2001).
- Modification 6 of the above in respect to the mining of Area 3 (Area 3 Modification).
- SMP Approval to mine in Area 3A (Longwalls 6 to 10*).

**The longwalls in Area 3A have since been modified. Longwall 10 has been omitted (i.e. not extracted) and Longwall 9 has been renamed Longwall 19 and will be extracted after Longwalls 9 to 18.*

The finishing (western) end of Longwall 19 in Area 3A adopted in this report is 75 m shorter than the approved length. The shortened finishing end of Longwall 19 will be addressed in a separate modification application. The modifications also included shortened finishing ends for Longwalls 6, 7 and 8 and increased void widths of Longwalls 8 and 19

1.4 APPROVALS SOUGHT

This SMP Application seeks approval for the development of roadways and extraction of Wongawilli Seam coal by longwall mining from Longwalls 9 to 18 in Dendrobium Area 3B (the **Activity**) (see **Figure 2.1**). The Activity includes the mitigation and remediation measures proposed in this report and the SMP to minimise the impacts from the proposed mining.

BHPBIC require SMP Approval from DP&I to carry out the Activity in Area 3B (Longwalls 9 to 18) in accordance with the requirements of the Area 3 Modification. Approval of the SMP by DRE under the conditions of the mining lease is also required. Once these approvals have been obtained BHPBIC may then obtain approval under section 88 of the *Coal Mines Health and Safety Regulation 2006* for extraction in Area 3B.

This document has been prepared to meet the requirements above and takes guidance from the Area 3 Modification Conditions (refer **Section 1.5**) as well as the *Guideline for Applications for Subsidence Management Approvals* (DPIM, 2003) (refer **Table 1.1**).

Table 1.1 - Document Compliance with SMP Guidelines

SMP Guideline Section		Relevant SMP Section
6.2	The SMP Area	Volume 1 – Section 2
6.3	Mining system and resource recovery	Volume 1 – Section 3
6.4	Site conditions within the SMP Area;	Volume 1 – Section 4
6.5	Stability of the underground workings	Volume 1 – Section 4.8
6.6	Characterisation of surface and subsurface	Volume 1 – Section 5

SMP Guideline Section		Relevant SMP Section
	features within the SMP Area	
6.7	Subsidence Prediction	Volume 1 – Section 6
6.8	Community Consultation	Volume 1 – Section 9
6.9	Statutory Requirements	Volume 1 – Section 10
6.10	Subsidence Impacts	Volume 1 – Section 7
6.10.2	Risk Assessment	Volume 1 – Section 8
7	Proposed Subsidence Management Plan	Volume 2
9	Plans	Volume 3
10	SMP Approved Plan	Volume 3

Additional approvals which may also be required include:

- Asset Protection Plan to the satisfaction of the SCA pursuant to Dendrobium Consent, Condition 3.11.
- NSW Dams Safety Committee endorsement and approval by DRE for mining within the Cordeaux Dam Notification Area pursuant to Condition 13 of the Dendrobium mining lease (CCL768).
- Section 88 Approval under the *Coal Mines Health and Safety Regulation 2006* (only obtainable after the SMP has been approved).

1.5 COMPLIANCE WITH CONSENT CONDITIONS

Condition 7 Schedule 3 of the Area 3 Modification requires the preparation of SMPs to manage the potential environmental consequences of the proposed second workings.

Further additional requirements also apply to SMPs prepared for Areas 3B and 3C. **Table 1.2** details these requirements and where they have been met in this SMP.

Table 1.2 - Document Compliance with Area 3 Modification Conditions

Development Consent Condition	Relevant SMP Section
Schedule 3 – Condition 1 The Applicant shall ensure that, as a result of the development: (a) no rock fall occurs at Sandy Creek Waterfall or from its overhang (b) the structural integrity of the waterfall, its overhang and its pool are not impacted; (c) cracking in Sandy Creek within 30m of the waterfall is of negligible environmental and hydrological consequence; and (d) negligible diversion of water occurs from the lip of the waterfall to the satisfaction of the Director-General	Sandy Creek is not within Area 3B

Development Consent Condition	Relevant SMP Section
Schedule 3 – Condition 2 The Applicant shall ensure that underground operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than "minor impacts' (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Director-General.	Section 7.7, however Sandy Creek is not within Area 3B
Schedule 3 – Condition 2 The Applicant shall ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Director-General.	Section 7.7 and 7.8
Schedule 3 – Condition 4 (a) to (i) Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Director-General.	Watercourse Impact, Monitoring, Management and Contingency Plan
Schedule 3 – Condition 5 The Applicant shall ensure that subsidence does not cause erosion of the surface or changes in ecosystem functionality of Swamp 15a and that the structural integrity of its controlling rockbar is maintained or restored, to the satisfaction of the Director-General.	Swamp 15a is not within Area 3B
Schedule 3 – Condition 6 (a) to (i) Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant shall prepare a Swamp Impact Monitoring, Management and Contingency Plan to the satisfaction of the Director-General.	Swamp Impact, Monitoring, Management and Contingency Plan
Schedule 3 – Condition 7 Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, 3B or 3C, the Applicant shall prepare a Subsidence Management Plan (SMP) to the satisfaction of the Director-General and the Director-General of DPI (now DRE). Each such SMP must: (a) integrate ongoing management of Areas 1 and 2; (b) integrate the Watercourse and Swamp Impact Monitoring, Management and Contingency Plans required under Conditions 4 and 6; (c) include monitoring of subsidence effects; (d) include a SCA Assets Protection Plan; (e) include monitoring, management, and contingency plans for all other significant natural features and all significant man made features which may be impacted by subsidence, including: • landscape (including cliffs and steep slopes); • groundwater (see condition 13);	Volume 2 Volume 2 Volume 2 Plan currently being prepared Volume 2

Development Consent Condition	Relevant SMP Section
• terrestrial flora and fauna and ecology (including all threatened species assessed as being likely to be significantly affected by the development and their habitats); • Aboriginal and other cultural heritage (see condition 12); and • electrical, communications and other infrastructure;	Volume 2
(f) be prepared in consultation with DECC, SCA and DPI (now DRE);	Volume 2
(g) be approved prior to the carrying out of any underground mining operations that could cause subsidence in the relevant Area; and	
(h) be implemented to the satisfaction of the Director-General and the Director-General of DPI (now DRE).	Section 9
Schedule 3 - Condition 8 The SMPs prepared under Condition 7 for Areas 3B and 3C must:	
(a) include a mine plan for the relevant Area;	Section 2
(b) include a detailed subsidence impact assessment, clearly setting out all predicted subsidence effects, subsidence impacts and environmental consequences;	Section 7 and Attachment A
(c) include a minimum of 2 years of baseline data, collected at appropriate frequency and scale, for all significant natural features;	Section 5
(d) identify and assess the significance of all natural features located within 600 m of the edge of secondary extraction;	Section 7
(e) distinguish between, clearly describe and adequately quantify all subsidence effects, subsidence impacts and environmental consequences;	Section 11
(f) propose limits on subsidence impacts and environmental consequences to be applied within the relevant Area;	Section 6 and 7; Volume 2
(g) be otherwise prepared in accordance with any guidelines for SMPs developed by the Department and/or DPI (now DRE);	Section 1.4
(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence in the relevant Area; and	Section 1.5
(i) be implemented to the satisfaction of the Director-General and the Director-General of DPI (now DRE).	
Schedule 3 – Condition 12 The SMPs prepared under condition 7 must include an Aboriginal Heritage Plan, which must include a: (a) description of known Aboriginal heritage sites; (b) protocol for the ongoing consultation and involvement of the Aboriginal community in the conservation and management of	Volume 2; Section 21

Development Consent Condition	Relevant SMP Section
Aboriginal heritage; (c) description of the measures that would be implemented to protect Aboriginal sites generally, including measures that would be implemented to secure, analyse and record sites at risk of subsidence; (d) description of the measures that would be implemented to protect Aboriginal site 52-2-1646, including; • a full recording and assessment of the site's rock art; • a more detailed subsidence assessment for the site; • measures which seek to avoid any significant impact on the site and any necessary contingency plans to protect the site against collapse or substantial impact on its rock art; and • descriptions of the measures that would be implemented if any new Aboriginal objects or skeletal remains are discovered during development	Site not within Area 3B
Schedule 3 – Condition 13 The SMPs prepared under condition 7 must include a Groundwater Monitoring Program, which must include: (a) proposals to develop a detailed regional and local groundwater model, with special reference to flows and from nearby water storages; (b) detailed baseline data to benchmark the natural variation in groundwater levels, yield and quality; (c) groundwater impact assessment criteria; (d) a program to monitor the impact of the development on: • groundwater levels, yield and quality (particularly any potential loss of flow to, or flow from, SCA water storages); • groundwater springs and seeps; and (e) consideration of the requirements of the latest version (or subsequent replacement) of SCA's The Design of a Hydrological and Hydrogeological Monitoring Program to Access the Impacts *of Longwall Mining in SCA Catchment.*	Volume 2; Section 16
Schedule 8 – Condition 11 Within 3 months of the approval of any strategy/plan/program required under this consent (or any subsequent revision of these strategies/plans/programs), or the completion of the audits or AEMRs required under this consent, the Applicant shall: (a) provide a copy of the relevant document/s to the relevant agencies and CCC; and (b) put a copy of the relevant document/s on its website.	Section 9

A range of alternative longwall layouts were examined. The proposed longwall layout has been designed to meet specific impact minimisation criteria for environmental and built features such as streams, cliffs and major SCA infrastructure. In applying these criteria, BHPBIC has significantly reduced the extent of longwall mining within Dendrobium Area 3.

Due consideration has been given to all the relevant Area 3 Modification Conditions in the preparation of this SMP, including those relating to auditing, rehabilitation and environmental management. **Appendix 4** of the Area 3 Modification Conditions includes the commitments BHPBIC has made to reduce and manage potential impacts of mining within Area 3. These measures have been considered throughout the SMP and generally follow the avoidance, reduction, mitigation and rehabilitation measures outlined in **Appendix 4**. A summary of the identified impacts is included in **Section 11**. An overview of the measures proposed as part of the project to reduce and manage the impacts is outlined in **Table 1.3**.

Table 1.3 - Key Environmental Aspects - Impact Minimisation and Management

Aspect	Impact Minimisation and Management
Cliffs	• No cliffs in Area 3B are proposed to be directly mined under • Cliffs have been mapped and will be monitored • Public safety measures will be implemented prior to mining and additionally if cliffs are impacted • Revegetation and sediment control measures will be implemented as required
Steep slopes and other surface areas	• Steep slopes have been mapped and will be monitored • Public safety measures will be implemented prior to mining and additionally if steep slopes are impacted • Rehabilitation, revegetation and sediment control measures will be implemented as required
Swamps	• Swamps have been mapped and will be monitored • Grouting, rehabilitation, revegetation and sediment control measures will be implemented as required • See the Swamp Impact Monitoring Management Mitigation and Contingency Plan for more details
Fauna and Flora including Endangered Ecological Communities	• Not mining under key habitat areas e.g. Wongawilli Creek • Fauna and flora, including Endangered Ecological Communities have been mapped and will be monitored • Grouting, rehabilitation, revegetation and sediment control measures will be implemented as required
Permanently Flowing Creeks	• Not mining under Wongawilli Creek

Aspect	Impact Minimisation and Management
	• Permanently flowing creeks have been mapped and will be monitored • Grouting, rehabilitation and sediment control measures will be implemented as required • Water quality mitigation as required • See the Stream Impact Minimisation Monitoring Management and Contingency Plan for further details
Ephemeral Watercourses	• Ephemeral watercourses have been mapped and will be monitored • See the Stream Impact Minimisation Monitoring Management and Contingency Plan for further details
Groundwater Quality, Quantity and Levels	• Not mining under Wongawilli Creek • Groundwater monitoring is undertaken and a groundwater model has been developed
Aboriginal Places of Cultural Significance- Archaeological Sites	• Aboriginal places of cultural significance and archaeological sites have been identified and will be monitored • Detailed archival recording • Appropriate permits sought in case of impacts • Rehabilitation and mitigation of impacts • See the Aboriginal Cultural Heritage Impact Management Plan for further detail
Lakes	• No mining under Lake Avon • See the DSC Contingency Plan for further details

1.6 SPECIALIST ASSESSMENTS

A significant amount of background information exists for the development of Dendrobium Area 3B. This information can be found in the following documents and their supporting specialist assessments:

- Dendrobium Colliery EIS (Olsen Environmental Consulting, 2001)
- Dendrobium Area 3 EA (Cardno Forbes Rigby, 2007)
- Dendrobium Area 3A SMP (Cardno Forbes Rigby, 2007)

The following additional specialist assessments have been undertaken in support of the Area 3B SMP:

Attachment A: Subsidence Predictions and Impact Assessments on Natural Features and Surface Infrastructure (Mine Subsidence Engineering Consultants [MSEC])

Attachment B: Surfacewater and Shallow Groundwater Assessment (Ecoengineers)

Attachment C: Groundwater Assessment (Coffey)

Attachment D: Terrestrial Ecology (Niche Environment and Heritage)

Attachment E: Aquatic Ecology (Cardno Ecology Lab)

Attachment F: Cultural Heritage (Biosis Research)

2 APPLICATION AREA

The 'Application Area' is defined as the surface area that is likely to be affected by the proposed mining of Longwalls 9 to 18 in Dendrobium Area 3B. The 'Application Area' is also referred to as the 'SMP Area' and is shown in **Figure 2.1**. The extent of the SMP Area has been calculated by combining the areas bounded by the following limits:

- The 35 degree angle of draw from the proposed extents of Longwalls 9 to 18;
- The predicted vertical limit of subsidence, taken as the 20 mm subsidence contour resulting from extraction of the proposed Longwalls 9 to 18;
- The natural features within 600 m of the extent of secondary extraction (Condition 8(d) of the Consent);
- Features which are expected to experience either far-field horizontal movements, or valley related movements, and which could be sensitive to these movements

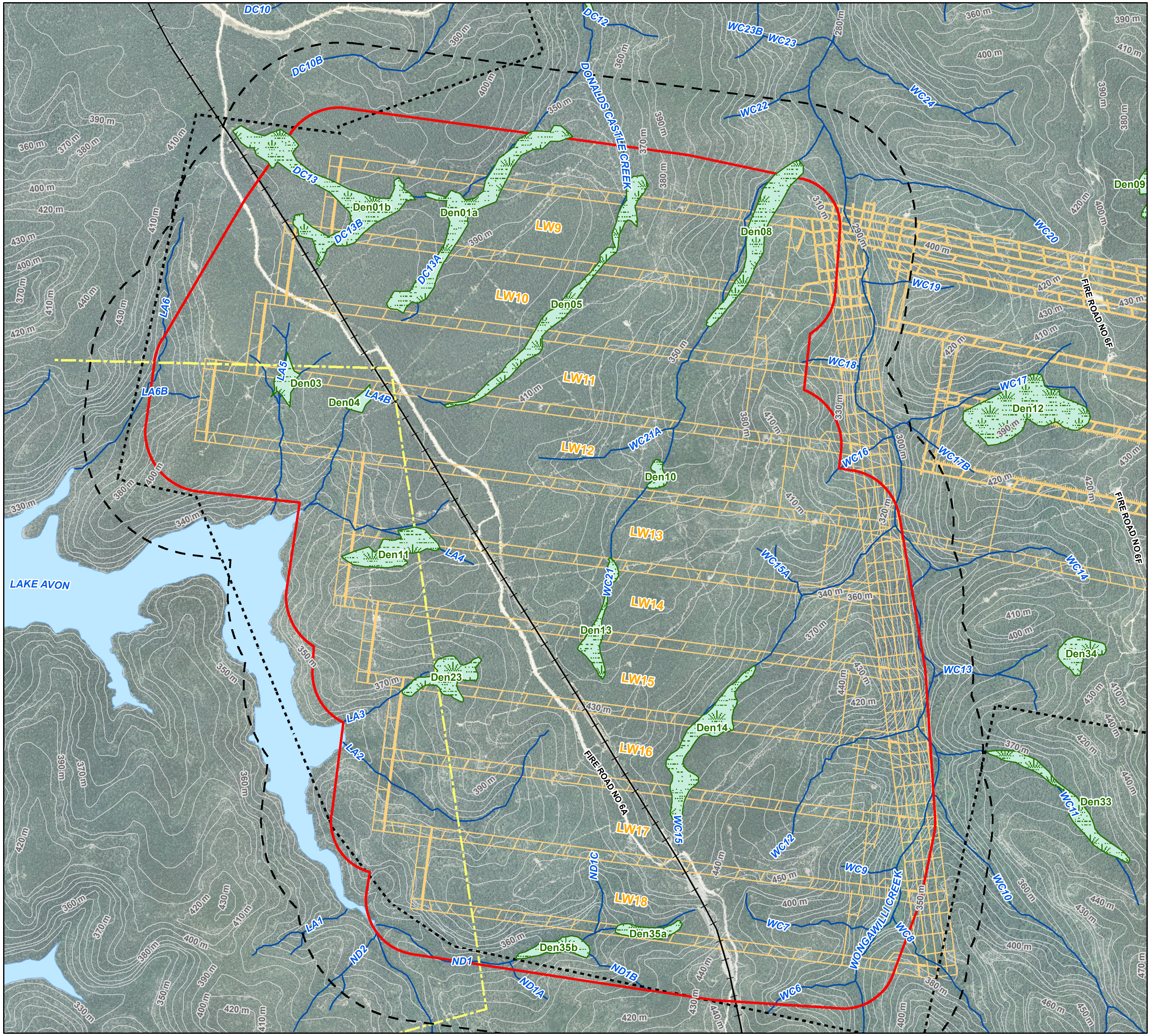
The 35 degree angle of draw is described as the "*surface area defined by the cover depths, angle of draw of 35 degree and the limit of the proposed extraction area in mining leases of the Southern Coalfield*", as stated in Section 6.2 of the SMP Guidelines (DPIM, 2003). The 35 degree angle of draw has been determined by drawing a line that is a horizontal distance varying between 215 m and 315 m around the limits of the proposed extraction areas (MSEC, 2012) based on the Wongawilli Seam depth of between 310 m and 450 m.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method (MSEC, 2012) (refer **Attachment A**).

Condition 8 (d) of the Consent refers to SMPs prepared for Dendrobium Area 3B (and 3C) having to identify and assess the significance of all natural features located within 600 m of the edge of secondary extraction and this area is also shown in **Figure 2.1**. There are areas outside the SMP Area (and within the area 600 m from the edge of secondary extraction) that are expected to experience either far-field movements or valley related movements. The natural and manmade features, which may be sensitive to such movements and those that lie within the area 600 m from the edge of secondary extraction, have been identified and assessed for their significance in the assessments provided in this report.

These features, as listed below, are described in later sections of this report:

- Streams and swamps within the predicted limits of 20 mm total upsidence and 20 mm closure;
- Cliffs and steep slopes;
- Lake Avon and Lake Cordeaux; and
- Survey Control Marks.



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Site Plan

DENDROBIUM AREA 3B SMP

Legend

- 600m Study Boundary - Condition 8(d)
- SMP Area
- Dendrobium Area 3
- DSC Notification Zone
- Maldon to Dombarton Rail
- Proposed Longwall Layout (BHPBIC, 2012)
- Stream Features
- Waterbodies (LPI)
- Area 3B Swamps (BHPBIC, 2011)

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FIGURE 2.1

1:17,500 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-10-03
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1039_SitePlan.mxd 02

Data supplied by MSEC (2012) unless otherwise stated
Aerial imagery supplied by BHPBIC (2009)

3 MINING SYSTEM AND RESOURCE RECOVERY

3.1 MINING METHOD

The Wongawilli Seam in Area 3B will be extracted using longwall mining methods. This is an established method of coal extraction used at Dendrobium mine and is also widely used in Australia and oversees. This type of mining is described in detail in the Area 3A SMP for Longwalls 6 to 10 and is summarised below.

The longwall is a complex system of mining equipment that incorporates roof support, coal cutting and coal transport equipment to provide a safe working environment.

During the preparation stages of a longwall operation, the roadways are developed to delineate proposed longwall blocks. These roadways define the boundaries of the longwall block and are required to provide employee access, ventilation, coal transport and other services.

The value of coal extracted when roadways are being driven does not meet the high mining costs of driving the roadways in the Southern Coalfield. The economic returns from investing in roadway development come from the subsequent longwall extraction, which require the previously developed roadways.

Longwall mining involves extracting a block of coal with longwall shearing machinery, which travels back and forth across the coalface, totally removing the blocks of coal between the developed roadways. This machinery cuts the coal from the coalface on each pass and a face conveyor, running along the full length of the coalface, carries this away to discharge onto a belt conveyor. The belt conveyor carries the coal out of the mine.

The section in front of the coal face is held up by a series of hydraulic roof supports. These temporarily hold up the roof strata and enable enough space for the shearer and face conveyor. After each slice of coal is removed, the face conveyor, hydraulic roof supports and the shearer are moved forward. When coal is extracted using this method, the roof immediately above the seam collapses (goafs) into the void that is left as the face retreats. This method of mining relies on the material 'goafing' as the longwall retreats. If this roof material does not collapse the longwall equipment is unable to hold the increasing weight above the coal seam.

At Dendrobium Mine, the coal is transported to the surface at the Kemira Valley Portal via conveyors and is hauled from site by rail to the Dendrobium Coal Preparation Plant at Port Kembla. The clean coal is then delivered to the Port Kembla steelworks or Port Kembla Coal Terminal. No additional surface facilities or activities are required as part of this Proposal.

3.2 PROPOSED MINING GEOMETRY

Mine layouts for Dendrobium 3B have been developed using BHPBIC's Integrated Mine Planning Process (IMPP). This process considers mining and surface impact issues when designing mine layouts. Mine layouts may be modified to take into account additional surface and underground information as it is obtained during the planning and approval process.

The development and implementation of an IMPP was identified as a key strategy to address stakeholder issues such as mining under rivers. In order to build an approach with the ownership of all stakeholders, the development of the IMPP has involved both internal and external consultation. This process was developed in consultation with DPI (now DRE) and is consistent with the requirements of the Subsidence Management Plan approvals process (DPIM, 2003).

BHPBIC have assessed each of the mining layout options for Dendrobium 3B against the following criteria:

- Extent, duration and nature of the impact to surface features;
- Community, social and environmental impacts;
- Coal customer requirements;
- Roadway development and longwall continuity;
- Mine services such as ventilation;
- Recovery of the resource for the business and the State; and
- Gas drainage, geological and geotechnical issues.

Previous experience gained in mining in the adjacent areas and the results of that mining, coupled with the results of the monitoring and mitigation measures where applicable, have been used in developing this application.

The development of the proposed mining geometry is further described in MSEC (2012) **Appendix A**, and the Dendrobium Area 3A SMP.

The proposed layout of Longwalls 9 to 18 within the Wongawilli Seam is shown in **Figure 2.1**and the **Approved Plan** in **Volume 3**. A summary of the proposed dimensions of these longwalls is provided in **Table 3.1**.

Table 3.1 - Proposed dimension of Longwalls 9 to 18 (MSEC, 2012)

Longwall	Overall Void Length (including installation heading) (m)	Overall Void Width (including first workings) (m)	Overall tailgate Chain Pillar Width (m)
9	2200	305	-
10	2280	305	45
11	2370	305	45
12	2790	305	45
13	2275	305	45
14	2365	305	45
15	2300	305	45
16	2225	305	45
17	2315	305	45
18	2055	305	45

3.3 SEAM TO BE MINED

The longwalls in Area 3B are proposed to be extracted from the Wongawilli Seam, of the Illawarra Coal Measures. The Wongawilli Seam underlies the Bulli Seam by approximately 20 m.

The Wongawilli Seam in Area 3B is nominally 10 m thick and contains numerous bands of non-coal material. The Seam floor within the SMP Area generally dips from the south to the north having an average dip of around 2 % or 1 in 50 (MSEC, 2012).

The economic section of the Wongawilli Seam is the basal 3 m to 5 m. BHPBIC has reviewed the nature of the banding in Area 3B and has proposed to extract a height up to 4.6 m for Longwalls 9 to 18.

For figures of Seam floor contours and Seam thickness contours refer **Attachment A**.

3.4 SCHEDULE OF PROPOSED MINING

First workings for Longwall 9 to 18 commenced in December 2011. Longwall extraction is planned to commence in January 2013 and be completed by 2022. Development and longwall mining schedules are subject to continual revision based on changing mining conditions and timing could vary considerably. Ongoing discussions with key stakeholders, including DRE, will ensure that any changes to the mining schedule are communicated to key stakeholders.

A summary of the mining schedule for the proposed Area 3B as described in this application is presented in **Table 3.2**.

Table 3.2 - Mining Schedule

Longwall	Scheduled Start	Scheduled Finish
9	Jan 2013	Jan 2014
10	Feb 2014	Dec 2014
11	Jan 2015	Dec 2015
12	Jan 2016	End Jan 2017
13	Start Mar 2017	Jan 2018
14	Feb 2018	End Dec 2018
15	End Jan 2019	Dec 2019
16	Jan 2020	Nov 2020
17	Dec 2020	Mid Oct 2021
18	Nov 2021	Aug 2022

Longwall 8 is currently being extracted, followed by the proposed Longwalls 9 to 18 of Area 3B. Once all Longwalls in Area 3B have been extracted, mining will recommence in Area 3A with the extraction of Longwall 19 (previously known as Longwall 9).

3.5 CONTINGENT LONGWALL MINING OPTIONS

BHPBIC supplies the Port Kembla and Whyalla Steelworks and overseas export customers with a blend of Wongawilli Seam and Bulli Seam coal. When combined, this coal has unique characteristics and BHPBIC's major customers have developed their facilities based on these characteristics. Consequently, BHPBIC must continue to provide this blended coal to its customers. It is important to note that the Appin and West Cliff Collieries extract coal from the Bulli Seam, and that the Appin and West Cliff Bulli Seam coal alone cannot meet the specifications required by BHPBIC customers. Without an ongoing supply of Wongawilli Seam coal for the blend, BHPBIC will not be able to meet current market specifications for the Australian steel industry or export markets.

Area 3B provides sufficient coal to be considered as a viable area for coal extraction after Area 3A. Several layout alternatives for Area 3B were assessed by BHPBIC using a multi-disciplinary team including environment, community, mining and exploration expertise. These included variations in the number of longwalls and orientations, lengths, and offsets of the longwalls from key surface features. These options were reviewed, analysed and modified until an optimised longwall layout in Area 3B was achieved.

Area 3B is part of the overall mining schedule for Dendrobium Colliery and has been designed to flow on from Areas 1, 2 and 3A to provide a continuous mining operation. There are a number of surface and subsurface constraints within the vicinity of the proposed Area 3B including major surface water features such as Lake Avon, and Wongawilli Creek; and a number of geological constraints such as dykes, faults, and particularly the Dendrobium Nepheline Syenite Intrusion. The process of developing the layout for Area 3B has considered the impacts on major natural surface features and aimed to minimise these impacts within geological constraints.

No contingent mining areas containing Wongawilli Seam Coal resources with the possibility for extraction in place of Area 3B have been identified.

The reasons for selecting the particular mining method and layout in the Approved Mine Plan are that it maximises the recovery of the resource and results in acceptable surface impacts when the mitigation measures are implemented as part of the Activity.

3.6 BENEFITS OF THE PROPOSED DEVELOPMENT

The extraction of underground coal reserves from Area 3B is necessary to ensure continuity of coal supply to customers and achieve business objectives for BHPBIC. At the same time, it provides financial benefits at international, national, state and local levels.

The majority of the high quality coal produced is blended with coal with different characteristics to supply a specific coal product to the steelworks. The remainder is exported to overseas customers. The proposed extraction of coal from Area 3B represents a continuing significant operating investment in the Southern Coalfield of NSW. Continuing benefits occur through continuity of employment, expendable income, export earnings and government revenue.

Dendrobium Area 3B will ensure 406 full time equivalent jobs, these jobs are reliant on maintaining continuity of longwall coal extraction.

There are no alternative supplies of Wongawilli Seam coal in the local region that are currently economic to mine, other than those being mined and exported to India by Gujarat NRE. BHPBIC does not consider this coal available for local use. Imported coal suitable as a replacement for Wongawilli Seam coal is more costly and does not constitute an exact replacement. Should imported coal be used, it will pose potential technical difficulties to key customers.

The proposed extraction of coal from Area 3B is vital to the business as minimal reserves of such coal exist. It also represents continuing significant capital and operating investments in the Southern Coalfield. Continuing benefits occur through continuity of employment, expendable income, export earnings and government revenue.

The BlueScope Port Kembla Steel Works and Whyalla Steel Works are major customers, in addition to these Australian based customers, the coal is exported via the Port Kembla Coal Terminal. Thus in addition to direct jobs at BHPBIC, the jobs of workers at the Port Kembla Steel Works and Coal Terminal are secured by the local supply of coking coal from BHPBIC's mines.

BHPBIC is a major contributor to the local region and New South Wales. As a result of mining in Dendrobium Area 3B the company would contribute approximately $788 M in government revenue comprising of royalties ($521 M), levies ($232 M) and payroll tax ($34 M).

3.7 IMPACT ON RESOURCE RECOVERY

The consequences of not mining Area 3B include loss of coal production from the Dendrobium Colliery and potential closure of all BHPBIC operations. Losses from the only supply of Wongawilli Seam coal from BHPBIC operations would severely disrupt processing and logistics and prevent the production of the unique BHPBIC blend, which is the basis of BHPBIC customer requirements.

Area 3B is constrained by Wongawilli Creek and Area 3A to the east and Lake Avon to the west. Similar constraints from Lake Cordeaux have resulted in reduced resource recovery in the adjacent Area 3A and Area 2. However, the proposed mining is considered to be efficient in terms of resource recovery.

From experience in extracting coal within the Wongawilli Seam in the Dendrobium Areas 1 and 2, and the current mining of Area 3A, BHPBIC has demonstrated safety of personnel, equipment operability, economic viability, acceptable environmental impact and maximising resource recovery.

3.8 ESTIMATED RECOVERY

The estimated total amount of longwall ROM coal designated for extraction from the Dendrobium Area 3B is 47 Mt, including 3.1 Mt of associated development roadways.

3.9 POSSIBLE EFFECTS ON OTHER SEAMS

The two most prominent seams above the Wongawilli Seam are the Balgownie Seam and the Bulli Seam. The Balgownie Seam is uneconomic due to a thickness of generally less than 1.0 m. Within Area 3A, the Bulli Seam is not economic due to average thickness of 1.2 m, an ash content of 12-14%, poor coking coal properties and a vitrinite content of 32% mmf. Both the Balgownie and Bulli Seams are likely to be sterilised (using current technology) by subsidence from the underlying Wongawilli Seam longwall extraction. Seams below the Wongawilli Seam are uneconomic due to poor quality and inadequate thickness.

3.10 FURTHER PLANS FOR MINING OTHER SEAMS

Using available technology the Wongawilli Seam is currently the only economic Seam in the area and there are no future plans for mining other seams.

4 SITE CONDITIONS

4.1 GEOMORPHOLOGY

The SMP Area is situated south of Sydney and is within the southern part of the Sydney Basin. The surface geology of the SMP Area is dominated by Hawkesbury Sandstone. There are also some small isolated areas which have been identified as comprising of Wianamatta Shale (refer **Figure 4.1**).

The landform is hilly and includes several distinct catchments. Land within the eastern and northern parts of the SMP Area drains into Wongawilli Creek. The western and southern parts of the SMP Area drain into Lake Avon.

The largest watercourse in the SMP Area is Wongawilli Creek.

4.2 SOIL LANDSCAPES

Almost the entire surface of Area 3B is founded on highly weathered Hawkesbury Sandstone outcrop and soils derived from this parent material.

The ridge and the uplands in the west of the SMP Area between the Wongawilli Creek catchment and the Native Dog Creek Arm of Lake Avon are partly mantled by Mittagong Formation derived soils (overlaid on Hawkesbury Sandstone).

The five major soil landscape types which appear in Area 3 (**Figure 4.1**) as characterised by (DNR, 2006) are:

- Penrose Variant A (code ERpea) type developed on the moderately steeper 10 – 20% slopes of Hawkesbury Sandstone.
- Hawkesbury (code COha) type developed on very steep slopes of Hawkesbury Sandstone of greater than 25% within creek main valleys and lower sections of tributaries.
- Lucas Heights (code REh) developed on gentle undulating crests, ridges and plateaus of slope <10% on Wianamatta Shale or Mittagong Formation (the latter being a thin mixed sandstone/shale sequence lying between the Wianamatta Shales and Hawkesbury Sandstone) derived soils.
- Gymea (code ERgy) developed on Hawkesbury Sandstone undulating to rolling low hills with local relief 20 – 80 m and moderately steep slopes of 10 – 25%.
- Stockyard Swamp (code SWss) developed on flat low relief areas of Hawkesbury Sandstone of slopes generally <2%.

Soil landscapes are particularly significant in relation to upland swamps. This relationship is discussed in **Section 5.2.11**.

4.3 COVER DEPTHS

The depth of cover to the Wongawilli Seam varies from a minimum of 310 m, above the eastern end of the proposed Longwalls 9, and a maximum of 450 m, above the eastern ends of the proposed Longwalls 17 and 18. For figures relating to depth of cover refer **Attachment A**.

4.4 OVERBURDEN STRATIGRAPHY

The geology of the Dendrobium Area was outlined in Volume 2 of the Dendrobium Area 3 EIS. A summary is provided below.

Dendrobium Mine lies in the southern part of the Permo-Triassic Sydney Basin, within which the main coal bearing sequence is the Illawarra Coal Measures, of late Permian age. The geology mainly comprises sedimentary sandstones, shales and claystones, which have been intruded by igneous sills. The Illawarra Coal Measures contain a number of workable seams throughout the area. The Wongawilli Seam is the third workable seam (refer **Figure 4.2**).

The seams are interbedded and overlain by a succession of sandstone and shale units, the major units being the Scarborough, the Bulgo and the Hawkesbury. The sandstone units vary in thickness from a few metres to as much as 120 m. The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates.

The major sedimentary units at Dendrobium are, from the top down:

- The Hawkesbury Sandstone.
- The Narrabeen Group.
- The Eckersley Formation.

The Narrabeen Group contains the Newport Formation (sometimes referred to as the Gosford Formation) the Bald Hill Claystone, the Bulgo Sandstone, the Stanwell Park Claystone, the Scarborough Sandstone the Wombarra Shale and the Coalcliff Sandstone.

The Eckersley Formation contains sandstones, shales and minor coal seams and forms the upper section of the Illawarra Coal Measures. The Bulli Seam lies directly above the Eckersley Formation and the Wongawilli Seam lies directly below it.

The major claystone units are the Bald Hill and Stanwell Park Claystones, which lie above and below the Bulgo Sandstone at the base of the Hawkesbury Sandstone. Due to the nature of the claystones, which swell when wetted, they tend to act as aquitards. The Wombarra Shale lies within the collapsed zone above the proposed longwalls and will be less effective in reducing vertical permeability. A typical section of the stratigraphy at the Dendrobium Mine area is shown in **Figure 4.2**.

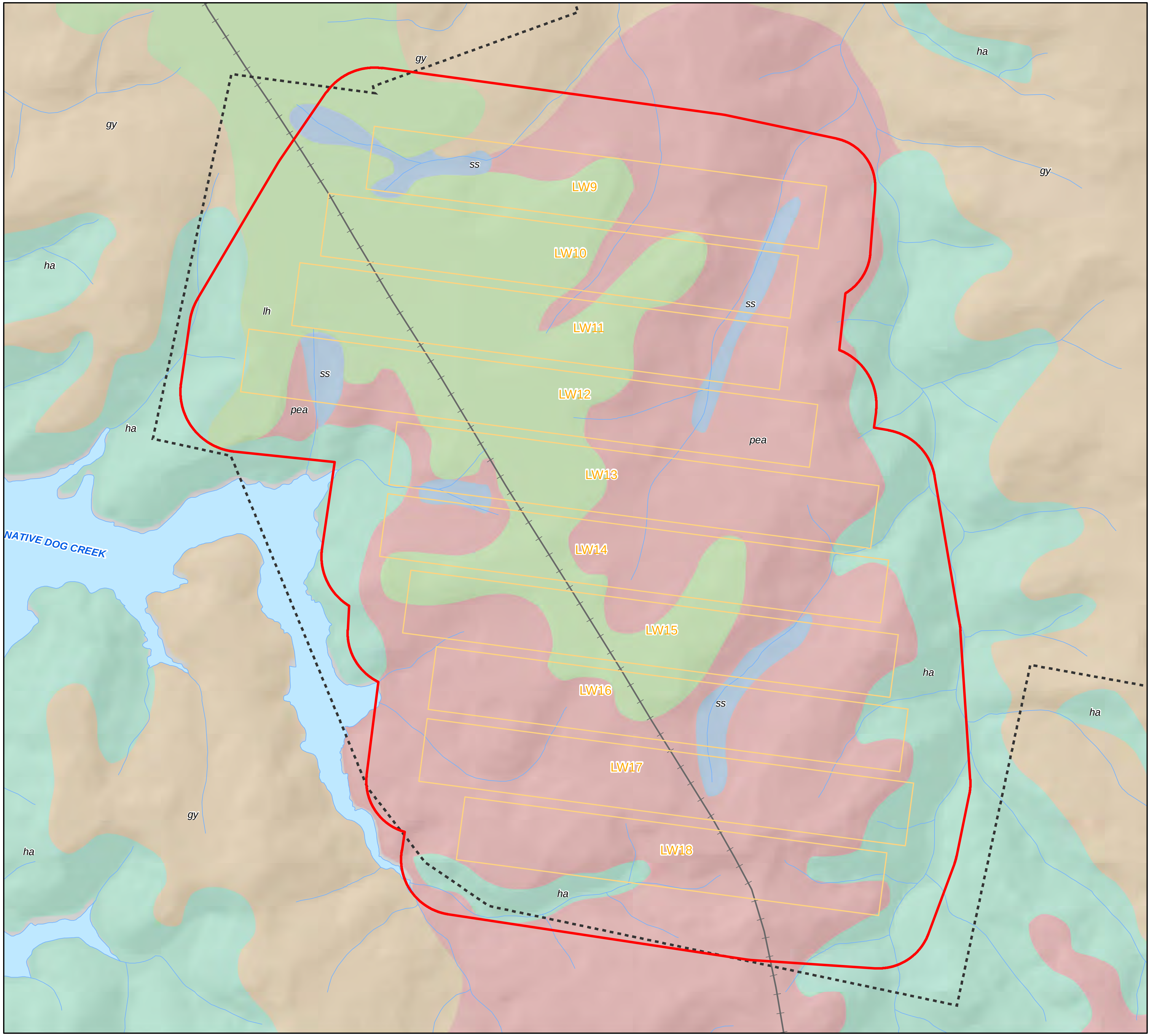
There are several igneous structures within Area 3B, the most noteworthy igneous sill being the Nepheline Syenite intrusion in the south eastern part of the mining area. Another sill and cindered zone have been identified north-west of the proposed longwalls.

Several geological structures have been identified at ground level in the vicinity of the proposed longwalls in Area 3B. A series of faults have been identified south of Longwall 18, between the proposed longwalls and the existing Elouera workings, having throws of between 25 m and 40 m. Dykes have also been identified north, south-west and south-east of the proposed longwalls. Further detail regarding the overburden stratigraphy and geology of the Study Area is provided in Waddington Kay (2001).

4.5 LOCATION OF EXISTING AND FUTURE WORKINGS

Dendrobium Area 1 (comprising Longwalls 1 and 2) and Dendrobium Area 2 (comprising Longwalls 3, 4, and 5) lie to the east of the proposed Area 3B and have been successfully mined. Area 3A lies to the east and is currently being mined. Mining of Longwall 6 and Longwall 7 has been completed.

The locations of existing workings and designated areas for future workings are shown in **Figure 4.3**.



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Soil Landscapes

DENDROBIUM AREA 3B

Legend

- SMP Area (1,199 ha)
- Maximum Footprint Area 3
- Maldon to Dombarton Rail
- Outlines of Longwalls 9 to 18
- Watercourses (LPI)
- Waterbodies (LPI)

Soil Landscapes/Erosion Hazard *

- Other
- Gymea (gy) - High-Extreme
- Hawkesbury (ha) - Extreme
- Lucas Heights (lh) - Moderate
- Penrose Variant A (pea) - Moderate-High
- Stockyard Swamp (ss) - Moderate-High

** concentrated flow erodibility*

N E S W

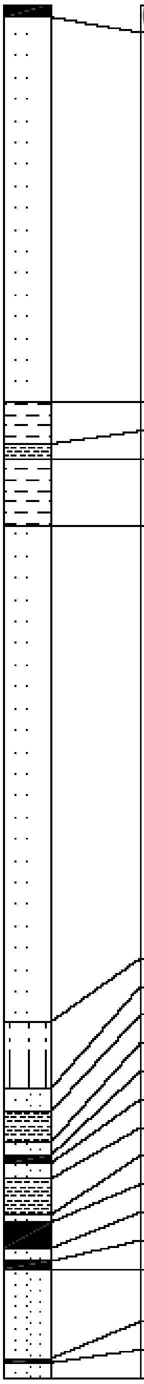
FIGURE 4.1

1:17,500 Scale at A3

Metres
0 250 500 750 1,000

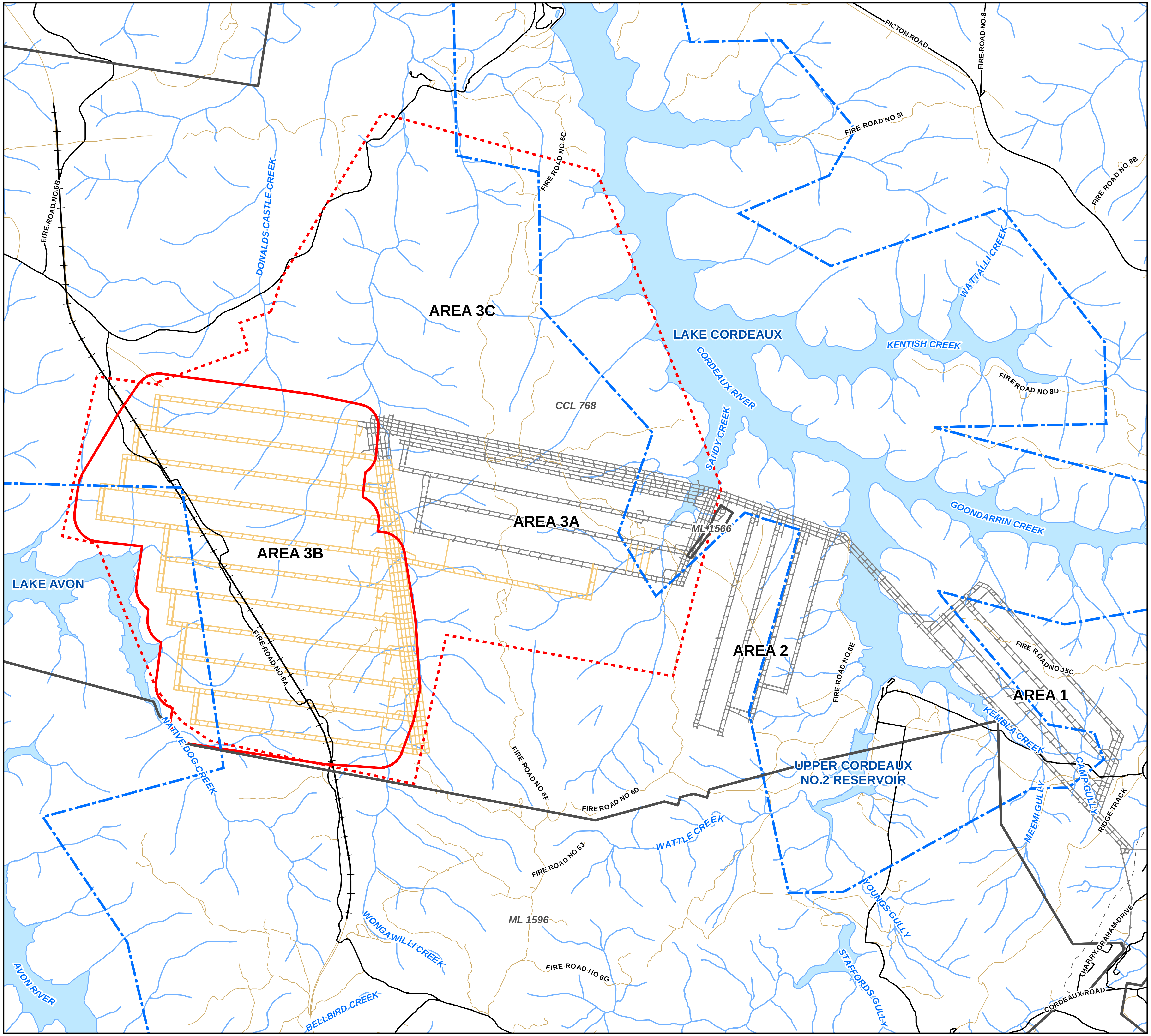
Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-21
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1004_SoilLandscapesArea3B.mxd 03



	FORMATION	GROUP
0-20		WIANAMATTA
155	Hawkesbury Sandstone	HAWKESBURY SANDSTONE
16	Newport Formation	NARRABEEN
6	Garie Formation	
26	Bald Hill Claystone	
193	Bulgo Sandstone	
26	Stanwell Park Claystone	
9	Scarborough Sandstone	
12	Wombarra Claystone	
5	Coal Cliff Sandstone	
3	Bulli Seam	ILLAWARRA COAL MEASURES
6	Balgownie Seam	
14	Cape Horn Seam	
3	Hargraves Seam	
10	Wongawilli Seam	
5	Kembla Sandstone	
3	American Creek Seam	
35	Appin Formation	
1.5	Tongarra Seam	
6	Wilton Formation	

Figure 4.2 - Typical Stratigraphic Section - Southern Coalfield



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Existing and Future Workings

DENDROBIUM

Legend

- SMP Area (MSEC 2012)
- Dendrobium Area 3
- Maldon to Dombarton Rail
- Local/Main Roads (LPI)
- Vehicular Track (LPI)
- Path (LPI)
- Major Watercourses (LPI)
- Proposed 3B Longwall Layout (BHPBIC, Feb 2012)
- Existing Longwall Layout (BHPBIC, Feb 2012)
- Waterbodies (LPI)
- DSC Notification Areas
- Mining Lease Boundary

N
W E
S

FIGURE 4.3

1:40,000 Scale at A3

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

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-18
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1037_DendrobiumContext.mxd 02

4.6 LITHOLOGICAL AND GEOTECHNICAL CHARACTERISTICS OF THE ROOF AND FLOOR

The Seam floor within the mining area generally dips from the south to the north, having an average dip of around 2% (1 in 50).

The stratum around the Wongawilli Seam provides good longwall conditions and in particular the sandstone floor is hard and competent. The immediate roof is a combination of bedded mudstone, inter-bedded siltstone and sandstone. It caves readily and is strong enough to stand in front of the supports, unless affected by geological features or poor face management.

Dendrobium Mine employs a Strata Management Plan as its statutory management system. The plan has been approved by DRE and will be applied to mining in Area 3B. The Plan manages the following issues:

- Primary support in all roadways (principally using roof bolts and mesh);
- Secondary support (principally with cable-bolts) in more critical areas such as at intersections, and in some belt roads;
- Stratigraphy and rock properties are confirmed through periodic coring of the immediate 8 m of roof strata;
- Roof dilation is routinely monitored with extensometers; and
- Provides trigger actions for defined terms of the measured and observed strata behavior.

Dendrobium's longwalls also operate under a Face Management Plan, which aims to maintain strata integrity in and around the operating face. There is provision for the use of specialised bolting, the use of recovery equipment and access to experienced contractors for processes such as polyurethane injection, when required.

4.7 UNCONTROLLED COLLAPSE OF ROOF (FOR SHALLOW WORKINGS)

Given that the depth of cover over Area 3B typically is around 310 m to 450 m, the consideration for uncontrolled collapse due to shallow (<30 m) overburden effects is not applicable and is not considered further for this application.

4.8 STABILITY OF UNDERGROUND WORKINGS

BHPBIC Geotechnical Engineers have designed the underground workings to be stable. The design considers the stability of the roadways for secondary extraction via longwall mining methods. In addition, the Dendrobium Mine Strata Management Plan will be used to manage the ongoing stability of the workings. The underground workings are not required to provide long term support to the surface, or the overburden, of the relevant part of the SMP Area.

5 IDENTIFICATION AND CHARACTERISATION OF SURFACE AND SUBSURFACE FEATURES

The SMP Area lies within the Metropolitan Catchment Area, which is a special declared area controlled by the SCA. The area is largely comprised of undisturbed bushland with a number of fire roads.

Land use over the SMP Area includes:

- Drinking water catchment;
- Electrical transmission easements; and
- Fire roads.

Although the longwalls do not mine under Lake Avon, the SMP Area does intersect the Dams Safety Committee (DSC) Notification Area for the reservoir.

Area 3B is not within a specified Mine Subsidence District.

Studies of the surface and sub-surface features have been completed for the SMP by a team of experts in relevant fields. The information provided in this section is derived from two years of data and is also drawn from the MSEC subsidence report (**Attachment A**), other specialist reports and additional useful documentation where relevant.

Table 5.1 identifies which features are present in the SMP Area. Further details regarding the features which are present are provided in the following sections.

Table 5.1 - Natural Features and Surface Improvements (MSEC, 2012)

Item	Within SMP Area	Section Number Reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	✓	6.2.1
Rivers or Creeks	✓	6.2.2&6.2.3
Aquifers or Known Groundwater Resources	✓	6.2.4
Springs	×	
Sea or Lakes	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	✓	6.2.7
Steep Slopes	✓	6.2.8
Escarpments	×	
Land Prone to Flooding or Inundation	×	
Swamps, Wetlands or Water Related Ecosystems	✓	6.2.11
Threatened, Protected Species or Critical Habitats	✓	6.2.12
National Parks	×	
State Forests	×	
State Conservation Areas	×	
Natural Vegetation	✓	6.2.13
Areas of Significant Geological Interest	×	
Any Other Natural Feature Considered Significant	×	
PUBLIC UTILITIES		
Railways	✓	6.5.6
Roads (All Types)	✓	6.5.7
Bridges	×	
Tunnels	×	
Culverts	✓	6.5.8
Water, Gas or Sewerage infrastructure	×	
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	×	
Telecommunication Lines or Associated Plants	×	
Water Tanks, Water or Sewage Treatment Works	×	
Dams, Reservoirs or Associated Works	✓	6.5.9
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	×	
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	

Item	Within SMP Area	Section Number Reference
FARM LAND AND FACILITIES		
Agricultural Utilisation, Agricultural Improvements or Agricultural Suitability of Farm Land	×	
Farm Buildings or Sheds	×	
Tanks	×	
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	×	
Farm Dams	×	
Wells or Bores	×	
Any Other Farm Features	×	
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories	×	
Workshops	×	
Business or Commercial Establishments or Improvements	×	
Gas or Fuel Storages or Associated Plants	×	
Waste Storages and Associated Plants	×	
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids and Rehabilitated Areas	×	
Mine Infrastructure Including Tailings Dams or Emplacement Areas	✓	6.5.11
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	6.5.12
ITEMS OF ARCHITECTURAL SIGNIFICANCE		
PERMANENT SURVEY CONTROL MARKS	✓	6.5.10
RESIDENTIAL ESTABLISHMENTS		
Houses	×	
Flats or Units	×	
Caravan Parks	×	
Retirement or Aged Care Villages	×	
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts	×	
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

5.1 AREAS OF ENVIRONMENTAL SENSITIVITY

Table 5.2 provides a brief summary of features identified in areas of environmental sensitivity within the SMP Area (as defined in Section 6.6.3 of the SMP Guideline (DPIM, 2003)).

Table 5.2 - Summary of Areas of Environmental Sensitivity within the SMP Area

No.	Description	Within SMP Area	Details	Section No. Ref.
1	Land reserved as a State Conservation Area under the *National Parks and Wildlife Act 1974*	None		
2	Land declared as an Aboriginal Place under the *National Parks and Wildlife Act 1974*	None		
3	Land identified as *Wilderness* by the Director, National Parks and Wildlife under the *Wilderness Act 1987*	None		
4	Land subject to a 'conservation agreement' under the *National Parks and Wildlife Act 1974*	None		
5	Land acquired by the Minister for the Environment under Part 11 of the *National Parks and Wildlife Act 1974*	None		
6	Land within State forests mapped as Forestry Management Zone 1, 2 or 3	None		
7	Wetlands mapped under SEPP 14 – Coastal Wetlands	None		
8	Wetlands listed under the Ramsar Wetlands Convention	None		
9	Lands mapped under SEPP 26 – Coastal Rainforests	None		
10	Areas listed on the Register of the National Estate	None		
11	Areas listed under the *Heritage Act 1977* for which a plan of management has been prepared	None		
12	Land declared as critical habitat under the *Threatened Species Conservation Act 1995*	None		
13	Land within a restricted area prescribed by a controlling water authority	✓	Metropolitan Catchment Area and the DSC Notification Area	6.2.1
14	Land reserved or dedicated under the *Crown Lands Act 1989* for the preservation of flora, fauna, geological formations or other environmental protection purpose	None		
15	Significant surface watercourses and groundwater resources identified through consultation with relevant government agencies	✓	Wongawilli Creek, Donalds Castle Creek Avon reservoir	6.2.2 6.5.9
16	Lake foreshores and flood prone areas	✓	Avon Reservoir	6.5.9
17	Cliffs, escarpments and other significant natural features	✓	Cliffs	6.2.7
18	Areas containing significant ecological values	✓	Flora and Fauna	6.3
19	Major surface infrastructure	✓	Decommissioned Maldon-Dombarton Railway Fire Road 6A, 6N and 6Q	6.5.6 6.5.7
20	Surface features of community significance (including cultural, heritage or archaeological significance)	✓	Archaeological Sites	6.5.12
21	Any other land identified by the Department to the titleholder	None		

5.2 SIGNIFICANT NATURAL FEATURES

5.2.1 Catchment Areas or Declared Special Areas

The SMP Area lies entirely within the Metropolitan Catchment Area, which is a special declared area controlled by the SCA. The proposed longwalls are also partly located within DSC Notification Area for the Avon Reservoir, also known as Lake Avon.

The water storages in the Metropolitan Catchment Area provide the sole water supply for the Macarthur and Illawarra regions and the townships of Campbelltown, Camden, Bargo, Picton, Thirlmere, Tahmoor, The Oaks, Buxton and Oakdale, and provide approximately 20 % of the supply to the Sydney Metropolitan Area, via the Prospect Reservoir.

The Metropolitan Catchment Area has been defined as an area of environmental sensitivity for the purposes of the SMP approval process.

An SCA Assets Protection Plan has been developed for Dendrobium Area 3 in consultation with the SCA to ensure that measures are in place for the protection of SCA Assets in the Metropolitan Catchment Area.

5.2.2 Rivers

There are no rivers within the SMP Area. The closest river is the Cordeaux River, downstream of the Cordeaux Dam, which is approximately 4 km north of Longwall 9, at its closest point.

At this distance, the Cordeaux River is not predicted to experience any significant (i.e. measurable) systematic or non-systematic mine subsidence movements. It is therefore unlikely, that the river would experience any adverse impacts resulting from the extraction of the proposed longwalls.

The locations of creeks and tributaries within the SMP Area are shown in **Figure 5.1.**

5.2.3 Watercourses

Wongawilli Creek

The largest stream within the SMP Area is Wongawilli Creek which is located on the eastern side of the SMP Area. The proposed longwalls do not directly mine beneath the creek.

The total length of Wongawilli Creek within the SMP Area, is approximately 1.1 km. The average natural gradient of Wongawilli Creek, excluding Waterfall WC-WF54, is approximately 10 mm/m (i.e. 1 %, or 1 in 100) (MSEC, 2012).

Wongawilli Creek is a 3rd order perennial stream with a small base flow and increased flows for short periods of time after each significant rain event. The creek generally flows in a northerly direction and drains into the Cordeaux River approximately 4 km north of the proposed Longwall 9.

Pools in the creek are permanent (based on monitoring to date) and naturally develop behind rock-bars and at the sediment and debris accumulations. The locations of features within Wongawilli Creek are illustrated in **Figure 5.2** and a summary description provided in **Attachment A**.

Wongawilli Creek Waterfall

There is a waterfall along Wongawilli Creek in the southern part of the SMP Area (WC-WF54 **Appendix A**). The top section of the waterfall has been formed in Hawkesbury Sandstone and the base of the waterfall is founded in Bulgo Sandstone.

The waterfall has cut through the basal section of the Hawkesbury Sandstone and the Newport Formation, Garie Formation and the Bald Hill Claystone.

The calculated height of the waterfall, based on the surface level contours, is approximately 20 m. There is also a steep section of creek, just downstream of the waterfall, which drops a further of 10 m over a distance of approximately 100 m.

Donalds Castle Creek

The upper reaches of Donalds Castle Creek are located in the northern part of the SMP Area above Longwalls 9 to 12. The creek generally flows in a northerly direction and drains into the Cordeaux River approximately 6.5 km north of the proposed Longwall 9.

The section of Donalds Castle Creek located above the proposed longwalls is confined within Swamp Den05. The bed of the creek has mostly been covered by the soil accumulation and vegetation within this swamp. The sandstone creek bed is exposed in some locations and rockbars, pools and small cascades exist at the downstream end of the swamp.

The natural gradient of Donalds Castle Creek, within the extent of Swamp Den05, typically varies between 10 mm/m (i.e. 1 %, or 1 in 100) and 100 mm/m (i.e. 10 %, or 1 in 10), with an average natural gradient of approximately 30 mm/m (i.e. 3 %, or 1 in 35) (MSEC, 2012).

Other Creek Features

There are a number of smaller drainage lines which have also been identified within the SMP Area, which are shown in **Figure 5.1**.

There are a number of stream features such as pools, rockbars, riffles and sandbars, along Wongawilli and Donalds Castle Creeks. The locations of these features are shown in **Figure 5.2**.

5.2.4 Aquifers and known Groundwater Resources

Shallow aquifers have been identified within the SMP Area and these are associated with the drainage lines and upland swamps. The hydrogeology including the aquifers and groundwater resources within the SMP Area is discussed in **Section 5.4** and are investigated in **Attachment B** and **Attachment C**.

5.2.5 Sea or Lake

There are no natural lakes within the SMP Area. There is, however, a reservoir which is partially located within the SMP Area, which is discussed in **Section 5.7.4**.

5.2.6 Shorelines

There are no shorelines within the SMP Area, other than those associated with the reservoir which is discussed in **Section 5.7.4**.

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Swamps and Watercourses

DENDROBIUM AREA 3

Legend

- Area3 Waterfalls
- SMP Area (1,199 ha)
- Maximum Footprint Area 3
- Longwall Layout (MSEC)
- Watercourses (LPI)
- Minor Streams (BHPBIC)
- Waterbodies (LPI)
- Area 3B Swamps (BHPBIC)

N
W E
S

FIGURE 5.1

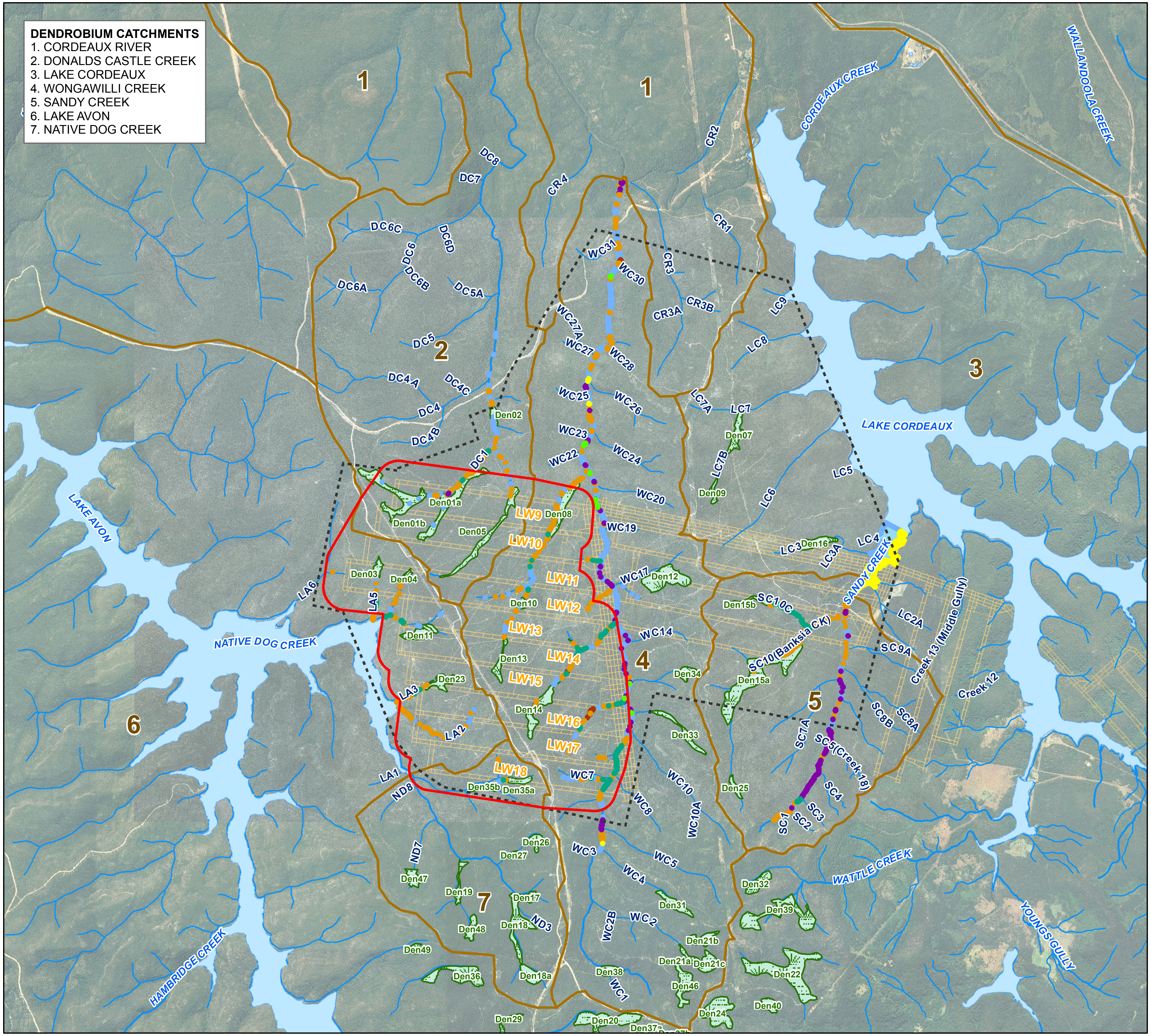
1:26,000 Scale at A3

Metres
0 500 1,000 1,500

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-21
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1005_SwampWatercoursePlan.mxd 04

Aerial imagery supplied by BHPBIC (2009)



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Hydrological Features

DENDROBIUM AREA 3

Legend

- SMP Area (1,199 ha)
- Maximum Footprint Area 3
- Longwall Layout (BHPBIC, 2012)
- Major Catchments (Cardno)
- Rivers & Creeks (LPI)
- Waterbodies (LPI)

Stream Features (Illawarra Coal)

- Swamp
- Cliff Line
- Island
- Boulder field
- Riffle
- Rock Bar
- Rock Shelf
- Sand Bar
- Lake or Pool

FIGURE 5.2

1:45,000 Scale at A3

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

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-26
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1006_HydrologicalFeaturesCopy.mxd 04

Aerial imagery supplied by BHPBIC (2009) and LPI

5.2.7 Cliffs

For the purposes of this report, a cliff has been defined in accordance with MSEC (2012) 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°). The locations of cliffs within the SMP Area were determined by MSEC (2012) from site investigations, from an ortho-photograph and from the 1 m surface level contours, generated from an aerial laser scan of the area.

Most of the cliffs within the SMP Area have been identified within the valley of Wongawilli Creek and Drainage Lines WC12 and WC15.

In addition to the cliffs, there are also numerous rock outcrops which are located across the SMP Area. A rock outcrop has been defined as an isolated rock face having a height of less than 10 m. There are rock outcrops primarily located within the valleys of Wongawilli Creek and the associated tributaries and are generally less than 5 m in height.

The locations of cliffs within the SMP Area are shown in **Figure 5.3** and details are provided in **Table 5.3.** The rocky outcrops are located across the SMP Area.

Table 5.3 - Details of the Cliffs within the SMP Area (MSEC, 2012)

Cliff ID	Overall Length (m)	Maximum Height (m)	Location
DA3-CF19	15	10	190 m east of Longwall 13
DA3-CF20	50	20	130 m east of Longwall 13
DA3-CF21	35	20	90 m east of Longwall 13
DA3-CF22	15	15	90 m east of Longwall 13
DA3-CF23	85	20	30 m east of Longwall 13
DA3-CF25	160	25	150 m east of Longwall 17
DA3-CF26	180	25	100 m east of Longwall 17
DA3-CF41	15	20	80 m east of Longwall 18
DA3-CF42	20	20	75 m east of Longwall 18
DA3-CF43	60	20	85 m east of Longwall 18
DA3-CF44	10	10	460 m west of Longwall 12
DA3-CF45	50	15	280 m south-west of Longwall 12
DA3-CF46	15	15	180 m east of Longwall 14
DA3-CF47	35	20	310 m east of Longwall 15

The longer cliff lines within the SMP Area are made up of a number of separate cliffs, rather than being a single continuous cliff line. The cliffs have formed predominantly from Hawkesbury Sandstone, with the faces being at various stages of weathering and erosion.

The cliffs have many overhangs and undercuts which are generally less than 6 m of overhang.

The cliffs have been defined as areas of environmental sensitivity for the purposes of the SMP approval process.

5.2.8 Steep Slopes

A number of steep slopes have been identified within the SMP Area. The reason for identifying the steep slopes is to highlight areas in which existing ground slopes may be marginally stable. For the purposes of this report, a steep slope has been defined in accordance with MSEC (2012) as an area of land having a natural gradient greater than 1 in 3 (i.e. a grade of 33 %, or an angle to the horizontal of 18°). The locations have been shown in **Figure 5.3.**

The steepest slopes within the SMP Area, not including the cliffs and rock outcrops, were identified within the valley of Wongawilli Creek, which have natural grades of up to 1 in 1, or angles to the horizontal of up to 45°. Steep slopes were also identified directly above the proposed longwalls in Area 3B, along Donalds Castle Creek and the other major drainage lines, which have natural grades of up to 1 in 1.5, or angles to the horizontal of up to 34°.

The surface within the SMP Area generally consists of soils derived from Hawkesbury Sandstone, which are in varying stages of weathering. The majority of the slopes are stabilised, to some extent, by the natural vegetation.

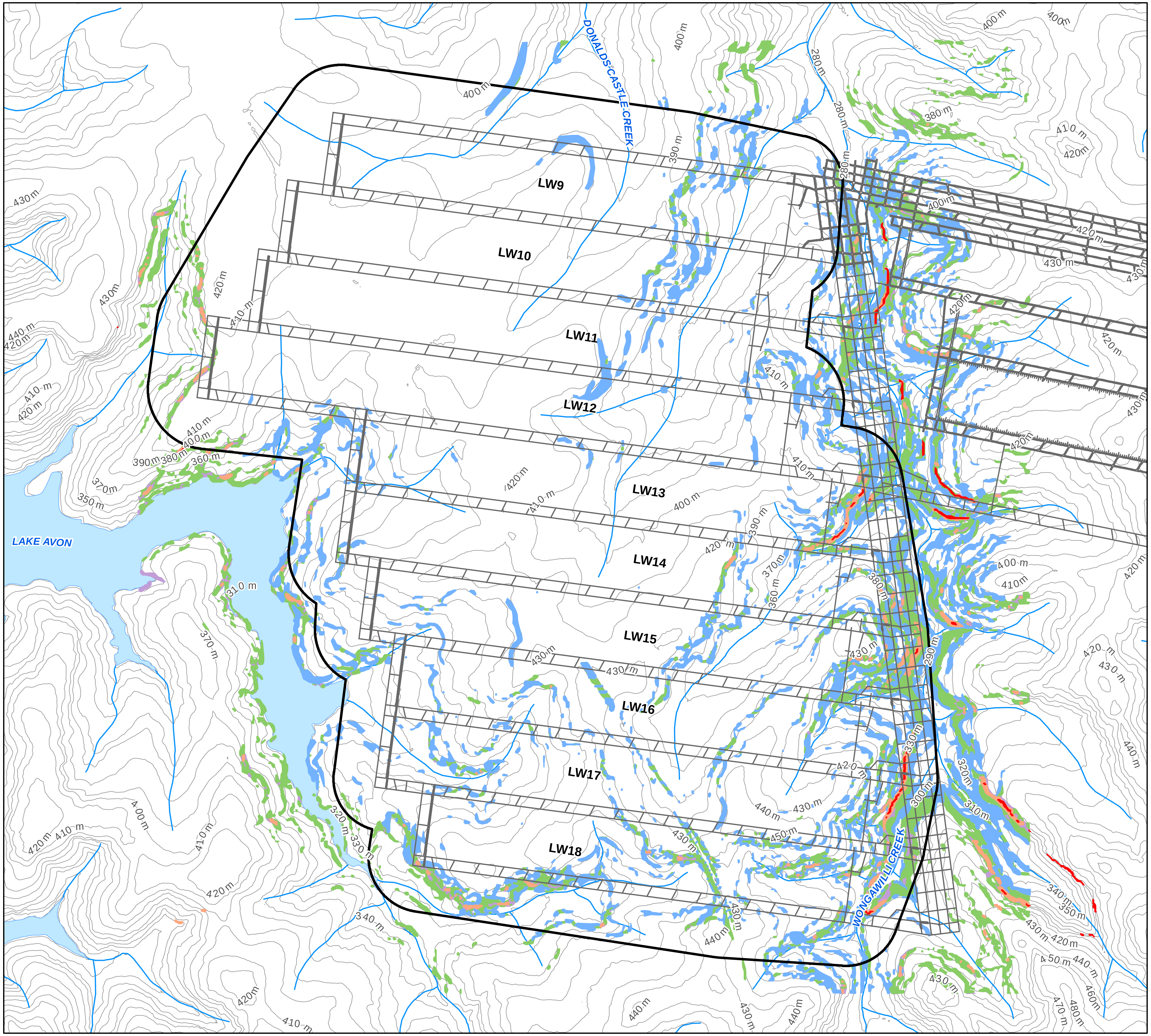
5.2.9 Escarpments

There are no escarpments within the SMP Area. The ridgeline in Dendrobium Area 2 is located approximately 4 km to the east and the Illawarra Escarpment is located more than 8 km east of the proposed longwalls. At this distance, the ridgeline and the Escarpment are not expected to experience any significant mine subsidence movements or impacts resulting from the extraction of the proposed longwalls.

5.2.10 Land Prone to Flooding and Inundation

The catchment areas of the streams within the SMP Area are relatively small and the land drains freely into Wongawilli Creek and Lake Avon. There are no major flood prone areas identified within the SMP Area.

The predicted changes in the surface levels of the watercourses, resulting from the extraction of the proposed longwalls, will have only a marginal effect on their natural gradients, and hence, on their discharge characteristics.



bhpbilliton ILLAWARRA COAL

Cliffs and Steep Slopes

DENDROBIUM AREA 3B SMP

Legend

- SMP Area
- Watercourses (LPI)
- Contours 10m (BHPBIC)
- Proposed Longwall Layout (BHPBIC, 2012)
- Waterbodies (LPI)
- Cliffs

Steep Slopes

- 1:3 to 1:2
- 1:2 to 1:1.5
- 1:1.5 to 1:1
- 1:1 to 2:1

N
W E
S

FIGURE 5.3

1:17,500 Scale at A3

Metres

0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-10-03
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1059_CliffsSteepSlopes.mxd 01

Data supplied by MSEC (2012) unless otherwise stated

5.2.11 Swamps, Wetlands and Water Related Ecosystems

Thirteen upland swamps have been identified within the SMP Area as shown in **Figure 5.1**. The locations and extents of these upland swamps have been interpreted from detailed aerial photogrammetry.

A description of the swamps in Area 3B is provided in the Landscape Impact Assessment which was undertaken by CFR (2007) for the entire Dendrobium Area 3. Additional detailed investigations of the swamps have been undertaken and are described in **Attachment B** (Ecoengineers, 2012) and **Attachment D** (Niche, 2012).

The upland swamps comprise two fundamental types, the *Valley Infill* swamps which form within the drainage lines, and *Headwater* Swamps which form within relatively low sloped areas of weathered Hawkesbury Sandstone where hill-slope aquifers exist (MSEC, 2012).

Headwater swamps within the SMP Area include Upland Swamps 1b, 3, 4, 11 and 13. Valley Infill swamps of the SMP Area include 1a, 5, 8, 10, 14, 23, 35a and 35b.

A number of smaller swamps, or swamp-like vegetation are scattered throughout the SMP Area. A number of smaller swamps or swamp-like vegetation are scattered throughout the Study Area. These small patches of swamp like vegetation occur in small areas of impeded drainage that contain a mix of plant species common to the upland swamps and fringing eucalypt woodlands of the region. These patches of vegetation have not been identified in the existing vegetation mapping of the Study Area. Field observations indicate that these patches of vegetation occur randomly in the landscape and are not typically restrained by sandstone rock bars. Further these vegetation patches do not occur in valley floors and therefore, are not likely to be subject to valley closure movements resulting from longwall extraction.

The final determination to list Coastal Upland Swamps in the Sydney Basin Bioregion as an endangered ecological community (EEC) in the *Threatened Species Conservation Act 1995* (TSC Act) notes that vegetation boundaries of upland swamps are not static but will shift according to localised hydrology. Further, the localised surface hydrology of an area may itself be subject to the effects of transpiration from trees recruited into the area thus lowering the local water table. Conversely, loss of trees from an area results in reduced transpiration which, in turn allows the localised ground water level to rise resulting in waterlogged soils. It appears that these smaller patches of swamp like vegetation occur as a result of this localised and natural flux of near-surface groundwater movement in the local area. For the purposes of this assessment, these small areas of swamp like vegetation have been included in the impact assessment for the Upland Swamp EEC.

Swamp Characteristics

The pre-mining swamp catchment areas of the swamps within Area 3B range from a minimum of 10 ha (Swamp 14) to a maximum of 240 ha (Swamp 8) (CFR, 2007).

The slope length for the swamps within Area 3B varies from 147 m (Swamp 10) to 1500 m (Swamp 5) (CFR, 2007). The average length is approximately 630 m.

The *average* swamp gradient varies from a minimum of 2.4% (Swamp 1b) to a maximum 6.3% (Swamp 4). The overall *average* swamp gradient for all swamps within Area 3B is 4.2%. The maximum swamp gradient varies significantly from 6.2% (Swamp 1b) up to 25% (Swamp 5). The average maximum swamp gradient is 12.6%.

Swamp Vegetation Cover

Upland Swamps in the SMP Area range in character from relatively dry swamps supporting thickets and sometimes patchy canopy trees, to permanently inundated swamps with no canopy and abundant sedges and herbs.

Inspections were initiated by BHPBIC at eight of the 13 swamps within the SMP Area during Spring 2010. Signs of prior vegetation stress were noted at all of the eight swamps. Types of vegetation stress observed included minor to moderate discolouring and/or browning of various vegetative species. A full description of swamp vegetative health is provided in BHPBIC (2010).

No swamps within Area 3B have been observed to show evidence of fire scarring, and thus exhibit very good vegetation cover and soil protection (CFR, 2007).

Swamp Soil Landscapes

The majority of swamps occur on soil landscapes with moderate to high erosion hazards, while watercourses within Area 3B occur on all soil landscapes and flow through several soil landscapes (CFR, 2007).

No swamps within Area 3B occur on the Gymea soil landscape which is associated with an extreme erosion hazard and is located within Dendrobium Area 3 (refer CFR, 2007).

Fire History and Climatic Events

A major bushfire occurred in the region between December 24^{th} 2001 and January 11^{th} 2002. Most swamps examined within Dendrobium mining areas were classified as being burnt to an extreme or high extent, with a few being burnt to a medium extent. Inspections of the swamps by BHPBIC in 2006 and 2007 show that only Swamp 15b shows evidence of minor fire scarring. Hence the swamps in Area 3B have been observed to have good vegetative cover.

Existing Points of Disturbance

Existing points of disturbance within swamps and watercourses in Area 3 were determined by reference to the BHPBIC 'Understanding Swamp Conditions' inspection reports 2010.

Monitoring by BHPBIC and EarthTech indicates the only swamps with any existing points of disturbance (nick points) where any scour may be expected to be initiated, are some small sections of slightly scoured (but stable) channels in Swamp 5 (Luke Pascot pers comm) and a section of channel within Swamp 8 that has recently been incised and scoured (EarthTech, 2005).

Both of these swamps are long linear valley floor swamps with relatively large catchment areas and have been formed from fluvial processes such as erosion and deposition. Therefore, it would be expected that these swamps may show existing signs of such processes (CFR, 2007).

Further information on the swamps within the SMP Area is provided in CFR (2007) and EarthTech (2005).

Vegetation Communities

Upland Swamps within the SMP Area consist of a number of vegetation units. These are listed in **Table 5.4** and further discussed in **Section 5.3.**

Table 5.4 - Upland Swamps and Corresponding Mapping Unit

Swamp	MU42 Banksia Thicket	MU43 Tea Tree Thicket	MU44a Sedge-land	MU44b Restoid Heath	MU44C	MU45 Eucalypt Fringing Woodland
1a		X		X	X	X
1b				X	X	X
3	X					X
4			X			
5	X	X	X	X	X	X
8	X		X			X
10	X		X			
11	X	X	X	X	X	X
13	X	X	X			
14		X	X			
23	X	X	X			X
35a		X				
35b	X					

5.2.12 Threatened, Protected Species or Critical Habitats

There are no lands within the SMP Area that have been declared as critical habitat under the TSC Act. There are, however, threatened and protected species within the SMP Area which are described in **Section 5.3**, **Attachment D** and **Attachment E**.

5.2.13 Natural Vegetation

The vegetation within the SMP Area generally consists of undisturbed native bush. A survey of the natural vegetation within the SMP Area has been undertaken and details are provided in **Attachment D** (Niche, 2012) and summarised in **Section 5.3**. Refer to **Section 5.3.2** for a description of the vegetation communities within the SMP Area.

5.3 ECOLOGY

Biosis Research was commissioned by BHPBIC to undertake a Species Impact Statement (SIS) for terrestrial flora and fauna within Area 3 (including Areas 3A, 3B and 3C) (Biosis, 2007a). The SIS assesses the ecological values of the Study Area (which includes the greater Dendrobium Area 3) and the potential impacts of mining in this area in terms of threatened species, populations or ecological communities potentially occurring within the Study Area.

Niche Environment and Heritage (Niche) undertook a further detailed assessment of impacts on aquatic ecosystems and biota from the proposed mining of Dendrobium Area 3B (refer **Attachment D**) based on the revised mine layout and MSEC (2012) subsidence predictions and the findings of the Biosis (2007a) report.

Areas sensitive to subsidence (swamps, creek lines and ridge lines) which had been subject to limited or no previous survey were targeted. The flora survey targeted vegetation validation of swamps and a targeted survey of threatened plant species such as *Pultenaea* *aristata*. Fauna survey effort focussed on areas susceptible to subsidence impacts and associated fauna species.

5.3.1 Vegetation Communities

The SIS identified 13 plant communities as occurring within the Area 3 Study Area (Biosis, 2007a). The current survey undertaken by Niche (2012) utilised the findings of the SIS and focussed on ground-truthing of Upland Swamps which had not been previously surveyed in detail. Ground-truthing revealed some Upland Swamps contained different Upland Swamp sub-species, these are discussed in detail in **Attachment D**.

The area occupied by each community in the Study Area and Locality (a 10 km radius) is included in **Table 5.5**.

Table 5.5 - Area of Vegetation Communities in the Study Area & Locality (Niche, 2012)

Map Unit (NPWS 2003)	Vegetation Community	Area in Study Area	Area in Locality
MU2	Coachwood Warm Temperate Rainforest (CWTR)	13.54	250.37
MU4	Sandstone Riparian Scrub (SRS)	0.79	15.89
MU14	Tall Open Peppermint Blue Gum Forest	6.42	48.30
MU23	Transitional Shale Stringybark Forest (TSSF)	9.43	191.87
MU26	Sandstone Gully Peppermint Forest (SGPF)	443.29	3708.42
MU27	Nepean Sandstone Gully Forest (NSGF)	68.29	1580.81
MU29	Exposed Sandstone Scribbly Gum Woodland (ESSGW)	854.75	7168.22
MU39	Rock Plate Heath-Mallee (RPHM)	2.49	64.26
MU42	Upland Swamps: Banksia Thicket (USBT)	19.73	173.40
MU43	Upland Swamps: Tea-Tree Thicket (USTTT)	0.57	4.66
MU44	Upland Swamps: Sedgeland-Heath (USSH) Complex	42.09	316.88
MU45	Upland Swamps: Fringing Eucalypt Woodland (USFEW)	11.73	110.19
MU45	Upland Swamps: Fringing Eucalypt Woodland (USFEW)	35.11	370.29

5.3.2 Flora

Two threatened plant species were recorded within 10 km of the Study Area, *Acacia bynoeana* and *Pultenaea aristata* (Biosis, 2007a).

A population of *Pultenaea aristata* was identified during the current survey by Niche (2012) in upland Swamp 35a. No other threatened species were recorded.

Habitat for 10 threatened species considered to have a moderate to high likelihood of occurring within the Study Area, includes the following:

- *Acacia bynoeana*
- *Acacia baueri ssp. aspera*
- *Cryptostylis hunteriana*
- *Epacris purpurascens var. purpurascens*
- *Grevillea parviflora ssp. parviflora*
- *Leucopogon exolasius*
- *Melaleuca deanei*
- *Persoonia acerosa*
- *Persoonia hirsuta*
- *Pultenaea aristata.*

Seven Part Tests undertaken by Biosis (2007a) concluded that the Proposal was unlikely to have a significant impact on any threatened flora with known or potential habitat in the Study Area.

Impact assessments were also undertaken by Niche (2012) for the four threatened flora species with habitat identified as likely to be impacted by subsidence. In conclusion, the Niche assessments determined that significant impacts to these flora species are unlikely.

5.3.3 Fauna

The Biosis SIS identified 55 fauna species listed under the *TSC Act* and/or the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act*),* which may have potential habitat within the Study Area (Biosis, 2007a). Sixteen threatened animal species were recorded in Dendrobium Area 3, either during the SIS or during studies conducted by Biosis Research.

Niche (2012) identified 28 fauna species, five of which are listed on the *TSC Act* or *EPBC Act.* **Table 5.6** describes the results of both of these surveys.

Table 5.6 - Threatened Terrestrial Fauna Species in Area 3 and Area 3B

Species	Area 3 (Biosis, 2007)	Area 3B (Niche 2012)
Littlejohn's Tree Frog	X	X
Giant Burrowing Frog	X	
Red-crowned Toadlet	X	X
Gang-gang Cockatoo	X	X
Glossy Black Cockatoo	X	
Olive Whistler	X	
Barking Owl	X	
Powerful Owl	X	
Eastern Pygmy-possum	X	
Eastern Freetail Bat	X	
Koala	X	
Grey-headed Flying-fox	X	X
Eastern Bentwing-bat	X	
Large-eared Pied Bat	X	
Southern Myotis	X	
Rosenberg's Goanna.	X	

Biosis Research has also recorded the following threatened microbats within the SIS Study Area with '*probable*' certainty, (being that they are likely to be the species named): Little Bentwing-bat, Eastern False Pipistrelle, Yellow-bellied Sheathtail Bat and Greater Broad-nosed Bat; and '*possible*' certainty, (being that there is a higher probability of being confused with other species): Golden-tipped Bat and Eastern Cave Bat. One other threatened species previously recorded within the Study Area is the Southern Brown Bandicoot (DEC Atlas of NSW Wildlife).

The Cardno Ecology Lab (CEL) was commissioned by BHPBIC to undertake an aquatic ecology assessment of Dendrobium Area 3 and assess the potential impacts on aquatic ecology resulting from mine subsidence associated with mining of Dendrobium Areas 3A, 3B and 3C.

Four threatened species have been predicted to potentially occur within Dendrobium Area 3, however there is only suitable habitat for the first three species within Dendrobium Area 3B (CEL, 2012)

Table 5.7 - Habitat for Threatened Aquatic Species in Area 3B

Species	Habitat in Area 3B
Macquarie Perch (*Macquaria australasica*)	Macquarie Perch is the only threatened species that has been recorded in the area, identified in the mid to lower reaches of Wongawilli Creek (including pools just upstream and downstream of Fire Road 6), the lower arm of Sandy Creek and Lake Cordeaux. There is suitable habitat for Macquarie Perch (including spawning areas) within the reach of Wongawilli Creek located within the SMP Area however, no species have been recorded here (CEL, 2012). The presence of waterfalls and rock bar cascades may present barriers to fish migration upstream and therefore the species may be unable to access the entire reach of Wongawilli Creek.

Adams Emerald Dragonfly *(Archaephya adamsi)*	Potential habitat for the Sydney Hawk and Adams Emerald dragonflies exists within Wongawilli and Sandy Creeks.
Sydney Hawk Dragonfly (*Austrocordulia leonardi)*	
Australian Grayling (*Prototroctes mareana*)	The Australian grayling is a migratory species and is unlikely to occur in the Study Area, because of the lack of provision for fish passage in the upper Nepean/Cordeaux system.

5.3.4 Aquatic Habitat

A summary of the aquatic habitat and biota for Area 3 is summarised in the Dendrobium Area 3A SMP (Cardno, 2007).

Wongawilli Creek is the only major watercourse in the SMP Area. It can be divided into four distinct habitat zones as described in **Table 5.8**.

Table 5.8 - Wongawilli Creek Habitat Zones (CEL, 2012)

Zone Location	Habitat Description
Zone 1 - the main channel of the creek between its confluence with the Cordeaux River and rock bar WC-RB23 at Site No. 30 and tributaries WC25-31	The main channel contains significant aquatic habitat and is characterised by a series of large deep pools. The tributaries to Wongawilli Creek including WC25, WC26, WC27 and WC31 contain 'minimal' aquatic habitat. WC26 contains some pools and is therefore likely to provide some aquatic habitat for aquatic macroinvertebrates, including Freshwater Crayfish.
Zone 2 - the main channel of the creek extending from rock bar WC-RB 23 upstream to the inflow of tributary WC16 and tributaries WC18-24	The main channel is situated within a steep, narrow valley and is surrounded by dry Eucalypt forest which extends down to the banks and partially shades the channel. The main channel of the creek contains significant aquatic habitat including a series of long pools interspersed by small sandstone rock bars, sandbars, debris, dams and small boulder fields. Tributary 21 contains 'moderate' aquatic habitat, WC17, WC20, WC23 and WC24 represent 'minimal' aquatic habitat. WC18, WC19 and WC22 are 'unlikely' to contain aquatic habitat
Zone 3 - the main channel of the creek extending from the confluence of tributary WC16 upstream to the large waterfall (WC-WF54) at Site No. 4	The creek is situated within a steep and narrow gorge and is surrounded by rainforest vegetation, except towards the downstream reach, where there are patches of dry Eucalypt forest amongst the rainforest. The creek is almost in permanent shade. The main channel contains 'significant' aquatic habitat and is characterised by long, narrow, shallow pools separated by boulder fields and beds of gravel and pebbles. There are also sandbars and small areas of bedrock. Tributary WC15 and WC10 contain 'moderate' aquatic habitat and the lower reaches of WC8, WC11, WC12, WC13 and WC14 provide only 'minimal' habitat. WC7 and WC9 are 'unlikely' to provide aquatic habitat. WC15 is characterised by a series of permanent pools. These pools would provide habitat for some fish and invertebrates throughout dry periods. WC10 has a well defined channel through the sandy soil banks with a substratum of gravel, pebbles and cobbles. There may be permanent pools upstream in this tributary that would provide aquatic habitat. The habitat within the four zones in Wongawilli Creek is further described in CEL (2012).

Zone Location	Habitat Description
Zone 4 - the main channel of the creek extending upstream from the waterfall WC-WF54 to the upper reaches of Wongawilli Creek.	This reach of the creek is located within a steep and narrow sandstone valley with vegetation dominated by dry Eucalypt forest. This native vegetation extends to the edge of the watercourse and creates some patchy shading of the creek. The main channel of the creek as far as the confluence with WC2 contains 'significant' aquatic habitats and is characterised by relatively small, shallow, pools, separated by retaining sandstone rockbars with steps up to 1 metre high that could pose a barrier to some fish species, but not Freshwater Eels and Galaxids. There are numerous in-stream habitat features. Tributary W6C and WC3 are considered to be 'unlikely' aquatic habitat. WC4 and WC5 contain 'moderate' aquatic habitat in the form of small permanent pools in their lower reaches.

5.4 SURFACEWATER AND SHALLOW GROUNDWATER

Ecoengineers were commissioned by BHPBIC to undertake an assessment of potential mining induced subsidence impacts on the surface water quality and hydrology that is predicted to occur as a result of the extraction of Longwalls 9 to 18 (**Attachment B**).

5.4.1 Surface Hydrology

The hydrologic impacts of mining longwalls directly under the Sandy Creek Catchment (Dendrobium Areas 2 and 3A) have been studied closely since early 2008 and assessed systematically following the completion of Longwall 5 (Area 2) in December 2009 and the completion of Longwall 6 (Area 3A) in March 2011.

The surface and shallow groundwater hydrologic system as it relates to the SMP has been previously discussed in the Dendrobium Area 3A Longwalls 6 to 10 SMP Application (Cardno, 2007) and further assessed for Area 3B by Ecoengineers (2012) (**Attachment B)**.

It is expected (based on available data to date) that there is no deep aquifer in the bulk of the Hawkesbury Sandstone in Area 3B (Ecoengineers, 2012). It is also believed that the hydrologic systems at or near the surface, are well separated from proposed longwall workings by a number of well recognised claystone units and relatively tight sandstone strata.

Base flows of streams (which may be expected to be most affected by mining induced subsidence effects) are generally provided by hillslope aquifers. The hillslope aquifers do not appear to be directly connected to any deep water-bearing strata.

Hydrographic monitoring, as well as catchment and sub-catchment modelling of the mining of Area 3A carried out thus far (Longwalls 6 and 7) has shown no hydrologic evidence for any deep (unrecoverable) loss to deep storage(s).

There has also been no evidence that the overall Sandy Creek Catchment (located just east of Dendrobium Area 3B) or any of its sub-catchments suffered any significant net loss of water to deep (unrecoverable) storages due to longwall mining by Longwall 5 (Area 2).

This is despite one instance of fracturing of one minor catchment creek bed and a temporary diversion of water into the creek bedrock over a period of about 6 months only.

5.4.2 Stream Baseline Water Quality Issues

The pHs of all upland streams within Hawkesbury Sandstone located in the Special Metropolitan Areas are all invariably well below the default trigger value of 6.5 for upland rivers in southeast Australia given in the national water quality guideline

(ANZECC/ARMCANZ, 2000). This has been confirmed by long term monitoring of streams in the local area (Ecoengineers Pty Ltd., 2003, 2004a, 2004b, 2005a, 2005b, 2006a), the SMP Area for Dendrobium Area 2 (Manly Hydraulics Laboratory, 2006; The Ecology Lab, 2006a) and also for the SMP Area for Dendrobium Area 3A (Ecoengineers, 2012).

Low pH levels arise naturally in Area 3B due to dissolution of silica and the leaching of small concentrations of organic acids from peats and other sources of dead plant organic matter, particularly in the swamps.

In addition, it has been found that levels of dissolved aluminium (Al) are usually in excess of the default trigger value for the protection of 95% of all aquatic species at pHs >6.5 for freshwater ecosystems in the national water quality guidelines (ANZECC/ARMCANZ, 2000).

However, for pHs <6.5 a low reliability trigger value for aluminium for protection of 95% of all aquatic species in freshwater ecosystems has been set at 0.8 μg/L (i.e. approximately 1μg/L on ecotoxicological grounds (ANZECC/ARMCANZ, 2000)).

Aluminium is only ecologically toxic in its cationic forms where it has a positive charge (Tessier and Turner, 1995).

Measured levels of sulfate and dissolved organic carbon levels in the creeks in the Dendrobium mining areas, indicate that there would be insufficient levels of sulfate and organic acids present to significantly ameliorate the ecotoxicity of cationic aluminium.

Established ecotoxicity literature indicates that the levels of dissolved aluminium that have been observed at most baseline sites surrounding Dendrobium, excluding the downstream Donalds Castle Creek site DCL3 and the Lake Avon Native Dog Creek Arm site LA1, and even in downstream permanent pools, would be ecotoxic to a large number of species. This would especially include benthic macroinvertebrates, amphibians and many fish species that have not evolved to tolerate such acidic, soft water that contains relatively high dissolved aluminium concentration (Tessier and Turner, 1995).

A key feature of the baseline sites that have been studied is that the diversity and abundance of the aquatic ecology would be very constrained by the relatively low pH levels as well as the higher levels of dissolved aluminium.

The low diversity of the benthic fauna in local headwater catchments has also been confirmed by previous and recent studies (The Ecology Lab, 2007). The national default trigger value for Zinc for protection of 95% of all aquatic species is 0.008 mg/L (8 μg/L).

Mean concentrations of filterable Zn in almost all Elouera EMP baseline water sites were found to lie at, or around 0.008 mg/L (range 0.004 – 0.018 mg/L).

It is likely that modelling or certain methods of direct measurement of cationic Zinc would show that cationic Zinc species would not, in general, sum to over 0.008 mg/L at these sites, despite the relatively fresh nature of these waters (Tessier and Turner, 1995). That is, unless pH’s were below 5.5.

Zinc is generally the least (potential or actual) ecotoxic metal present at baseline sites. However, this conclusion would not be valid where the underlying lithology was not of a sedimentary sandstone type.

5.4.3 Subsidence Induced Erosion Issues

Ground movements caused by mine subsidence may increase erosion and loss of soil materials through rock falls, or fissure opening in cohesive surface soils. Rock falls and surface soil cracking occurred as the result of mining Dendrobium Areas 1 and 2.

Monitoring and inspection by BHPBIC and its consultants for Dendrobium Mine shows there has been no evidence of sustained subsidence-induced erosion of the valley slopes of

Sandy Creek or Wongawilli Creek and its tributaries during the three year period since commencement of mining of Longwall 5 in December 2008, including during the most recent high rainfall period since May 2010.

Cliff lines associated with Wongawilli Creek and its tributaries in Area 3B are no larger than those that have been previously mined under in Dendrobium Areas 1, 2 and 3A. Slopes are no steeper or more extensive than those that have been previously mined under in Areas 1, 2 and 3A. Soil landscape types are closely similar to those previously encountered in upper Wongawilli Creek. Based on that experience no significant erosive effects on water quality from the mining of Area 3B are expected.

5.5 GROUNDWATER

GHD (2007) were commissioned by BHPBIC to undertake a detailed assessment on the hydrogeological features and potential impacts in Dendrobium Area 3. Furthermore, exploration in Area 3 by BHPBIC has permitted the development of an understanding of the hydrogeological conditions in and around Area 3B. The hydrogeology of Area 3 is detailed in the Area 3A SMP (Volume 1). The hydrogeology of Area 3B is briefly summarised below.

Most of the central plateau and ridgelines in the SMP Area consist of outcropping Hawkesbury Sandstone. The sandstone consists of intercalated fine to very coarse grained sandstone beds, usually separated by bedding planes and paleo-erosion surfaces. Minor siltstone and mudstone bands and lenses are often recognised in outcrop.

The highest permeability's occur horizontally and usually along bedding planes. Vertical movement of water is locally dependant and is variable throughout the Hawkesbury. Vertical migration is not insignificant, particularly in areas closer to the edges of cliff lines and benched escarpments. At these points, vertical fracturing caused by tilt effects causes natural valley closure, possibly enhanced by past tectonic events, and provides vertical conduits for groundwaters migrating down gradient.

Springs or seeps occurring deeper in the gullies are usually concentrated in areas of outcropped paleo-erosion surfaces or bedding planes within the Lower Hawkesbury or between the Hawkesbury, Newport and Garie Formations. These seeps identify zones of higher horizontal permeability. Springs or seeps are usually associated with pronounced deep chemical weathering, chemical precipitation and deposition, and the formation of cavernous zones within cliff line features.

The incised nature of the major creek catchments indicates that shallow groundwater movements would be extensive throughout Area 3. Where perched water storages exist they appear to be hydraulically supported by a broader scale semi-confined (unconfined above, confined below) hillslope aquifer or groups of such shallow aquifers. These aquifers occur in soils developed on Hawkesbury sandstone bedding planes, in natural fractures of the Sandstone.

The existence of the Nepean Monocline (a geological fold of strata) which dips from the southwest of Area 3A, northeast towards Lake Cordeaux suggests that within Area 3, deeper groundwaters contained within the beddings of Hawkesbury Sandstone would probably be directed north towards Lake Cordeaux and Lower Cordeaux River.

In broad terms, the rockmass in Dendrobium Area 3B is generally consistent with the surrounding regional stratigraphy of the Sydney Sedimentary Basin in that it encompasses a sub-horizontal sedimentary rock sequence. The sedimentary sequence supports a sequence of aquitards and aquifers, these being both low permeability and relatively higher permeability relative to the layers that act as aquitards. These aquifers do not constitute a viable water resource.

Low permeability aquitards (Bald Hill Claystone, Stanwell Park Claystone and Wombarra Claystone) induce the migration of water in a horizontal direction. The data in Area 3 is consistent with the presence of aquitards which direct horizontal flow (GHD, 2007).

This clear separation of groundwater systems is attributed to past underground mining that has occurred in the region surrounding Dendrobium Area 3B. In particular, mining has occurred in an arc from the south and east (in Elouera, Wongawilli and Nebo Collieries) in the Wongawilli Seam that has drained the rockmass. The effect of this drainage has extended into Area 3B, and is observable as the separated groundwater profiles. The separation of the groundwater profiles has occurred because the integrity of the aquitards has been maintained.

Structural geological features of a vertical to sub-vertical nature (faults and dykes) that bound Area 3B are not dissimilar to features regularly encountered in the Southern Coalfield. These features do not influence the overall horizontal trend for the movement of groundwater throughout the sedimentary sequence. For example, evidence has not been established which indicates that the north-south fault on the eastern side of Area 3A (i.e. between Area 3A and Area 2) influences hydrogeological response between the two Areas (refer Figure HG 316 of GHD, 2007).

Further assessments of the groundwater system were undertaken by Coffey (2012) (**Attachment C**), which utilised numerical flow monitoring in order to estimate the impacts of mining in Dendrobium Mine Area 3B on the groundwater system and Lakes Avon and Cordeaux. The results of this assessment are discussed in **Section 7.8**.

5.6 ARCHAEOLOGICAL SITES

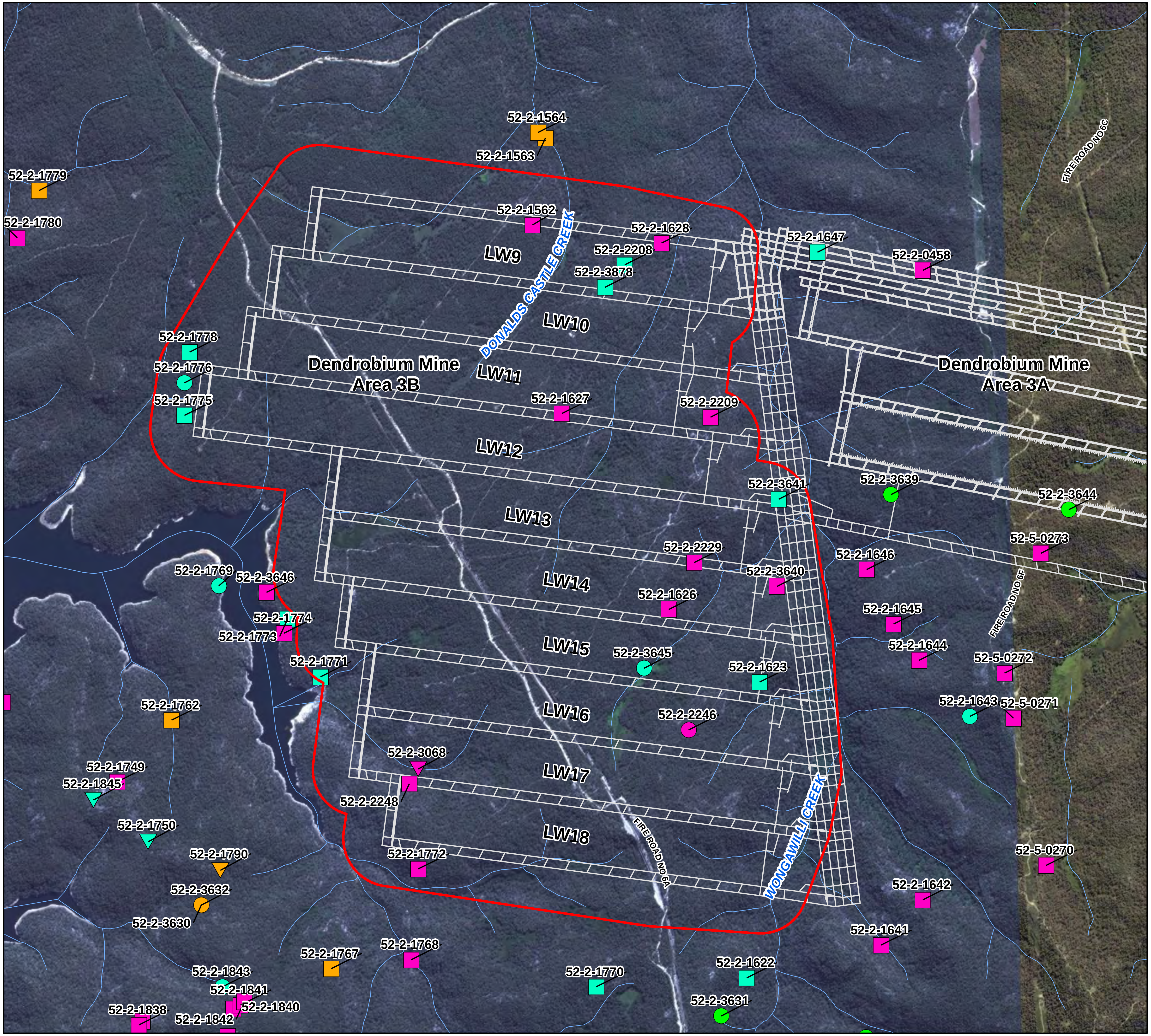
Biosis Research undertook an Aboriginal heritage assessment of Dendrobium Area 3 in 2007. The survey results indicated that the SMP Area contains archaeological sites typical of the Woronora Plateau. The sites encompass a variety of shelter sites, art motifs and techniques consistent with the local region. Biosis (2007b) concluded that Dendrobium Area 3 presents a strong sample to accurately characterise Aboriginal site patterning of the region. The condition of the sites and art is highly variable, with the charcoal art poorly preserved.

Twenty-three Aboriginal heritage items identified in the Biosis (2007 b) study fall within the Area 3B SMP Area, as shown in **Figure 5.4**. A summary of the archaeological sites within the SMP Area are provided in **Table 5.9**, a detailed description of each site is provided in **Attachment F**.

Table 5.9 - Aboriginal Sites within the SMP Area (Biosis, 2012)

Site Number	Site Name	Site Type
52-2-1562	Donald Castle Creek Site 1; Cordeaux Catchment area	Shelter with Art
52-2-1623	Browns Road Site 8	Shelter with Deposit
52-2-1626	Browns Road Site 11	Shelter with Art
52-2-1627	Browns Road Site 12	Shelter with Art
52-2-1628	Browns Road Site 13	Shelter with Art
52-2-1771	Upper Avon 35	Shelter with Deposit

Site Number	Site Name	Site Type
52-2-1772	Upper Avon 36	Shelter with Art
52-2-1773	Upper Avon 37	Shelter with Deposit
52-2-1774	Upper Avon 38	Shelter with Art
52-2-1775	Upper Avon 39	Shelter with Deposit
52-2-1776	Upper Avon 40	Shelter with Art, Shelter with Deposit
52-2-1778	Upper Avon 41	Shelter with Deposit
52-2-2208	DENDROBIUM 1	Shelter with Deposit
52-2-2209	DENDROBIUM 2	Shelter with Art
52-2-2229	SITE 1 - DB1	Shelter with Art
52-2-2246	DENDROBIUM 6	Isolated Artefact
52-2-2248	DENDROBIUM 7	Shelter with Art
52-2-3068	DENDROBIUM 8	Shelter with Art; Grinding Grooves
52-2-3640	DM 16	Shelter with Art
52-2-3641	DM 17	Shelter with Deposit
52-2-3645	DM 21	Shelter with Art; Shelter with Deposit
52-2-3646	DM 22	Shelter with Art
52-2-3878	DM 2	Shelter with Deposit



bhpbilliton ILLAWARRA COAL

Archaeological Sites within the SMP Area

DENDROBIUM AREA 3B SMP

Legend

- SMP Area (1,199 ha, MSEC 2012)
- Longwall Layout (BHPBIC, 2012)
- Watercourses (LPI)

AHIMS Site (Biosis Research)

- Artefact Scatter
- Axe Grinding Groove
- Axe Grinding Groove, Shelter with Art, Shelter with Deposit
- Isolated Find
- Shelter with Art
- Shelter with Art, Axe Grinding Groove
- Shelter with Art, Shelter with Deposit
- Shelter with Deposit
- Stone Arrangement
- Unknown

N W E S

FIGURE 5.4

1:20,000 Scale at A3

Metres
0 250 500 750 1,000 1,250

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-06-07
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1015_ArchaeologicalSites_SMP_Vol1.mxd 01

Aerial imagery supplied by Bing Maps and associated third party suppliers

5.7 SIGNIFICANT MAN MADE FEATURES

5.7.1 Railway Infrastructure

There are no operating railways in the SMP Area. The disused Maldon-Dombarton Railway Corridor Crosses the SMP Area as shown in **Figure 1.1**. At the time of abandoning the work, the major earthworks had been completed, but no tracks or associated equipment has been installed. Any plans for the future of the corridor remain uncertain and are the subject of continuing assessment.

5.7.2 Unsealed Roads

There are no public roads within the SMP Area. There are, however, unsealed fire trails and four wheel drive tracks within the SMP Area, which are used by SCA and other groups for fire fighting and other activities.

5.7.3 Drainage Culverts

There are small drainage culverts located across the SMP Area associated with the unsealed fire trails and four wheel drive tracks. The culverts comprise small concrete pipes which are located at the drainage line crossings.

5.7.4 Dams, Reservoirs or Associated Works

Avon Reservoir is located to the west of the proposed longwalls (refer **Figure 1.1**). The Lake receives water from the Avon River and its many tributaries. It has a length of approximately 19 km and a total operating capacity of ~147,000 ML.

The commencing ends of Longwalls 11 to 18 are located within the DSC Notification Area.

Lake Cordeaux is located approximately 3 km east of the proposed longwalls. At this distance, the lake is not predicted to experience any measurable mine subsidence movements. It is not expected, therefore, that the lake would experience any impacts resulting from the extraction of the proposed longwalls.

There are no dam walls or associated works within the SMP Area. The closest dam walls are the Cordeaux Dam Wall and the Upper Cordeaux No. 2 Dam Wall which are both located approximately 5 km from the proposed longwalls. At this distance it is not expected that the dam walls would experience any impacts resulting from the extraction of the proposed longwalls.

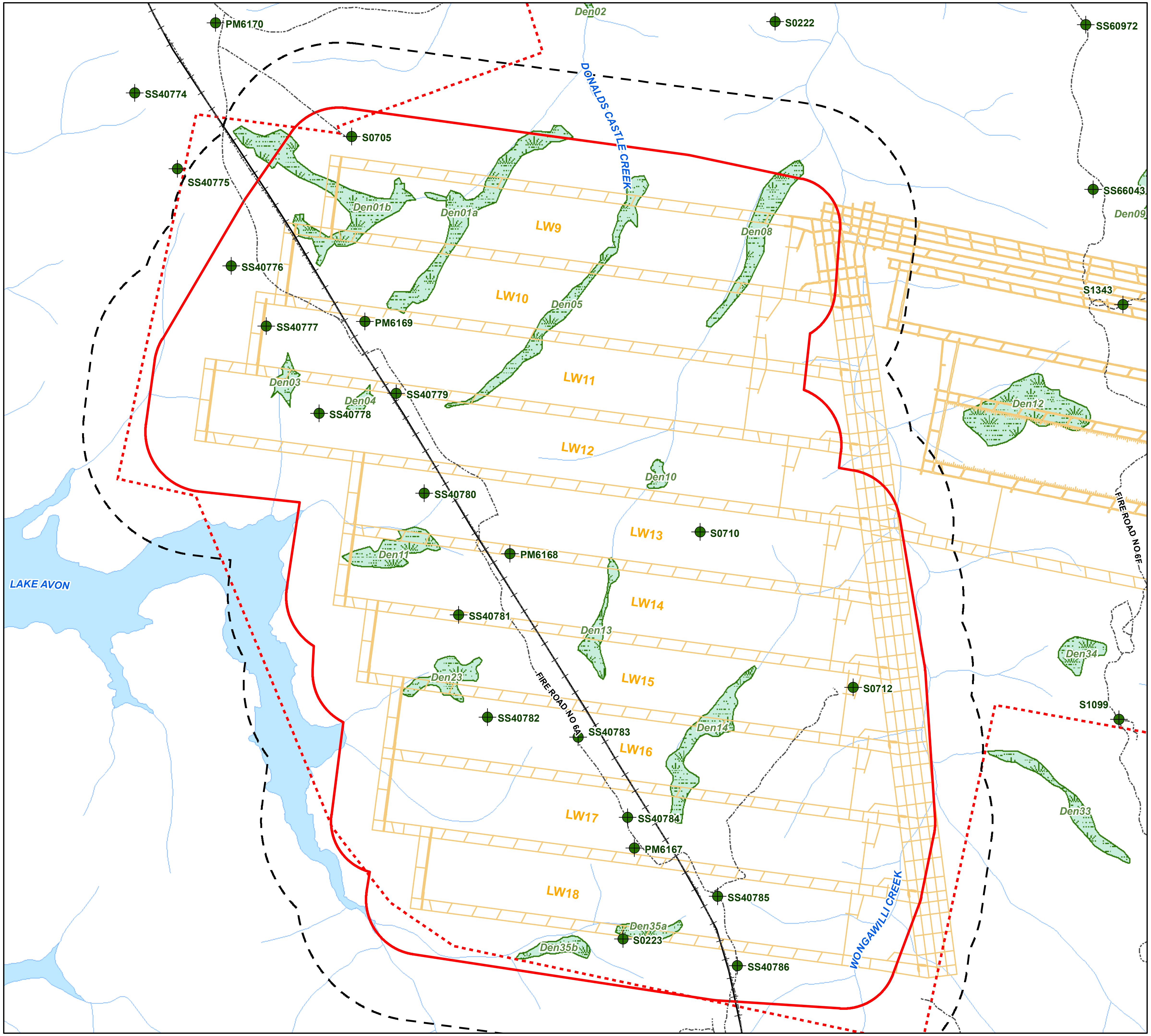
5.7.5 Survey Control Marks

The locations of the survey control marks within and immediately adjacent to the SMP Area are shown in **Figure 5.5**. The locations of the survey control marks were obtained from the *Land and Property Management Authority* using the *SCIMS Online* website (SCIMS, 2011).

5.7.6 Mine Infrastructure including Tailings Dams or Emplacement Areas

A number of exploration and monitoring drill holes are located within the SMP Area. The exploration holes are owned by BHPBIC and most contain piezometers or have been grouted or rehabilitated.

There is no other mine infrastructure within the SMP Area.



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ILLAWARRA COAL

Survey Control Marks within and adjacent to the SMP Area

DENDROBIUM AREA 3B SMP

Legend

- Survey Control Marks
- Tracks and Roads (LPI)
- Watercourses (LPI)
- 600m Study Boundary - Condition 8(d)
- SMP Area (MSEC 2012)
- Dendrobium Area 3
- DSC Notification Zone
- Maldon to Dombarton Rail
- Proposed Longwall Layout (BHPBIC, 2012)
- Waterbodies (LPI)
- Area 3B Swamps (Illawarra Coal, 2011)

N
W E
S

FIGURE 5.5

1:17,500 Scale at A3

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (WOL)
Date: 2012-09-27
Coordinate System: GDA 1994 MGA Zone 56
Project: 112041-01
Map: G1041_SurveyControlMarks.mxd 09

Data supplied by MSEC (2012) unless otherwise stated

6 SUBSIDENCE PREDICTIONS

Mining Subsidence Engineering Consultants (MSEC) has prepared detailed subsidence predictions (subsidence effects) for Area 3B which are fully described in **Attachment A**.

6.1 PREDICTION METHOD AND RELIABILILTY

The following is a summary of key aspects only. Further detail on the methods employed, factors that may influence the development of subsidence over the SMP Area and the reliability of subsidence predictions are provided in **Attachment A.**

Conventional Subsidence

The *Incremental Profile Method* used by MSEC makes its predictions based on extensive databases of historical monitoring data in the Southern Coalfield. The predicted strains have been determined by analysing the strains measured at other NSW Collieries, where the longwall width-to-depth ratios and extraction heights are similar to those for the proposed longwalls. This ensures relatively high confidence in the subsidence profiles predicted. The predictive model also uses the surface level contours, seam floor contours and seam extraction thickness contours to make predictions for other parameters.

The following assumptions are made when employing the Incremental Profile Method:

- Impacts will be similar to those previously observed in comparable areas.
- There may be anomalous cases where subsidence will not occur as predicted.
- Surface features and land use at the time of the assessment remains similar.
- Effects on infrastructure include ground strains being fully transferred to the feature.

Wherever faults, dykes and abrupt changes in geology are present, it is possible that irregularities in the subsidence profile could occur. Faults and dykes have been identified north, south-west and south-east of the proposed longwalls and there are several igneous structures in the locality, including the Nepheline Syenite intrusion to the south-east of the mining area. It is possible that some irregularity could occur in the subsidence profiles due to these geological structures. The likelihood of irregular profiles is discussed further in **Attachment A**.

Conventional Strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. This is because strain is affected by many factors including ground curvature and horizontal movement, as well as local variations in surface geology, the locations of pre-existing natural joints at bedrock and the depth of bedrock. The profiles of observed strain can therefore be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In the Southern Coalfield, it has been found that applying a factor of 15 to hogging or convex curvature provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains (MSEC, 2012). Based on this method, the maximum predicted conventional strains (both tensile and compressive) resulting from the extraction of Longwalls 9 to 18 are 15 mm/m (MSEC, 2012).

There may, however, be considerable variation from the linear relationship where there are non-conventional movements or other contributing factors. MSEC has therefore provided a statistical approach (using monitoring data from Dendrobium Area 3A and other NSW Coalfield locations where mine geometries were reasonably similar to Dendrobium Area 3B) to account for the variability, rather than just providing a single predicted conventional strain. These data are provided in **Attachment A.**

Upsidence and Closure

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled General Discussion on Mine Subsidence Ground Movements which can be obtained at www.minesubsidence.com. Discussions on the reliability of the method of prediction were provided in Report No. MSEC311.

6.2 SUBSIDENCE PREDICTIONS

A detailed description of the subsidence parameters and results of the subsidence predictions determined for the SMP Area are provided in **Attachment A** (MSEC, 2012). Copies of the relevant Plans are also provided in **Volume 3** of this SMP.

A summary of the maximum predicted conventional subsidence, tilt and curvature resulting from the extraction of each of the proposed longwalls are provided in **Table 6.1**.

Table 6.1 - Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Each of the Proposed Longwalls 9 to18

Longwall	Maximum Predicted Incremental Subsidence (mm)	Maximum Predicted Incremental Tilt (mm/m)	Maximum Predicted Incremental Conventional Hogging (km^{-1})	Maximum Predicted Incremental Conventional Sagging Curvature (km^{-1})
9	2050	25	0.5	0.6
10	2450	30	0.5	0.7
11	2500	30	0.6	0.7
12	2450	30	0.5	0.7
13	2250	30	0.5	0.7
14	2550	35	0.8	0.7
15	2450	30	0.5	0.7
16	2450	30	0.7	0.7
17	2700	40	0.9	1.0
18	2550	35	0.8	0.8

A summary of the maximum predicted cumulative subsidence parameters, after the extraction of each proposed longwall, is provided in **Table 6.2**. The predicted tilts provided in the above table are the maxima after the completion of the proposed longwalls.

Table 6.2 - Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of each of the Proposed Longwalls 9-18

Longwall	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})**
9	2050	25	0.5	0.6
10	2450	30	0.5	0.7
11	2550	30	0.6	0.7
12	2550	30	0.6	0.7
13	2550	30	0.6	0.7
14	2550	35	0.8	0.7
15	2600	35	0.8	0.7
16	2600	35	0.8	0.7
17	2700	40	0.9	1.0
18	2800	40	1.0	1.0

* Maxima after the completion of each of the proposed longwalls.

**Maxima at any time during or after the extraction of each of the proposed longwalls.

The maximum predicted subsidence, after the completion of the proposed longwalls, is 2800 mm which represents around 61 % of the extraction height. The maximum predicted conventional tilt is 40 mm/m (i.e. 4 %), which represents a change in grade of 1 in 25. The maximum predicted conventional hogging and sagging curvatures are both 1.0 km^{-1}, which represent minimum radius of curvature of 1 km (MSEC, 2012).

The predicted conventional subsidence parameters vary across the SMP Area as the result of, variations in the longwall geometry and the depths of cover as well as other factors.

7 SUBSIDENCE EFFECTS, IMPACTS AND ENVIRONMENTAL CONSEQUENCES

This chapter reports the subsidence effects, impacts and environmental consequences for natural and man-made features within the SMP Area as predicted by MSEC (2012). The potential subsidence impacts and environmental consequences, as provided by specialist consultants and based on the predicted subsidence are also summarised in each section. Full assessment reports for each feature are provided in the Attachments to this report.

The predicted tilts provided in the tables below are the maxima after the completion of any or all of the proposed longwalls. The predicted curvatures provided in the tables below are the maxima at any time during or after the extraction of each of the proposed longwalls. Non-conventional movements can also occur and have occurred in the NSW Coalfield as a result of anomalous movements and downslope movements. An analysis of strain resulting from both conventional and non-conventional anomalous movements is provided in **Attachment A**.

7.1 CLIFFS

Subsidence Effects

The majority of cliffs located within the SMP Area are predicted to experience subsidence of less than 20 mm (except DA-CF22, 25 mm and DA-CF23, 100 mm) (refer **Table 7.1**). The maximum predicted tilts and curvatures also occur at Cliff DA3-CF23, which is the cliff located closest to the proposed longwalls.

The maximum predicted tilt at cliffs within the SMP Area is 2.0 mm/m (i.e. 0.2%), which represents a change in grade of 1 in 500. The maximum predicted curvatures at the cliffs are 0.07 km^{-1} hogging and less than 0.01 km^{-1} sagging, which represents minimum radii of curvature of 14 km and greater than 100 km respectively.

The maximum predicted strains for cliffs based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.1 mm/m tensile and less than 0.3 mm/m compressive (i.e. in the order of survey tolerance). The cliffs are located up the valley sides and, therefore are not expected to experience the valley closure strains which occur near the valley base.

Non-conventional movements can also occur as a result of anomalous movements and downslope movements. Further detailed analysis of strain resulting from conventional and non - conventional anomalous movements is provided in the report by MSEC as **Attachment A.**

Table 7.1 - Maximum Predicted Total Conventional Subsidence Parameters for the Cliffs Resulting from the Extraction of the Proposed Longwalls

Cliff Ref.	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})
DA-CF19	<20	<0.5	<0.01	<0.01
DA-CF20	<20	<0.5	0.04	<0.01
DA-CF21	<20	0.5	0.07	<0.01
DA CF22	25	0.5	<0.01	<0.01

DA-CF23	100	2.0	0.07	<0.01
DA-CF25	<20	<0.5	<0.01	<0.01
DA-CF26	<20	0.5	0.07	<0.01
DA-CF41	<20	0.5	0.05	<0.01
DA-CF42	<20	<0.5	0.03	<0.01
DA-CF43	<20	<0.5	0.03	<0.01
DA-CF44	<20	<0.5	<0.01	<0.01
DA CF45	<20	<0.5	<0.01	<0.01
DA-CF46	<20	<0.5	<0.01	<0.01
DA-CF47	<20	<0.5	<0.01	<0.01

Subsidence Impacts

Tilt can increase the overturning movements in steep or overhanging cliffs which, if of sufficient magnitude, could result in toppling type failures. The predicted maximum tilts for the SMP Area are very small in comparison to the existing slopes of the cliff faces and are unlikely, therefore, to result in toppling type failures.

If conventional curvatures and strains are of a high enough magnitude there is a possibility that fracturing of the rock will occur along existing bedding planes and joints leading to instabilities. This may result in sliding or toppling type failures along the cliffs, especially in heavy rainfall events.

The maximum predicted upsidence and compressive strains due to closure movements occur in the bases of the valleys and are unlikely, therefore, to result in impacts on the cliffs, which are located up the valley sides. Closure movements tend to be bodily movements of the valley sides, however, stresses can be induced in the strata where differential closure movements occur around bends in the river valley.

It is difficult to assess the likelihood of cliff instabilities as a number of factors contribute to a cliff becoming unstable. It is possible that cliff instabilities may occur during mining that may be attributable to either natural causes, mine subsidence, or both.

MSEC (2012) has assessed the likelihood of cliff instabilities in the SMP Area using case studies from previous longwall mining that has taken place at Dendrobium Mine and elsewhere in the Southern Coalfields. These case studies are further discussed in **Attachment A**.

Based on these case studies it is indicated that there have only been experiences of isolated rock falls observed outside the extents of longwall mining and these represent a very small proportion of the total length of cliff line.

The cliffs located in the SMP Area are all located outside the extents of the proposed longwalls, at minimum distances of 30 m to 460 m at the closest points. It is possible therefore that some small isolated rock falls could occur along the cliffs as a result of the extraction of the proposed longwalls. It is not expected however, that, any large scale cliff instabilities would occur based on previous experience at Dendrobium, Appin and Tower Collieries.

Increased Subsidence Predictions

If the predicted systematic tilts were increased by a factor of up to 2, the likelihood and extent of impacts would not significantly increase.

If the predicted curvatures were increased by a factor of up to 2, hogging curvatures would be similar in orders of magnitude, to the maximum predicted to have occurred directly above Tower Longwalls 1 to 17. Mining in this area occurred directly beneath approximately 5 km's of cliff line within the Cataract River and Nepean River valleys. There were a total of 10 cliff instabilities recorded along these valleys which represents approximately 4% of the total length of the clifflines directly mined beneath.

It is expected that the overall levels of impact on the cliffs resulting from the extraction of the proposed longwalls in the Dendrobium Area 3B, are expected to be similar to those observed where longwalls have previously mined close to, but not directly beneath the cliffs.

Recommendations

It is recommended that persons who enter the SMP Area are made aware of the potential for rock falls. The conditions of the cliffs should be monitored throughout the mining period and for a period after the completion of mining.

Further, it is recommended that monitoring and management strategies, as outlined in Section 18 of Dendrobium Area 3B SMP **Volume 2,** are implemented to ensure any rockfalls associated with the proposed activities are identified. With these measures in place, it is unlikely that there would be a significant impact associated with the cliffs resulting from the proposed mining.

7.2 STEEP SLOPES

Subsidence Effects

The steep slopes are scattered across the SMP Area, therefore, it's expected that the full range of predicted subsidence movements will be experienced. The maximum predicted values of total conventional subsidence, tilt and curvature, resulting from the extraction of Longwalls 9 to 18 are provided in **Table 7.2**.

Table 7.2 - Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Steep Slopes resulting from the Extraction of the Proposed Longwalls 9 to 18

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Steep Slopes	2800	40	1.0	1.0

The predicted tilts are the maximum values at the completion of any or all proposed longwalls. The curvatures are the maximum predicted values which occur at any time during or after the extraction of the proposed longwalls.

The predicted curvatures for the steep slopes, resulting from the extraction of the proposed longwalls, are both 1.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of 1 km.

Subsidence Impacts

The maximum predicted tilt at the steep slopes, resulting from extraction of the proposed longwalls is 40 mm/m, which represents a change in grade of 1 in 25. The predicted changes in grades are small in comparison to the natural grades of the steep slopes which are greater than 1 in 3. Therefore, the predicted tilts are insignificant relative to natural grades and therefore, are unlikely to result in any significant impact on the stability of the steep slopes.

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

The steep slopes in Area 3B are similar to those in Area 3A where the natural grades of the steep slopes are generally less than the steep slopes in Dendrobium Areas 1 and 2. Furthermore, the depths of cover at Area 3B are greater than those previously mined at Dendrobium Areas 1 and 2. Due to these factors it is likely that the sizes and extents of surface cracking at Area 3B will be less than those during extraction of longwalls in Area 1 and Area 2.

Impacts to steep slopes due to mining induced subsidence are most likely to occur in the form of surface cracks. Experience indicates that the likelihood of large-scale down-slope movements is extremely low due to the high depth of cover within the SMP Area.

If tension cracks do develop it is possible that soil erosion may occur if the cracks are left untreated. Some remediation may therefore be required, consistent with the mitigation and remediation measures discussed in the Dendrobium Area 3B SMP, **Volume 2**.

Increased Predictions

If the predicted systematic tilts were increased by a factor of up to 2, the likelihood and extent of impacts would not significantly increase.

If the curvatures were increased by a factor of 2, large tensile cracks may occur near the tops of steep slopes, in the order of and greater than 300 mm. It would not be expected that slope instabilities such as large scale soil slips would develop.

Recommendations

It is recommended that the steep slopes are monitored during and following mining in accordance with the Subsidence Landscape Monitoring and Management Plan as outlined in **Section 18** of Dendrobium Area 3B SMP, **Volume 2**. Additionally, any significant surface cracking should be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface where it is appropriate to do so and the proposed remedial measures do not themselves cause significant environmental impacts.

Management strategies should also be developed, in consultation with key stakeholders and with these appropriate management strategies in place, it is unlikely that there would be a significant impact to the steep slopes resulting from the proposed mining.

7.3 ROCK OUTCROPS

Subsidence Effects

The rock outcrops are scattered across the SMP Area and therefore are expected to experience the full range of predicted subsidence movements. The predicted maximum values of total conventional subsidence, tilt and curvature, resulting from the extraction of the proposed longwalls, is provided in **Table 7.3**.

Table 7.3 - Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Rock Outcrops resulting from the Extraction of the Proposed Longwalls 9 to 18

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Rock Outcrops	2800	40	1.0	1.0

The predicted tilts are the maximum values at the completion of any or all proposed longwalls. The curvatures are the maximum predicted values which occur at any time during or after the extraction of the proposed longwalls.

The maximum predicted conventional strains for the rock outcrops, based on applying a factor of 15 to the maximum predicted conventional curvatures are both 15 mm/m tensile and compressive.

Subsidence Impacts

The extraction of longwalls are likely to result in some fracturing of the rock outcrops, and where the rock is unstable, some instability could result. Previous experience of mining beneath rock outcrops at Dendrobium Mine indicate that the percentage of rock outcrops likely to be impacted by mining is very small.

Fracturing, rockfall and spalling have been observed to occur after longwall extraction at Longwall 6 in Area 3A. It is expected therefore, that these impacts will occur at some of the rock outcrops which are located directly above the proposed Longwalls 9 to 18. The incidence of these impacts is expected to be low, similar to that previously observed at Dendrobium Mine.

Increased Subsidence Predictions

If the actual subsidence movements were increased by a factor of up to 2, the incidence of impacts would increase for rock outcrops located directly above the proposed longwalls. The incidence of impacts on the rock outcrops within Dendrobium have previously been very small and therefore, based on past experience the incidence of impacts on rock outcrops in the SMP Area are also expected to be small where actual movements are greater than expected.

Recommendations

It is recommended that persons who enter the SMP Area are made aware of the potential for rock falls resulting from the extraction of the proposed longwalls. The conditions of the rock outcrops should be visually monitored throughout the mining period and for a period after the completion of mining.

In addition to this, it is recommended that appropriate management strategies as detailed in Section 18 of the Dendrobium Area SMP **Volume 2**, are put in place to ensure the safety of people that may be within the vicinity of the rock outcrops during the mining period. With these measures in place, it is unlikely that there would be significant impacts associated with the rock outcrops resulting from the proposed mining.

7.4 SWAMPS

Subsidence Effects

Coastal Upland Swamps of the Sydney Basin Bioregion are listed as an EEC in the TSC Act and have been identified in the SMP Area. Upland Swamps (all variations) located directly above proposed longwalls may be subject to impacts from subsidence.

Swamps are located throughout the SMP Area and as such will be subject to a range of subsidence values from less than 20 mm to 2550 mm at Den08 (refer **Table 7.4**). The maximum predicted tilt at the swamps within the SMP Area is 30 mm/m at swamps Den10, Den14, and Den23 which represents a change in grade of 1 in 33.

Tilts are the maximum values at the completion of any or all proposed longwalls. The curvatures are the maximum predicted values which occur at any time during or after the extraction of the proposed longwalls.

The maximum predicted hogging and sagging curvatures for the swamps are 0.55 km^{-1} (minimum radii of curvature 2 km) and 0.70 km^{-1} (minimum radii of curvature 1.5 km).

The maximum predicted conventional strains for the swamps, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 8 mm/m tensile and 11mm/m compressive.

A number of swamps are located in the bases of drainage lines and, therefore, could experience valley related movements. A summary of the maximum predicted upsidence and closure movements for the swamps is provided in **Table 7.5**.

Table 7.4 - Maximum Predicted Total Conventional Subsidence, Parameters for the Swamps resulting from the Extraction of the Proposed Longwalls

Swamp Ref.	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})
Swamp Den01a	2000	20	0.30	0.45
Swamp Den01b	1500	16	0.25	0.35
Swamp Den03	2250	17	0.25	0.30
Swamp Den04	2150	16	0.20	0.30
Swamp Den05	2050	25	0.35	0.45
Swamp Den08	2550	25	0.55	0.65
Swamp Den10	2450	30	0.55	0.70
Swamp Den11	2200	25	0.40	0.40
Swamp Den13	2200	25	0.45	0.55
Swamp Den14	2500	30	0.55	0.65
Swamp Den23	2400	30	0.50	0.65
Swamp Den35a	1000	25	0.55	0.07
Swamp Den35b	<20	<0.5	<0.01	<0.01

Table 7.5 - Maximum Predicted Total Upsidence and Closure for the Swamps resulting from the Extraction of the Proposed Longwalls

Swamp Ref.	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm/m)
Swamp Den01a	325	200
Swamp Den01b	**200**	**100**
Swamp Den03	**175**	**100**
Swamp Den04	**175**	**175**
Swamp Den05	375	275
Swamp Den08	700	600
Swamp Den10	275	275
Swamp Den11	**250**	**250**
Swamp Den13	**400**	**400**
Swamp Den14	650	650
Swamp Den23	350	225
Swamp Den35a	200	350
Swamp Den35b	175	425

Note: Headwater swamps are shown in Bold

The predicted valley related movements provided in the above table are the maxima which occur in the bases of the streams within the extents of the swamps. The headwater swamps are located partly up the valley sides and, therefore, in these cases the predicted upsidence movements for these swamps are less than the maxima provided in the above table.

Subsidence Impacts

The predicted changes in grade are smaller than the natural surface gradients within the swamps. There are no overall predicted reversals of grade within the extents of these swamps resulting from mining.

The predicted differential total subsidence and total tilt within swamps located directly above the proposed longwalls could result in increased ponding above the centrelines of longwalls, and decreased water levels above the chain pillars and longwall goaf edges. It is possible that the changes in water level could impact the distribution of local vegetation within the swamps. However, the swamps are generally free draining and therefore, significant changes in water levels are not expected to occur. Swamp monitoring undertaken within Area 3A since 2003 has indicated no significant difference in soil surface moisture between swamps that have or have not been undermined (BHPBIC, 2010).

The upland swamps in Area 3B consist of both *Valley Infill* and *Headwater Swamps.* Significant quantities of sediment are naturally found above the bedrock which is fractured and weathered through natural processes.

Valley infill swamps may be at risk of scour and erosion if the swamps are located well down stream where there is sufficient upstream catchment to provide high stream powers. The risk of erosion may also increase if the vegetation in the swamp has been previously impacted, for example, by bushfire (Tomkins and Humphries, 2006).

Den05 is the only valley infill swamp identified in Area 3B that may be susceptible to scour effects enhanced by changes in grade due to mine subsidence (CFR, 2007). However, based on past experience of mining on the Woronora Plateau the likelihood of the described impacts occurring is considered unlikely (Ecoengineers, 2012). Scouring of such swamps is more likely to occur due to natural events which result in the formation of scour pools that become progressively channelized to form gullies (Tomkins and Humphries, 2006).

Due to the predicted magnitudes of curvature and strains it is expected that some fracturing of the bedrock beneath the swamps could occur. Such fracturing is likely to coincide with sandstone that already contains naturally well weathered bedding planes and fractures. Therefore, in this case, further fracturing is likely only to enhance an existing conductance and transmission capability, rather than to create a wholesale loss of water from a swamp (Ecoengineers, 2012).

Hydrologic and/or geochemical effects on a headwater swamp are only likely to be significant where mining induced subsidence effects have induced a significant change to a broad scale hillslope aquifer (Ecoengineers, 2012).

Studies of the swamps in the Dendrobium area have found that the overall surface soil moisture conditions in the swamps, which have experienced mine subsidence movements, were not significantly different to swamps that have not experienced mine subsidence movements (BHPBIC, 2011).

The confirmed incidence of impacts to upland swamps due to longwall mining is therefore low. Particularly considering that in many studies, such as the Southern Coalfield Inquiry (2008), the impacts to swamps were associated with natural events or non-mining disturbances.

A Seven Part Test for Coastal Upland Swamps of the Sydney Basin Bioregion has been undertaken by Niche (2012) and concludes that the Proposal is unlikely to significantly impact the community based on the following:

- The predicted isolated impacts of the Proposal on Upland Swamps in the SMP Area are unlikely to remove, modify, fragment or isolate the EEC in the SMP Area;
- It is unlikely that all Coastal Upland Swamps will be impacted by the Proposal;
- The Coastal Upland Swamps that will not be impacted by the Proposal are within Conservation reserves;
- Significant long-term changes to species composition within Coastal Upland Swamps in the Study Area are unlikely to occur;

Previous studies within Upland Swamps in the Southern Coalfield support the predicted low potential for impacts on Coastal Upland Swamps (Niche, 2012; Section 6.2).

Further detail on the impact of mining induced subsidence on swamps as well as a detailed assessment of the susceptibility of swamps within the SMP Area is discussed in **Attachment B**.

Increased Subsidence Predictions

If the predicted tilts were increased by a factor of 2, the potential for changes in the surface water flows would increase for the valley infill swamps which are located in the bases of streams. In particular this relates to Swamp Den05 (refer **Figure 5.1**). Reversals in grade are predicted to occur adjacent to the tailgates of Longwalls 9, 10 and 11, if subsidence was to increase by a factor of 2. Similar increased levels of ponding would be anticipated along other valley infill swamps, immediately upstream of longwall chain pillars and goaf edges. The predicted impacts on the headwater swamps would be less, as tilts would be smaller than the natural surface grades of the valley sides.

If the predicted systematic strains or the predicted upsidence and closure movements at the swamps were increased by a factor of up to 2, the likelihood and extent of fracturing, buckling and dilation in the topmost bedrock would increase. As discussed previously, however, significant quantities of sediment are found above the bedrock at the swamps which is fractured and weathered naturally. It is unlikely, therefore, that any additional fracturing in the bedrock, as a result of mine subsidence, would have a significant impact on the sediments, aquifers and, hence, the swamps.

Recommendations

The recommendations currently in place for Dendrobium Area 3A should be continued for Area 3B. Recommendations also include the deployment of a wide network of piezometers within and outside swamps to gauge changes to the extent and/or vertical thickness of the hillslope aquifer over the proposed longwalls as detailed in **Section 17.5** of the Dendrobium Area 3B SMP **Volume 2**.

It is recommended that piezometers be installed within Area 3B sub catchment areas including Swamps Den01a, Den01b, Den05 and Den09, Den10 and Den13.

7.5 ECOLOGY

Subsidence Effects

As flora and fauna are diversely distributed throughout the SMP Area, the full range of predicted subsidence effects is applicable to the prediction of impacts to flora and fauna. Based on MSEC (2012) subsidence prediction, CEL (2012) and Niche (2012) have assessed the potential mine subsidence impacts for flora and fauna, as summarised below.

Fracturing of bedrock is likely in Donalds Castle Creek and in the drainage lines that are directly mined beneath, which may result in re-direction of surface flows. This fracturing is likely to lead to draining of some pools over the longwalls, however the likelihood of this occurring throughout the mining area has been considered low.

Rock falls may alter roosting or sheltering habitat, however significant areas of habitat will not be impacted and new habitat is likely to be created. Rock falls have the potential to harm or result in mortality to the species that reside under them. Given the minimal predicted occurrence of rock falls predicted, the likelihood is low.

Predicted ground strains may result in the slippage of soils down steep slopes, resulting in tension cracks at the top of the slopes and compression ridges at the bottom of the slopes. Habitats can be affected by the cracking of soils however, it is unlikely that any cracking or erosion would have a significant impact on flora or fauna. It is unlikely that mine subsidence will result in any large-scale slope failure.

Flora could be adversely affected by the emission of gas at the surface. It is possible but unlikely, that strata gas emissions at the surface would result in vegetation dieback due to the extraction of the proposed longwall. Emission of gases has not been a major issue in the past, since such emissions tend to be short lived and the consequences are generally minor and readily managed.

Plant communities independent of groundwater, such as those occurring on ridgetops and upper slopes, are not likely to be impacted by subsidence. Changes to species composition of these communities are unlikely to occur. Plant communities that are dependent on groundwater, such as riparian vegetation and upland swamps, are more likely to be impacted by subsidence.

Riparian habitats may be affected by subsidence through surface water diversions, strata gas emissions at the surface, the fracturing of bedrock and the cracking of soils. These impacts, however, are predicted to be minor, and are unlikely to result in significant changes to species composition of the riparian vegetation communities in the long-term.

Coastal Upland Swamps of the Sydney Basin Bioregion are listed as an EEC in the TSC Act and have been identified in the SMP Area. Upland Swamps (all variations) located directly above proposed longwalls may be subject to impacts from subsidence. These impacts may include changes to the distribution of local vegetation within the swamp due to changes in water levels. Generally, however, the surfaces of swamps are free draining, and it is not anticipated that significant changes to ponding would occur as a result of differential subsidence (MSEC 2012). It is unlikely therefore, that significant long-term change to species composition within Upland Swamp vegetation would occur as a result of the proposed extraction of Area 3B.

<u>Subsidence Impacts</u>

Only one threatened flora species *Pultenaea aristata* was recorded in the current survey undertaken by Niche (2012). The population was large in the order of approximately a thousand individual plants. A seven-part test was conducted for *Pultenaea aristata* (refer **Attachment D**) and it concluded that the extraction of the proposed longwalls is unlikely to significantly impact on the species.

A revised assessment of the potential subsidence impacts for threatened fauna within the SMP Area was undertaken by Niche (2012). Fifty-four threatened fauna species were determined to have a moderate to high likelihood of occurrence in the Study Area. Seven Part Tests were completed for threatened fauna with habitat that has the potential to be impacted by subsidence.

A Seven Part Test for Coastal Upland Swamps of the Sydney Basin Bioregion has been undertaken by Niche (2012) and concludes that the Proposal is unlikely to significantly impact the community based on the following:

- The predicted isolated impacts of the Proposal on Upland Swamps in the SMP Area are unlikely to remove, modify, fragment or isolate the EEC in the SMP Area;
- It is unlikely that all Coastal Upland Swamps will be impacted by the Proposal;
- The Coastal Upland Swamps that will not be impacted by the Proposal are within Conservation reserves;
- Significant long-term changes to species composition within Coastal Upland Swamps in the Study Area are unlikely to occur;
- Previous studies within Upland Swamps in the Southern Coalfield support the predicted low potential for impacts on Coastal Upland Swamps (Niche, 2012 Section 6.2).

Seven Part Tests concluded that the Proposal was likely to have a significant impact on local populations of Little John’s Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet and Giant Dragonfly.

As was concluded in the SIS (Biosis, 2007a) that the possible mechanism and physical effects of subsidence was determined to have a direct impact on known and potential habitat for the species. This was due to the reliance of the species upon Donalds Castle Creek, and drainage lines, Upland Swamps, ridgelines and rock outcrops.

A revised assessment of the potential subsidence impacts for aquatic habitat and biota for the SMP Area within Dendrobium Area 3B was undertaken by CEL (2012) (**Attachment E**). Assessments of Significance were undertaken for the Adams Emerald Dragonfly, the Sydney Hawk Dragonfly and the Macquarie Perch. The assessments concluded that it is highly unlikely that the proposed Project will have a significant impact on the species as they would only be subject to temporary, localised, minor impacts.

Recommendations

The recommendations currently in place for Dendrobium Area 3A should be continued for Area 3B. This includes undertaking relevant monitoring such as habitat assessments, water quality sampling, aquatic macroinvertebrate sampling, fish sampling, transects, swamp mapping and amphibian monitoring, and management measures as outlined in Section 19 and Section 20 of the Dendrobium Area 3B SMP **Volume 2**.

7.6 SURFACEWATER AND SHALLOW GROUNDWATER

The following section describes the potential physical changes to shallow groundwater and hydrology within the SMP Area. The potential impacts from any physical changes to the creeks in the SMP Area on ecology and swamps are discussed in **Section 7.5** and **Section 7.4.**

7.6.1 Hydrology

Subsidence Effects

The subsidence effects on surface water in Wongawilli Creek, Donalds Castle Creek and drainage lines are provided in **Section 7.7**. Longwalls within Dendrobium Area 3B have been designed with a setback from Wongawilli Creek and Lake Avon to avoid significant surface fracturing and surface water diversion in the creek beds or beneath the Lake. Wongawilli Creek will not be directly undermined and so maximum predicted subsidence is less than 20 mm. Donalds Castle Creek and other drainage lines will be directly undermined and therefore maximum subsidence is predicted up to 2050 mm.

The subsidence effects for swamps within the SMP Area are provided in **Section 7.4**. Maximum subsidence for swamps has been predicted between 20 to 2550mm depending on the location of the swamp as detailed in **Table 7.4**.

Impact Assessment

Hydrologic studies of Donalds Castle Creek and Wongawilli Creek in the vicinity of Dendrobium Area 3 have been undertaken since 2001 by Ecoengineers. It is considered that base flows of the drainage systems, which may be considered as the most effected by mining induced subsidence, are generally provided by semi-confined hillslope aquifers.

On the basis of prior hydrologic modelling studies of the Wongawilli Creek, Native Dog Creek, Sandy Creek and Donalds Castle Creek catchments, it is believed that such hillslope aquifers are very common in Area 3B (Ecoengineers, 2006b). The basic systematic mathematical features of such hillslope aquifers are discussed in detail in **Attachment B**.

Longwalls in Area 3B will be set back from major creeks such as Wongawilli Creek to a distance that has been, guided by prior subsidence monitoring and modelling, to avoid significant fracturing and surface water diversion in these creek beds. Due to the set back distances of the Area 3B longwalls, it is not expected that any fracturing resulting in sub-bed flow diversions will occur in Wongawilli Creek or that there will be detectable losses of outflows from these catchments.

Continued hydrographic and pluviometric monitoring is required to quantify the hydrological and hydrogeological effects of longwall mining in Area 3B. It is proposed that the monitoring approach established for Area 3A is an appropriate one to guide the design and implementation of the hydrographic monitoring in Area 3B and provide a systematic framework for the hydrologic analysis of the data they produce.

With the monitoring outlined in **Volume 2** of the SMP in place and mitigation measures such as grouting available in some circumstances (as outlined in previous sections) as part of the activity, it is assessed that it is unlikely there will be a significant impact on the surface hydrology and net yield of the Area 3B catchments as a whole. This is not withstanding possible minor surface diversions in ephemeral drainage lines discussed earlier.

Recommendations

The recommendations currently in place for Dendrobium Area 3A should be continued for Area 3B. This includes undertaking relevant monitoring such as surface levels, flows, surface slope gradient and erodibility, and management measures as outlined in Section 17 of the Dendrobium Area 3B SMP **Volume 2**.

7.6.2 Water Quality

Subsidence Effects

MSEC (2012) predicts that maximum tensile strains greater than 0.5 mm/m may be of sufficient magnitude to result in fracturing in the beds of tributary creeks. They also predict compressive strains greater than 2 mm/m may be of sufficient magnitude to result in the topmost bedrock buckling and fracturing, which can induce surface fracturing in the beds of the drainage lines.

Ground movements caused by mine subsidence may increase erosion and loss of soil materials through rock falls, or fissure opening in cohesive surface soils. Rock falls and surface soil cracking occurred as the result of mining Dendrobium Areas 1, 2 and 3A.

Monitoring and inspection by BHPBIC and its consultants for Dendrobium Mine during the three year period since commencement of mining of Longwall 5 in December 2008, including the most recent period of high rainfall since May 2010, shows that there has been no evidence of sustained subsidence-induced erosion of the valley slopes of Sandy Creek or Wongawilli Creek and its tributaries.

Cliff lines associated with Wongawilli Creek and its tributaries in Area 3B are no larger than those that have been previously mined under in Dendrobium Areas 1, 2 and 3A. Slopes are no steeper or more extensive than those that have been previously mined under in Areas 1, 2 and 3A. Soil landscape types are closely similar to those previously encountered in upper Wongawilli Creek. Based on that experience no significant erosive effects on water quality from the mining of Area 3B are expected.

Dendrobium Area 3B longwalls will not mine directly under the main channels of Wongawilli Creek and the cliff lines and slopes of the area are similar to those extensively mined under further upstream by Elouera Longwalls 1 through 6. Therefore, it has been concluded that it is highly unlikely that the mining of Area 3B would lead to any deleterious effects on water quality through erosive effects induced by cliff or surface instabilities resulting from mine subsidence. It is also unlikely that the mining of Area 3B will lead to significant fracturing of the creek bed in the main channel of Wongawilli Creek and it is therefore unlikely that any subsequent sub-bed diversion hydrologic and geochemical effects will occur. It is also not expected to alter bulk flows from these creeks or to significantly alter bulk water quality in the major sections of them. It is therefore considered highly unlikely that there would be any adverse effect on bulk drinking water supply quality in the Lake Avon system.

It is likely that fracturing will occur at the Donalds Castle Creek and the minor drainage lines overlying the longwalls. Mine subsidence can potentially impact on the quality of water in the creeks due to leaching of minerals from freshly fractured bedrock. Such impacts tend to be temporary, localised and associated with low flow conditions. The impact is predicted to be minor.

While these effects are considered likely to be minor, the water quality monitoring protocols of the proposed Monitoring Plan outlined in the **SMP (Volume 2)** will ensure their early geochemical detection and assessment, and if needed, mitigating measures such as grouting of fractures may be deployed where it is appropriate to do so.

Impact Assessment

Ecoengineers have completed an assessment of potential water effects in the SMP Area including the Cordeaux River, Wongawilli Creek, Donalds Castle Creek and Lake Avon. (**Attachment B**). The impacts outlined in the report by Ecoengineers are summarised in the sections below.

In terms of surface water quality and flow in Dendrobium Area 3B, key considerations were given to whether mining induced subsidence effects will adversely impact the following:

- Hydrologic productivity of the Cordeaux River and Avon headwater sub-catchments contained within Area 3B;
- The ecological integrity of the streams, swamps or the Lake due to changes in water quality;
- Raw water quality for drinking water supply purposes; and
- If any such effects arise, significant or otherwise, whether they attenuate with time and over what timescale(s) and/or are amenable to prediction and avoidance prior to mining or remediation post mining.

Streambed Fracturing Effects

Subsidence caused by longwall mining beneath creeks and riverbeds can produce a complex suite of physico-chemical effects. Hydrological measurements, visual observations and water quality monitoring in the Southern Coalfield have indicated the principal effects of subsidence beneath creeks and riverbeds. These are discussed in the Dendrobium 3A SMP (Cardno, 2007) and **Attachment B**.

It has been demonstrated that adequate standoffs from the sides or ends of longwalls from major watercourses can avoid the above-described hydrologic and geochemical effects (Ecoengineers, 2012). Recent examples are provided in **Attachment B**.

During the mining of Dendrobium Area 3A, Longwalls 6 and 7 were offset from Wongawilli Creek such that no direct impacts have been observed within the stream. On this basis it is unlikely that the mining of Area 3B will lead to significant creek bed fracturing and subsequent sub-bed diversion hydrologic and geochemical effects in Wongawilli Creek or Lake Avon.

The current assessment of the effects of longwall mining on fracturing of creek beds included results from all pre-and post-mining monthly Wongawilli stream chemistry data, and therefore takes into account the entire period during which both Longwall 6 and Longwall 7 were mined beneath the Wongawilli Creek catchment.

This assessment found no evidence of significant change in any key water quality parameters at Wongawilli site WWM3, located immediately downstream of Longwall 6, nor further downstream at site WWL2.

The data indicates that if there has been fracturing in Wongawilli Creek adjacent to Longwalls 6 and 7, or any other minor eastern tributaries lying over Longwalls 6 and 7, it has been very minor and of limited consequence.

Ferruginous Springs

Induction of ferruginous springs as a consequence of mining-related subsidence has been identified in the Southern Coalfield in sub-catchments of the Nepean, Cataract and Georges River.

Mining-related subsidence can have the effect of delaminating erosion surfaces and bedding planes within and between strata. These effects are predicted to occur preferentially along the interfaces between materials with different elastic properties. It is now recognised that subsidence, as a consequence of longwall mining, has the potential to induce dilation and enhancement of interfacial permeability of variable duration, at the sub-horizontal interface between sub-cropping Hawkesbury Sandstone and an overlying Wianamatta Shale or Mittagong Formation-based outcrop.

A portion of Area 3B is mantled by outcropping Mittagong Formation-based clay-rich soils occupying several catchments at the 1 – 2 km^2 scale, some of which drain via steep (10 – 20%) slopes with sandstone outcrops southwest of the Native Dog Creek Arm of Lake Avon. It is therefore considered that shallow ferruginous springs may be induced in the slopes of some sub-catchments over Area 3B. Such an effect, if it does occur, is likely to be largely aesthetic rather than posing any adverse impact on stream ecology due to the relatively short length, high gradients and aeration coefficients applying in the ephemeral creeks potentially involved. Notwithstanding this, specific water quality monitoring sites have been proposed for this part of Area 3B to provide early detection and ongoing assessment of this potential effect.

Drainage of Mittagong Formation-based landscape type to the northwest of tributaries of Donalds Castle and Wongawilli Creeks occurs over much longer distances of far lower slopes and there are numerous intervening upland swamps. It is considered unlikely that springs would be induced in this area and if they were, would be likely to occur around the margins of swamps or upslope of swamps and their effects be largely attenuated by those landscape features.

Water Quality Impacts on Water Supply Reservoirs

There is good evidence from five years of monitoring that there has been no significant effect, in the short or long term, on either bulk raw water quality or even drinking water quality in the Native Dog Creek Arm of Lake Avon, despite Native Dog Creek being directly undermined by Elouera Colliery longwalls, causing creek bedrock fracturing.

Due to the standoffs from Wongawilli Creek of the Area 3B longwalls, it is not expected any significant fracturing and sub-bed flow diversions will occur in Wongawilli Creek to alter flows or water quality other than minor impacts. Due to the substantial distance downstream it is predicted there will be no reduction (other than negligible reduction) in the quality or quantity of surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.

Due to the standoffs from Lake Avon of the Area 3B longwalls, it is not expected there will be a reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Avon. In addition, due to the substantial size of the Lake Avon system, it is predicted that there will be no measurable reduction in the quality or quantity of surface within Lake Avon.

Based on past experience from Wongawilli and Native Dog Creeks which were directly mined under by Elouera Colliery longwalls, it is also considered highly unlikely that there would be any adverse effect on bulk drinking water supply quality in the Lake Avon or Cordeaux River (into which Donalds Castle and Wongawilli Creeks discharge) systems.

Recommendations

The recommendations currently in place for Dendrobium Area 3A should be continued for Area 3B. This includes undertaking relevant monitoring such as rainfall, surface flows and water quality, and management measures as outlined in Section 17 of the Dendrobium Area 3B SMP **Volume 2**.

7.7 CREEKS

The following sections describe the potential physical changes to creeks within the SMP Area. The potential impacts from any physical changes to the creeks in the SMP Area on ecology are discussed in **Section 7.5** and water quality in **Section 7.6.2.**

7.7.1 Wongawilli Creek

Subsidence Effects

The proposed longwalls do not mine directly beneath the creek and the section of the creek within the SMP Area has not been previously mined beneath (although the adjacent mining of Area 3A is included in the modelling). As such the maximum predicted subsidence for the creek is less than 20 mm (refer **Table 7.6**).

As the creek will not be directly undermined a solid coal factor of 0.7 has been used in calculating the predicted valley related upsidence and closure movements (using ACARP method – refer **Section 3**).

The maximum predicted subsidence along the Creek is less than 20 mm, thus the predicted conventional tilts along the creek are expected to be small (MSEC, 2012). If the creek experienced subsidence slightly greater than 20 mm, conventional tilts would be less than 0.5 mm/m (i.e. less than 0.1%). The maximum predicted total conventional tensile and compressive strains for Wongawilli Creek, based on applying a factor of 15 to the maximum predicted conventional curvatures, are in the order of survey tolerance (i.e. less than 0.3 mm/m).

The maximum predicted upsidence in Wongawilli Creek is 160 mm and the predicted changes in grade resulting from upsidence are less than 1mm/m (i.e. less than 0.1%).

Detailed predictions for mapped boulder fields and riffles along the creekline are provided in the MSEC (2012) Assessment (refer **Attachment A**), but do not vary significantly from the above.

Table 7.6 - Maximum Predicted Total Subsidence, Upsidence and Closure for Wongawilli Creek resulting from the Extraction of the Proposed Longwalls

Location	Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Wongawilli Creek	After LW 8 (Area 3A)	<20	110	140
	After LW9	<20	130	170
	After LW10	<20	130	190
	After LW11	<20	140	210
	After LW12	<20	140	210
	After LW13	<20	140	210
	After LW 14	<20	140	210
	After LW15	<20	140	210
	After LW16	<20	140	210
	After LW17	<20	140	210
	After LW18	<20	160	210
	After LW19 (Area 3A)	<20	160	210

Impact Assessment

MSEC (2012) have demonstrated that the most relevant parameter for assessing the potential for subsidence impacts along the Creek is the predicted closure movements, as discussed in **Attachment A**.

The potential impacts along Wongawilli Creek have been reduced by setting back the finishing ends of the longwalls which limits the predicted mine subsidence movements at key features along the creek to the following predicted maximums:

- Valley closure of 200 mm.
- Conventional tensile strain of 0.5 mm/m.
- Conventional compressive strain of 2 mm/m.

Mine subsidence movements have the potential to fracture or reactivate existing joints within creek beds. Previous mining in the Southern Coalfield indicates that mining induced fracturing in bedrock is common in sections of streams that are located directly above extracted longwalls. Minor fracturing has also been found to occur beyond goaf areas, the majority of which have been within the limit of conventional subsidence. In a small number of cases this has occurred up to 400 m from the extracted longwall goaf edges. The fracturing of sandstone due to conventional subsidence movement in the Southern Coalfield has generally not been observed to occur where the conventional tensile strain is less than 0.5 mm/m and the compressive strain less than 2 mm/m. The maximum predicted total conventional tensile and compressive strains at Wongawilli Creek are both less than 0.3 mm/m.

The predicted closure slightly exceeds 200 mm away from the mapped rockbars and riffles, which occurs for only a short section of the creek, with a maximum value of 210 mm. The approach of maintaining a maximum predicted closure of 200 mm at the mapped rockbars and riffles, whilst slightly exceeding 200 mm closure elsewhere along the creek, is consistent with the approach adopted in Report No. MSEC404, which supported the Bulli Seam Operations Part 3A Application.

The potential for the fracturing of bedrock and, hence, the potential for surface water flow diversions along Wongawilli Creek has been assessed using case studies from the Southern Coalfield where previous longwalls have been mined near to or directly beneath streams.

Adopting a maximum predicted closure of 200 mm for the mapped rockbars and riffles along Wongawilli Creek should be viewed as an indication of low probability of impact rather than certainty. There are many pools that have not experienced flow diversion even though the predicted total closure was well above 200 mm. It cannot be assumed, therefore, that all pools will be drained when the predicted total closure is greater than 200 mm. Similarly, it is possible that flow diversion impacts will be observed, in the future, at sites where the predicted total closure is less than 200 mm.

The adoption of the 200 mm closure criteria has resulted in the proposed Longwalls 9 to 17 to be setback more than 150 metres from all the mapped rockbars and riffles. There are only three rockbars which are located within 150 metres of the proposed Longwall 18, which are WC-RB51, WC-RB55 and WC-RB56.

There are no riffles identified within 150 metres of Longwall 18. Whilst there are three rockbars identified within 150 metres of Longwall 18, extensive experience will be gained during the extraction of the earlier Longwalls 9 to 17, which will allow the impact assessments to be reviewed, prior to these rockbars experiencing mine subsidence movements.

It has been assessed, therefore, that it is unlikely that significant fracturing or surface water flow diversions would occur along Wongawilli Creek as a result of the extraction of the proposed Longwalls 9 to 18. This assessment has been based on limiting the predicted closure at the mapped rockbars and riffles to 200 mm and, as a result, the proposed longwalls have been setback more than 150 metres from the majority of the mapped rockbars and more than 150 metres from all of the mapped riffles.

It should be noted, however, that minor fracturing could still occur in the bed of Wongawilli Creek as a result of the extraction of the proposed longwalls. Based on previously observed fractures in the beds of streams adjacent to longwall mining in the Southern Coalfield, it is possible that minor fractures could occur within 400 metres from the proposed longwalls. Any fracturing that does occur in the bed of the creek would be expected to be isolated and of a minor nature and not result in any significant surface water flow diversions.

The average gradient of Wongawilli Creek is approximately 10 mm/m. Although the creek has a relatively shallow natural gradient it is unlikely that there would be any significant increases in the levels of ponding, flooding or scouring of the creek banks as the maximum changes in grade of the creek bed is very small, i.e. less than 0.1% (MSEC, 2012). There is a possibility for small localised changes to occur, where maximum changes in grade coincide with existing pools or other features however, changes are not expected to result in adverse impacts.

The Waterfall WC-WF54 is located 75 m east of the finishing end of the proposed Longwall 18. The waterfall is a ‘horse shoe’ shaped cliff which wraps around both sides of the valley of Wongawilli Creek.

The Waterfall is expected to experience less than 20 mm subsidence as a result of the extraction of the proposed longwalls. The waterfall may experience subsidence greater than 20 mm, however it would not be expected to experience any significant conventional tilts, curvatures or strains.

A number of waterfalls occur within the Southern Coalfield, including Sandy Creek in Dendrobium Area 3A and within Elouera Colliery. Based on the previous experience of mining in the vicinity, but not directly beneath cliffs in the Southern Coalfield, the likelihood of a large cliff instability at the Waterfall WC-WF54 is considered to be low. However, there is a possibility for isolated rock falls.

As the majority of past experiences was based on cliffs lined along the valley sides, rather than the ‘horse-shoe’ cliff that characterises WC-WF54 it is recommended that appropriate monitoring and management strategies are developed to management the potential impacts at the WC-WF54.

As WC-WF54 is a key feature of Wongawilli Creek it will have the same performance measure of “minor impacts” (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality). In addition, it is not expected that the proposed mining in Area 3B will affect the structural integrity of the waterfall.

Increased Subsidence Predictions

If conventional subsidence exceeded the predicted levels by a factor of 2 (an additional 100% of prediction as per Section 6.10.3 of the SMP Guidelines), the conventional tilts along Wongawilli Creek would still be very small. Any minor changes in the levels of ponding, flooding and scouring of the banks would remain small in comparison with those experienced during natural flooding events.

If upsidence and closure movements exceed predictions by a factor of 2, fracturing and dilation of creek beds would likely occur, which may result in some surface water flow diversion. It should be noted, however, that the method used to predict the valley related movements adopts conservative upper-bound prediction curves and it is unlikely, therefore, that these movements would be exceeded by any more than 15 %.

Recommendations

It is recommended that the closure movements along Wongawilli Creek including Waterfall WC-WF54, are monitored during the extraction of the proposed longwalls as detailed in Section 15 of the Dendrobium Area 3B SMP **Volume 2**. It is also recommended that management strategies are developed for the creek, in consultation with key stakeholders, such that any impacts can be identified and, if required, remediated accordingly. With these strategies in place it is unlikely that there will be any significant impacts on the creek from mining the proposed longwalls.

7.7.2 Donalds Castle Creek and Drainage Lines

Subsidence Effects

The upper reaches of Donalds Castle Creek and other small drainage lines will be directly undermined by the proposed longwalls. Donalds Castle creek may experience subsidence of up to 2050 mm (refer **Table 7.7**).

The maximum predicted increasing and decreasing tilts along Donalds Castle Creek are both 20 mm/m (i.e. 2.0 %), which represent changes in grade of 1 in 50. The maximum predicted curvature for Donalds castle Creek is 0.50km^{-1} for both hogging and sagging (refer **Table 7.8**). The natural gradient of Donalds Castle Creek, directly above the proposed longwalls, varies between a minimum of 10 mm/m and a maximum of 100 mm/m, with an average natural gradient of 30 mm/m.

The maximum predicted upsidence and closure movements for Donalds Castle Creek are 370 mm and 280 mm respectively (refer **Table 7.9)**.

The predicted tilts and curvatures due to the valley movements are small and not considered significant when compared with the conventional values provided in the following Tables.

Table 7.7 - Maximum Predicted Total Subsidence, Upsidence and Closure for Donalds Castle Creek resulting from the Extraction of the Proposed Longwalls

Location	Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Donalds Castle Creek	After LW9	1625	150	100
	After LW10	2025	280	190
	After LW11	2050	320	230
	After LW12	2050	340	260
	After LW13	2050	360	270
	After LW 18	2050	370	280

Table 7.8 - Maximum Predicted Total Conventional Tilt and Curvatures for Donalds Castle Creek resulting from the Extraction of the Proposed Longwalls

Location	Longwall	Maximum Predicted Total Increasing Tilt (mm/m)	Maximum Predicted Total Decreasing Tilt (mm/m)	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Donalds	After LW9	20	20	0.50	0.50

Castle Creek	After LW10	20	20	0.50	0.50
	After LW11	20	20	0.50	0.50
	After LW12	20	20	0.50	0.50
	After LW13	20	20	0.50	0.50
	After LW 18	20	20	0.50	0.50

Table 7.9 - Maximum Predicted Total Subsidence, Upsidence and Closure at the Drainage Lines resulting from the Extraction of the Proposed Longwalls

Location	Name	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Drainage Lines	DC13	1500	250	225
	ND1	2350	275	425
	WC15	2600	725	700
	WC21	2550	700	700

The remaining drainage lines which are located directly above the proposed longwalls could experience the full range of predicted subsidence movements (refer **Table 7.9**).

The maximum predicted tilt for the drainage lines and tributaries within the SMP Area is 40 mm/m (i.e. 4.0 %), which represents a change in grade of 1 in 25. The average natural gradients of the drainage lines vary considerably, directly above the proposed longwalls, from less than 10 mm/m (i.e. less than 1 %, or 1 in 100) to more than 200 mm/m (i.e. more than 20 %, or 1 in 50).

The maximum predicted conventional curvatures for the streams, based on applying a factor of 15 to the maximum predicted conventional curvatures are 15mm/m for both the tensile and compressive strains.

The maximum predicted curvature for drainage lines within the SMP Area is 1.0km^{-1} for both hogging and sagging. The maximum predicted upsidence and closure movements for the Drainage Lines DC13, ND1, WC15 and WC21 are 725 mm and 700 mm, respectively.

The drainage lines are also likely to experience elevated compressive strains, resulting from valley related movements, which is discussed further in the impact assessment.

Impact Assessment

Increased levels of ponding and flooding of nearby riparian areas can occur in locations where mining induced tilts oppose and are greater than the natural stream gradients that exist before mining. Mining can also potentially increase scouring of banks in locations where mining induced tilts considerably increase the natural stream gradients.

The maximum predicted changes in grade in Donalds Castle Creek and other streams are similar to the natural gradients in the flatter parts of the creek. There are no predicted mining induced reversals of grade along the creek. Any changes in the levels of ponding, flooding and scouring of the banks would be expected to be very localised where maximum tilts occur or the natural gradients are very flat.

Elevated compressive strains across alignments of the streams are also likely to result from the valley related movements. These are more difficult to predict, however compressive strains between 10 mm/m and 20 mm/m have occurred above previously extracted longwalls, where the magnitudes are similar to or greater than those predicted for Donalds Castle Creek and the drainage lines. Fracturing of the uppermost bedrock has been observed to occur where tensile strains have been greater than 0.5 mm/m or where compressive strains are greater than 2 mm/m. The depth of buckling or dilation of the uppermost bedrock is usually to a depth of 10 m to 15 m (MSEC, 2012).

Based on previous experience at the mine it is expected that fracturing will occur in the bedrock along Donalds Castle Creek and the drainage lines which are directly mined beneath. It is also possible that surface flow diversion could also occur in some locations along these streams, however based on previous experience at the mine, the incidence of this occurring has been considered low.

Any surface cracking would tend to be naturally filled with soil and alluvial materials during subsequent flow events, especially during times of heavy rainfall. If any surface cracks were found not to fill naturally, some remedial measures may be required at the completion of mining. Where necessary any significant surface cracks in the stream beds could be remediated by grouting techniques previously deployed in the Georges River.

Increased Subsidence Predictions

If the predicted conventional subsidence movements along the drainage lines were increased by a factor of up to 2, increased levels of ponding and flooding could occur upstream of the longwall chain pillars and goaf edges and increased levels of scouring could occur downstream of the longwalls chain pillars.

If the actual curvatures, strains or valley related movements exceeded those predicted by a factor of 2, it would be expected that the extent of fracturing in the uppermost bedrock would increase along the sections of creek and drainage lines located directly above the proposed longwalls. As the depth of fracture or dilation of the bedrock is only expected to be10 m to 15 m no loss of surface water from the catchment would be anticipated.

Recommendations

BHPBIC has developed a number of management strategies for creeks and drainage lines which have been directly mined beneath by previously extracted longwalls at Dendrobium Mine. It is recommended that similar management strategies are developed, in consultation with key stakeholders, for the creek and drainage lines within the SMP Area. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the creek and drainage lines resulting from the extraction of the proposed longwalls.

7.8 GROUNDWATER

Subsidence Effects

The extraction of longwalls results in deformation throughout the overburden strata as described in **Attachment A**. At Dendrobium mine, the upper layer of overburden strata are relatively strong sandstones. The depth of cover above the overburden varies between 310 m and 450 m and, therefore, it is possible that the fractured zone could extend up to the surface, where the depths of cover are the shallowest. In other places, where the depths of cover are higher, it is expected that a *Constrained Zone* or *Continuous Deformation Zone* could occur between the fractured zone and the surface if the local geology is suitable.

The height of fracturing (based on significant bed separation and vertical dilation measured by extensometers) does not imply that vertical permeability is increased; it simply means that bed separation and horizontal permeability has increased.

The aquifers within the SMP Area are likely to be subject to the full range of predicted subsidence movements. The maximum predicted systematic tilt within the SMP Area is 40mm/m, and the associated minimum radii of curvatures are 0.9 km hogging and 1.0 km sagging.

Subsidence Impacts

Shallow aquifers associated with the drainage lines and upland swamps, have been identified within the SMP Area. Descriptions of these aquifers and potential impacts of the proposed longwalls in Area 3B on the groundwater resources are provided in **Attachment A** (MSEC, 2011), **Attachment B** (Ecoengineers, 2012), and **Attachment C** (Coffey Geotechnics), 2012), and summarised below.

The fracturing of bedrock and the dilation and differential movement between strata layers is likely to result in an increased hydraulic conductivity of water and gas in the strata above the longwalls. The movement of water and gas is likely to be largely inhibited by the known aquitards at different horizons, the most noteworthy being the Bald Hill Claystone. It has been largely recognised that there is no deep aquifer in the bulk of the Hawkesbury Sandstone in this area (Ecoengineers, 2012).

The upper strata layers are also likely to be located within the “constrained zone”, where it exists above the longwalls, which is described in **Section 4.8** of **Attachment A**. The constrained zone comprises confined rock strata which have sagged but, because they are constrained, having absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present, as well as discontinuous vertical cracks, usually on the underside of thick strong beds.

Thus, in these situations surface and near-surface groundwater hydrologic systems are separated from these well recognised claystone aquiclude units as well as relatively tight sandstones.

Baseflows of the drainage systems are provided by semi-confined hillslope aquifers in weathered sandstone slopes and swamps also do not appear to be connected to any deep water bearing strata.

Whilst underground mining in Area 3B will clearly influence the hydrogeologic conditions through the effects of subsidence upon the rockmass, the effect will be concentrated in the lower parts of the rockmass. It is expected that the current groundwater conditions, and their natural fluctuations, will remain unchanged in the majority of the Hawkesbury Sandstone whilst there will be minor influences only in the Bulgo Sandstone. Outside the collapsed and fractured zones, there is unlikely to be a significant increase in the hydraulic conductivity of sub-surface water in the strata.

The groundwater resources and hydrogeology of Area 3B is considered to be highly similar to the characteristics present in Area 3A. Therefore modification to the hydrogeology predicted to occur and observed within Area 3A as a result of longwall extraction is also likely to be exhibited to a similar extent within the SMP Area. Further discussion of the groundwater resources and hydrological impacts of longwall mining is therefore provided in the Dendrobium Area 3A SMP (Cardno, 2007).

Due to the standoffs from Wongawilli Creek of the proposed longwalls it is not expected that any fracturing resulting in sub-bed flow diversion will occur in Wongawilli Creek to alter outflows from this catchment.

Modelling undertaken by Coffey (2012) utilised the MODFLOW-SURFACT Version 3 numerical model to determine the estimated impacts of mining in the Dendrobium Mine Area 3B on the groundwater system and Lakes Avon and Cordeaux. The following results were obtained through the use of the model:

- The modeled probability distributions for induced seepages from Lakes Avon and Cordeaux, due to mining in Area 3B, fall in the tolerable range and comply with the probability criterion applied by the NSW Dams Safety Committee for Lake Cordeaux.

- The modeled Decile 5 induced seepages from Lakes Avon and Cordeaux, due to mining in Area 3B, are 0.02 and 0.03 ML/day respectively.
- The modeled Decile 5 diverted baseflows for Lakes Avon and Cordeaux, due to mining in Area 3B, are 0.60 and 0.47 ML/day respectively.
- The modeled Decile 5 diverted baseflow for rivers in the Northwest Catchment, due to mining in Area 3B with, is 0.95 ML/day.

Recommendations

The recommendations currently in place for Dendrobium Area 3A should be continued for Area 3B. This includes continuing relevant monitoring of installed piezometric pressure transducers and management measures as outlined in Section 16 of the Dendrobium Area 3B SMP **Volume 2**.

7.9 ARCHAEOLOGICAL SITES

Subsidence Effects

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the archaeological sites is provided in **Table 7.10**.

Table 7.10 - Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Archaeological Sites Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
52-2-1562	875	18	0.25	0.04
52-2-1563	<20	<0.5	<0.01	<0.01
52-2-1564	<20	<0.5	<0.01	<0.01
52-2-1623	50	1	0.02	<0.01
52-2-1626	1875	25	0.40	0.55
52-2-1627	950	10	0.15	0.06
52-2-1628	225	8	0.20	0.02
52-2-1771	<20	<0.5	<0.01	<0.01
52-2-1772	<20	<0.5	<0.01	<0.01
52-2-1773	<20	<0.5	<0.01	<0.01
52-2-1774	<20	<0.5	<0.01	<0.01
52-21775	<20	<0.5	<0.01	<0.01
52-2-1776	<20	<0.5	0.02	<0.01
52-2-1777	<20	<0.5	<0.01	<0.01
52-2-2208	1650	20	0.10	0.45
52-2-2209	<20	<0.5	<0.01	<0.01
52-2-2229	2400	20	0.20	0.70

52-2-2246	2025	25	0.45	0.60
52-2-2248	275	7	0.20	0.01
52-2-3088	575	9	0.20	0.15
DM16	<20	<0.5	<0.01	<0.01
DM17	<20	<0.5	<0.01	<0.01
DM2	500	3	0.20	0.02
DM21	1375	25	0.55	0.08
DM22	<20	<0.5	<0.01	<0.01

The predicted tilts provided in the above table are the maxima after the completion of any or all of the proposed longwalls. The predicted curvatures provided in the above table are the maxima at any time during or after the extraction of each of the proposed longwalls.

The maximum predicted conventional strains for the archaeological sites based on applying a factor of 15 to the maximum predicted conventional curvatures, are 8 mm/m tensile and 11 mm/m compressive. The analysis of strains measured in the NSW Coalfields, for previously extracted longwalls having similar width-to-depth ratios and extraction heights as the proposed longwalls is provided in **Section 4.3** of **Attachment A**.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of anomalous movements and downslope movements. An analysis of strain resulting from both conventional and non-conventional anomalous movements is provided in **Section 4.3** of **Attachment A.**

Subsidence Impacts

Aboriginal archaeological sites within the SMP Area include sandstone overhangs and outcrops with art and scattered artefacts. Extensive studies of the impacts to sandstone shelters within the Woronora Plateau have indicated a number of common characteristics are present in shelters that exhibit subsidence related impacts (Sefton, 2000 and Biosis, 2012). These characteristics include the following:

- An overhang size greater than 50 m^3
- The presence of joints or bedding planes with active water seeps
- Predicted subsidence greater than 300 mm
- Shelters with an aspect of 90 degrees to the goaf
- Landform in which the shelter is located
- Location of shelter in relation to the goaf (There are twelve sandstone overhang or outcrop sites located above the proposed longwalls in Area 3B)
- Systematic curvatures and strains

A total of 16 variables have been are used by Biosis (2012) to assess the impact of mining induced subsidence on archaeological heritage. These characteristics have been selected by Sefton (2000) to develop an assessment methodology which is known as ‘Principal Components Analysis’. This method has thus been further developed and employed by Biosis Research (2012).

The impact assessment criteria used to assign levels of risk to the Principal Components Analysis for the SMP Area is summarised below:

Moderate - Impacts are possible and are likely to occur in 50% of cases:

- The shelter has a volume larger than 50 cubic metres;
- The shelter has joints or bedding planes subject to water seepage; and
- Maximum predicted subsidence is greater than 300 mm.

Low - Impacts are unlikely and likely to only occur in 5% of cases:

- The shelter has a volume larger than 50 cubic metres; and
- Maximum predicted subsidence is greater than 300 mm

Very Low - Impacts are highly unlikely and likely to occur in less than 1% of cases:

- The shelter has a volume less than 50 cubic metres and maximum predicted subsidence is greater than 300 mm; or
- The shelter has a volume more than 50 cubic metres and maximum predicted subsidence less than 300 mm.

Negligible -

- The shelter has a volume less than 50 cubic metres;
- Maximum predicted subsidence is less than 300 mm, tensile strain predictions are <0.5mm/m and compressive strain estimates are <0.01mm/m; and
- Impacts are unlikely to occur and likely to be indistinguishable from natural background environment effects.

A summary of the predicted risk of impact to Aboriginal sites within the SMP Area is provided in **Table 7.11**. Further discussion of the assessment process and results are provided in **Attachment F**.

Table 7.11 - Summary of Risk of Impact to Aboriginal Sites in the Study Area

Site Number	Site Name	Site Type	Risk of Impact
52-2-1562	Donald Castle Creek Site 1; Cordeaux Catchment area	Shelter with Art	Very Low
52-2-1623	Browns Road Site 8	Shelter with Deposit	Very Low
52-2-1626	Browns Road Site 11	Shelter with Art	Very Low
52-2-1627	Browns Road Site 12	Shelter with Art	Low
52-2-1628	Browns Road Site 13	Shelter with Art	Very Low
52-2-1771	Upper Avon 35	Shelter with Deposit	Very Low
52-2-1772	Upper Avon 36	Shelter with Art	Very Low
52-2-1773	Upper Avon 37	Shelter with Deposit	Negligible
52-2-1774	Upper Avon 38	Shelter with Art	Very Low
52-2-1775	Upper Avon 39	Shelter with Deposit	Very Low
52-2-1776	Upper Avon 40	Shelter with Art, Shelter with Deposit	Very Low
52-2-1778	Upper Avon 41	Shelter with Deposit	Very Low

Site Number	Site Name	Site Type	Risk of Impact
52-2-2208	Dendrobium 1	Shelter with Deposit	Low
52-2-2209	Dendrobium 2	Shelter with Art	Very Low
52-2-2229	SITE 1 - DB1	Shelter with Art	Very Low
52-2-2246	Dendrobium 6	Isolated Artefact	Negligible
52-2-2248	Dendrobium 7	Shelter with Art	Very Low
52-2-3068	Dendrobium 8	Shelter with Art; Grinding Grooves	Low
52-2-3640	DM 16	Shelter with Art	Very Low
52-2-3641	DM 17	Shelter with Deposit	Very Low
52-2-3645	DM 21	Shelter with Art; Shelter with Deposit	Low
52-2-3646	DM 22	Shelter with Art	Negligible
52-2-3878	DM 2	Shelter with Deposit	Low

Recommendations

It is recommended that a detailed survey of the archaeological sites is undertaken and a monitoring programmed implemented to record the effects of mine subsidence at these sites. Baseline and ongoing monitoring, as well as management of the sites, is provided in section 21 of the Dendrobium Area 3B SMP **Volume 2**.

7.10 SIGNIFICANT MAN MADE FEATURES

7.10.1 The Abandoned Maldon-Dombarton Railway Corridor

Subsidence Effects

The predicted profiles of conventional subsidence, tilt and curvature along the abandoned railway corridor, resulting from the extraction of the proposed longwalls, are provided in **Appendix C** of MSEC (2012). A summary of the maximum predicted values of total conventional subsidence, tilt, and curvature, resulting from extraction of the proposed longwalls is provided in **Table 7.12**.

Table 7.12 - Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Abandoned Railway Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Abandoned Railway Corridor	2550	30	0.55	0.70

The maximum predicted conventional strains for the abandoned railway corridor based on applying a factor of 15 to the maximum predicted conventional curvatures, are 8 mm/m tensile and 11 mm/m compressive.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the cuttings and embankments is provided in **Table 7.13**.

Table 7.13 - Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Abandoned Railway Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
MDB-F1	1050	15	0.25	0.25
MDB-F2	1300	15	0.20	0.05
MDB-F3	2025	20	0.15	0.5
MDB-F4	1525	20	0.35	0.10
MDB-F5	2075	25	0.35	0.45
MDB-F6	2075	15	0.15	0.45
MDB-F7	1925	15	0.20	0.30
MDB-F8	2150	25	0.40	0.50
MDB-F9	1400	25	0.40	0.10
MDB-F10	2350	30	0.50	0.65
MDB-F11	2575	20	0.35	0.45
MDB-F12	2575	30	0.55	0.70
MDB-F13	200	7	0.15	<0.01

The parameters provided in the above table are the maxima values within a 20 metre radius of the extents of each feature.

Subsidence Impact

The maximum predicted change in grades for the abandoned railway cuttings and embankments are small when compared to the as-built grades of the cuttings and embankments, which are similar to or greater than 1 in 1 and, therefore, the tilts are unlikely to result in any significant impact on the stability of these features.

It is expected that the magnitudes of the predicted curvatures and strains, that the rock cuttings would experience mining induced impacts, including the fracturing and mobilisation of the joints and some spalling of the exposed rock faces which could result in isolated rock falls. The potential impacts area expected to be of a similar nature to that observed when Elouera Longwalls 10 and 11 mined beneath the abandoned railway corridor to the south of the proposed longwalls.

The earth embankments could also experience cracking as a result of mining induced curvatures and strains. Whilst surface cracking is unlikely to result in embankment instability, it is possible that soil erosion channels could develop at the larger cracks if these were left untreated.

Mining induced tilts could also adversely impact the serviceability of the drainage culverts, by reducing or reversing the as-built grades, in some cases, which could then affect the flow of water through these culverts.

The drainage culverts could also experience cracking in the pipes or the headwalls as a result of the mining induced curvatures and strains. It is unlikely that these impacts would result in the collapse of the culverts, as this has not occurred previously in the NSW Coalfields where there is extensive experience of mining beneath culverts.

Recommendations

It is recommended that persons who enter the SMP Area are made aware of the potential for rock falls in the cuttings along the corridor resulting from the extraction of the proposed longwalls. The conditions of the rock faces should be visually monitored throughout the mining period until such time that the mine subsidence movements have ceased, as may be required. It is also recommended that periodic visual inspections of the abandoned railway corridor are undertaken as the proposed longwalls mine beneath it. With the appropriate management strategies in place, it is unlikely that there would be any significant impacts on the corridor as a result of mining.

7.10.2 Unsealed Roads

Subsidence Effects

The unsealed roads are located across the SMP Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for unsealed roads resulting from the extraction of the proposed longwalls is provided in **Table 7.14**.

Table 7.14 - Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Unsealed Roads Resulting from the Extraction of the Proposed Longwalls 9 to 18

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Unsealed Roads	2800	40	1.0	1.0

The maximum predicted conventional hogging and sagging curvatures for the unsealed roads and tracks resulting from the extraction of the proposed longwalls, are both 1km^{-1}, which represents a minimum radius curvature of 1 km.

The maximum predicted conventional strains for the unsealed roads, based on applying a factor of 15 to maximum predicted conventional curvatures, are both 15 mm/m tensile and compressive.

Subsidence Impact

The maximum predicted conventional tilt for the unsealed roads, resulting from the extraction of the proposed longwalls is 40 mm/m which represents a change in grade of 1 in 25. The predicted maximum tilt could result in some changes in the surface water drainage for the unsealed roads and tracks. Any changes would be localised and it would be expected that any adverse impacts could be remediated.

It is expected at the magnitude of predicted curvatures and strains, that cracking and heaving of the unsealed road surfaces would occur as a result of the extraction of the proposed longwalls.

The unsealed roads in Dendrobium Areas 1, 2 and 3A were maintained in safe and serviceable conditions during mining using normal road maintenance techniques. It is expected therefore that the unsealed roads in Area 3B could also be maintained using similar remediation measures.

Recommendations

It is recommended that the unsealed roads are visually monitored as the proposed longwalls mine beneath them, so that any impacts can be identified and rectified accordingly. It is also recommended that management strategies are developed for the unsealed roads, in consultation with the SCA. With these strategies in place it is likely that the unsealed roads can be maintained in a safe and serviceable condition throughout the mining period.

7.10.3 Drainage Culverts

Subsidence Effects

Drainage culverts within the SMP Area could experience the full range of predicted subsidence movements.

The maximum predicted tilt within the SMP Area of 40 mm/m (i.e. 4%) represents a change in grade of 1 in 25. The predicted changes in grade could be of sufficient magnitude to affect the flow of water through the culverts in the location of maximum tilt.

The maximum predicted conventional strains for the drainage culverts based on applying a factor of 15 to the maximum predicted conventional curvatures, are both 15 mm/m tensile and compressive.

Subsidence Impact

The maximum predicted conventional strains for the drainage culverts could be of sufficient magnitude to result in cracking in the concrete culverts. Any impacted culverts could be readily repaired or, where required, the culverts can be replaced.

With remedial measures implemented, it is expected that the drainage culverts within the SMP Area could be maintained in a serviceable condition throughout the mining period.

Recommendations

It is recommended that the drainage culverts are visually monitored as the proposed longwalls mine beneath them, so that impacts can be identified and rectified accordingly. With remedial measures implemented it is likely that culverts will remain in a serviceable condition.

7.10.4 Dams, Reservoirs or Associated Works

Subsidence Effects

Lake Avon is located at a distance of 230 m from Longwall 16 at its closest point to the proposed longwalls. At this distance, the lake is predicted to experience conventional subsidence of less than 20 mm as a result of mining. While it is possible that the lake could experience subsidence slightly greater than 20 mm, it would not be expected to experience any significant conventional tilts, curvatures or strains.

Predicted movements of upsidence (50 mm) and closure (100 mm) for the Lake are relatively small, however it is possible that minor isolated cracking could occur in the bedrock.

Subsidence Impact

It is unlikely that any minor isolated cracking that occurs in the bedrock beneath the lake would result in any loss of water, as the depths of cracking resulting from valley related movements have been observed to be generally less than 10 m to 15 m (SCT, 2003 and Mills and Huuskes, 2004). Any minor isolated cracking in the bedrock beneath the Lake is likely to be filled by the alluvial materials and not result in any water loss from the system.

It is considered unlikely that there will be water quality impacts as a result of fracturing of the bedrock as there would be no continuous flow path through these structures.

Recommendations

It is recommended that BHPBIC consult with the SCA and DSC in relation to management of any potential impacts on Lake Avon. In addition, appropriate management strategies will be developed and implemented to ensure there is no unacceptable water loss from the lake. With these management strategies in place, it is unlikely that there would be any significant impacts on the lake resulting from the proposed mining.

7.10.5 Survey Control Marks

Subsidence Effects

The survey control marks are located across the SMP Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the SMP Area are provided in **Section 6**.

Impact Assessment

The survey control marks are expected to experience subsidence impacts. It will be necessary on the completion of longwall extraction to re-establish any survey control marks that will be required for future use.

Recommendations

Consultation between BHPBIC and the Department of Lands will be required to ensure that the survey control marks are reinstated at the appropriate time, as required.

8 RISK ASSESSMENT

In August 2007 AXY's Engineering facilitated a qualitative risk assessment for the Dendrobium Area 3A mine plan. AXY's Engineering was also engaged to undertake the risk assessment for Dendrobium Area 3B.

A risk assessment considers potential loss impacts including effects on Dendrobium Collieries strategic, business and operational objectives as well as third party and environmental aspects. Risk ranking is undertaken in accordance with the BHP Billiton Enterprise Wide Risk Management (EWRM) Standard Risk Matrix.

The objectives of the risk assessment were to:

- Assist Dendrobium Colliery in identification and control of subsidence risks associated with mining of Area 3B in accordance with:
  - BHP Billiton Policy and Standards;
  - Australian Standards;
  - Planning, Environmental, OH&S, Mining and other Legislation.
- Facilitate and record the risk assessment for the identification of hazards and assessment of risk in accordance with AS4360:2004, BHP Billiton EWRM Standard and MDG1010;
- Provide a report detailing the outcomes of the risk assessment, including:
  - Risk issues, causes and impacts;
  - Identification of existing risk mitigation controls;
  - EWRM risk rating;
  - Risk reduction strategy/actions.

High level risk issues were considered and recorded by the risk assessment team.

Attachment 2 (Analysis Worksheets) of **Attachment H** identifies all of the hazards, existing controls, risk rankings and any new treatment options and the people responsible for their implementation.

Attachment 5 (Risk Treatment Schedule) of **Attachment H** provides the new treatment options and the people responsible for their implementation. In addition a required date and sign off is also provided.

Attachment 3 and 4 (Risk Rank Order and Consequence Order) of **Attachment H** provides all of the identified hazards and treatment options in order of highest risk to lowest risk and from highest consequence to lowest consequence.

Areas of high risk that are more sensitive to impacts from mine subsidence can be further investigated to determine measures that will allow for the extraction of coal while having acceptable levels of impacts on the environment. As well as this formal risk assessment process, it has been customary for BHPBIC to develop and implement risk management plans with relevant stakeholders where the consequences of adverse impacts are considered high. This risk based approach to subsidence management will continue throughout the mining process.

9 CONSULTATION

The SMP Guidelines outline a process of community consultation regarding persons or organisations that may be impacted by predicted subsidence following extraction, this process has been applied to Dendrobium Area 3.

Extensive consultation has been undertaken with stakeholders from the commencement of the development of the management and monitoring programs (BHPB, 2005) and during the subsequent review process associated with the original monitoring and management for Areas 1, 2 and 3A. During this process BHPBIC has been involved in consultation with the Dendrobium Community Consultative Committee (DCCC), SCA, DP&I, NSW Fisheries, DSC, DPIM and DECC.

Previous SMPs (i.e. the SMP for Areas 1 and 2 and 3A) have also been subject to review from these stakeholders. The requirements and views of the various stakeholders have been addressed in these previous documents. The community consultation and outcomes from past SMP's are continuously revised and incorporated to update consultation strategies.

9.1 IDENTIFICATION OF RELEVANT STAKEHOLDERS

This SMP has been provided to key stakeholders as a draft and feedback has been incorporated into the SMP. The SMP has been presented and discussed with the DCCC on a number of occasions. Consultation with key stakeholders, including the DCCC, has involved a number of site visits to Area 3B.

Stakeholders have an interest in, or concern about subsidence issues that relate to the mining project include:

- OEH
- SCA
- DRE
- DCCC
- Rivers SOS
- Wollongong City Council (WCC)
- Wingecarribee Shire Council (WSC)
- Wollondilly Shire Council (WDSC)
- NSW Office of Water (NoW)
- NSW Mine Subsidence Board (MSB)
- Mt Kembla Community
- Tharawal Local Aboriginal Land Council
- Appin Area Community Working Group
- CSG External Affairs
- The wider Illawarra Coal community (e.g. Mt Kembla residents).

9.2 CONSULTATION PROCESS

Consultation undertaken with regards to mining in Dendrobium Area 3 has involved:

- Liaison with relevant Agencies
- Advertising Aboriginal heritage assessments in Local newspapers
- Community consultation via the DCCC
- Aboriginal consultation during the baseline archaeological survey
- Specific meetings with infrastructure owners.

9.3 INFRASTRUCTURE OWNERS CONSULTATION

This SMP and associated management plans will be developed in consultation with the appropriate infrastructure owners, such as the SCA, and will be based on the previous agreements in place for Area 3.

Regular meetings will be held with the SCA as appropriate to discuss pre-mining inspections, dilapidation surveys, mitigation options and proposed monitoring programs.

BHPBIC is continuing to work closely with owners of infrastructure, to develop strategies and management plans for the protection of the infrastructure and to ensure that any impacts are appropriately managed. These plans will be in place prior to subsidence of relevant infrastructure.

9.4 COMMUNITY CONSULTATION

The DCCC was established in January 2002 under the guidelines of the Dendrobium Consent (Schedule 8/Condition 9). The committee makes comments and recommendations about the implementation of environmental management plans, monitors compliance with the Dendrobium Consent and other matters relevant to the construction and operation of Dendrobium Colliery. The committee also acts as a conduit for information transfer from the broader community and discusses issues at regular meetings.

The DCCC membership comprises the following:

- An independent chairperson
- Up to five members of the local community
- Up to two members representing local environmental groups
- One representative of Wollongong City Council (WCC)
- Representatives from Dendrobium Mine and Illawarra Coal.

Minutes from the most recent DCCC meetings are available on the BHPBIC website:

www.bhpbilliton.com/regulatoryinformation

In 2002, Dendrobium Colliery, the community and Wollongong City Council created an agreement called the Dendrobium Community Enhancement Program (DCEP). The CEP resulted in an upfront payment of $600,000 directed to a WCC controlled trust fund with a further three cents per saleable tonne of coal directed to the fund.

The Community Enhancement Committee (CEC) is a committee established under the requirements of the original Dendrobium Consent and is responsible for assessing applications for funding made to the DCEP.

The committee is currently comprised of up to five community representatives and two Dendrobium Mine representatives. CEC meetings are held on a bi-monthly basis. Minutes are also provided on the BHPBIC website provided above.

BHPBIC is committed to working with the surrounding community in conducting its mining operations within the locality. The company has built a strong partnership with the community and contributes to the long-term wellbeing and social fabric of Wollongong and surrounding areas.

The proposal for Dendrobium Area 3B has been discussed in detail with the Dendrobium Community Consultative Committee at each meeting since 10 October 2011.

At each meeting slide shows are presented to the committee, a copy of a typical presentation is shown in **Attachment G**.

9.5 LANDOWNER CONSULTATION

The SCA is the only land owner in the SMP Area. Consultation with the SCA is addressed above.

9.6 ABORIGINAL COMMUNITIES CONSULTATION

Aboriginal consultation (including an archaeological assessment) has been undertaken by Biosis Research for the Dendrobium Area 3 Project, including discussions and field visits with representatives from a number of Aboriginal groups.

In accordance with the DECC's *Part 6 Approvals – Interim Community Consultation Requirements for Applicants* Biosis Research has notified the following bodies regarding proposed extraction at Dendrobium Area 3B:

- Illawarra Local Aboriginal Land Council;
- The Registrar of Aboriginal Owners;
- Native Title Services;
- The Wollondilly Shire Council; and
- OEH.

Public notifications and a notice for interested Aboriginal persons or groups to register and participate in the preparation of the archaeological assessment were placed in the Illawarra Mercury on Saturday 3 December and the Wollondilly Advertiser on Wednesday 7 December.

Written responses to the notifications were received from the following:

- Illawarra Local Aboriginal Land Council
- Korewal Elouera Jerrungurrah Tribal Elders Council
- Gary Caines
- Cubbitch Barta Native Title Claimants Aboriginal Corporation
- Wodi Wodi Traditional Owners
- National Koori Site Management
- Koori Site Consultants

In accordance with the DECC's *Part 6 Approvals – Interim Community Consultation Requirements for Applicants* stakeholders were provided with a methodology for the proposed cultural assessment and given 21 days to review the methodology and provide feedback. Formal responses regarding the cultural assessment methodology have been received from stakeholders.

Meetings to discuss broad cultural heritage issues with the project, and the general approach were held with the registered parties.

The SMP Area is within the boundaries of the Illawarra Local Aboriginal Land Council (LALC). The Cubbitch Barta and the Illawarra LALC have a long history of involvement in Aboriginal heritage management in the region. They have worked for many years with archaeologists and project managers recording archaeological sites, assessing impacts to the sites and providing cultural input to assist in the formulation of appropriate recommendations for the management of sites.

The cultural heritage report is being finalised prior to forwarding to the above listed Aboriginal groups for comment. Aboriginal groups will be requested to provide advice regarding the cultural significance of the heritage sites.

9.7 AGENCY CONSULTATION

Comprehensive and ongoing consultation between BHPPIC and relevant government agencies have been undertaken throughout the life of the Dendrobium Colliery Project.

This includes consultation undertaken with the following agencies:

- DP&I
- OEH
- DRE
- MSB
- SCA
- NoW
- DSC
- DPI-Fisheries.

Ongoing consultation has continued, and will include consultation for the Area 3B SMP and proposed extraction of Longwalls 9 to 18. A draft SMP was submitted to the abovementioned agencies for review, comment and input. The final SMP, this document, has been revised and is submitted to DRE and DP&I for approval.

10 STATUTORY REQUIREMENTS

A number of statutory requirements apply to the SMP Area and the proposed mining operation in relation to any potential subsidence impacts. A range of environmental legislation is applicable to mining in NSW and the DRE aims to promote the responsible development of the State's mining resources for the communities benefit.

These statutory requirements have previously been described and addressed in the Dendrobium Area 3A SMP (CFR, 2007). Adherence to these statutory requirements will be continued and applied to Dendrobium Area 3B. A summary of the statutory requirements are provided below.

10.1 STATUTORY PROCESS FOR APPROVALS

Under current legislation the major approvals required for mining Longwalls 9 to 18 include:

- Mining lease granted by the DRE under the Mining Act 1992 (obtained).
- Development Consent for mining in the area (obtained).
- Various approvals required under the mining lease associated with land use and environmental impacts. To obtain this a Subsidence Management Plan (SMP) must be prepared and approved by the DRE.
- Approval under the EPBC Act (obtained).
- Asset Protection Plan to the satisfaction of the SCA pursuant to Dendrobium Consent, *Schedule 3 Condition 7(d)*.
- NSW Dams Safety Committee endorsement and approval by DRE for mining within the Cordeaux Dam Notification Area pursuant to *condition 13* of the Dendrobium mining lease (CCL768).
- Section 88 Approval under the Coal Mines Health and Safety Regulation 2006 (only obtainable after the SMP has been approved).

In addition, Dendrobium Area 3B is within a water supply catchment and the Metropolitan Special Area and therefore the Special Areas Strategic Plan of Management and *Sydney Drinking Water Catchment State Environmental Planning Policy 2011* (SEPP 2011) are to be considered.

10.1.1 Mining Leases and Lease conditions

The mining lease covering Dendrobium Colliery is Consolidated Coal Lease No. 768, which covers the entire Dendrobium Colliery lease area.

10.1.2 Development Consent

Area 3B is within an existing mining lease, where there is an existing mine. Area 3 has been approved within the Dendrobium Colliery development consent (Part 4 EP&A Act), and a s75W modification to this consent has been approved by DP&I to modify the Area 3 mining footprint.

10.2 WATER SUPPLY CATCHMENT AREAS

The Special Areas Strategic plan has a number of objectives or goals that must be adhered to within these areas. These are:

1. Promote high quality raw water in the storages.
2. Protect the integrity of ecosystems throughout the Special Areas.
3. Improve environmental quality in the broader catchment to minimise adverse impacts on Special Areas.
4. Conserve the natural, spiritual, and cultural values of the Special Areas.
5. Control access to the Special Areas to protect water quality and ecological integrity.
6. Inform and consult with the community.
7. Adopt rigorous, accountable management, open to public scrutiny.

10.2.1 Sydney Drinking Water Catchment SEPP 2011

SEPP 2011 commenced on 1 March 2011 and applies to land within the Sydney drinking water catchment.

The aims of SEPP 2011 are:

- To provide for healthy water catchments that will deliver high quality water while permitting development that is compatible with that goal
- To provide that a consent authority must not grant consent to a proposed development unless it is satisfied that the proposed development will have a neutral or beneficial effect on water quality and
- To support the maintenance or achievement of the water quality objectives for the Sydney drinking water catchment.

10.2.2 DSC Notification Area

The DSC is a statutory body which is responsible for ensuring the safety of all prescribed dams in NSW, including the water or other materials impounded by them. The DSC has defined Notification Areas around all prescribed dams and storages which it considers may be affected by mining, including Lake Avon.

Prior to the commencement of mining within a Notification Area, mining companies must receive the consent of the Minister administering the Mining Act. The DSC advises the Minister on the extent and type of mining to be permitted, and on any special conditions which should apply.

10.2.3 Other Relevant Legislation

A number of other Acts and Regulations control the outcomes of mining within Dendrobium Area 3B. These are listed below:

- *Mining Act 1992*
- *Coal Mines Health and Safety Regulation 2006*
- *Environmental Planning and Assessment Act 1979*

- *Environmental Protection and Biodiversity and Conservation Act 1999*
- *Protection of the Environment Operations Act 1997*
- *Fisheries Management Act 1994*
- *Dams Safety Act 1978*
- *Sydney Water Catchment Management Act 1998*

10.3 OTHER APPROVALS AND PROVISIONS

Following mining and prior to any identified remediation measures being carried out, additional approvals will be required. Such approvals cannot be obtained until the areas requiring remediation are identified and site specific plans developed. These may include the following:

- Under the *Threatened Species and Conservation Act 1995* habitat alteration following subsidence due to longwall mining is listed as a key threatening process.
- Adherence to the *Heritage Act 1977* - there are no identified built heritage items of within the SMP Area. In the event that heritage items are discovered BHPBIC will seek to adhere to the requirements of this Act.
- Mining under areas of potential archaeological significance. Aboriginal heritage management in NSW is provided for by two pieces of legislation: the *National Parks and Wildlife Act* 1974 and the *Environmental Planning and Assessment Act* 1979. These acts provide protection for all material relating to the past Aboriginal occupation of Australia. Section 90 Applications will be sought as part of the SMP process for Aboriginal archaeological sites that have some potential to be impacted by the proposed longwall mining.

11 SUMMARY ASSESSMENT OF ENVIRONMENTAL FACTORS

This SMP document has described the expected subsidence and the potential mining impacts of the proposed extraction in Dendrobium Area 3B on public safety, the environment, community, and land use. This document has provided information on the proposed method of mining, resource recovery, community consultation and statutory requirements. A summary of the environmental assessment is provided below.

Potential mine subsidence impacts that may occur to natural features within the SMP Area are outlined in **Table 11.1**. The features specifically addressed by this table are as follows:

- Cliffs, including DA3-CF19, DA3-CF20, DA3-CF21, DA3-CF22, DA3-CF23, DA3-CF25, DA3-CF26, DA3-CF41, DA3-CF42, DA3-CF43, DA3-CF44, DA3-CF45, DA3-CF46, DA3-CF47;
- Steep slopes;
- Rock outcrops;
- Swamps 1a, 1b, 3, 4, 5, 8, 10, 11, 13,14, 23, 35a and 35b;
- Ecology, including terrestrial flora, fauna and aquatic ecology;
- Surface water, including Wongawilli Creek, Donalds Castle Creek and drainage lines;
- Groundwater;
- Archaeological sites, including 52-2-1562, 52-2-1623, 52-2-1626, 52-2-1627, 52-2-1628, 52-2-1771, 52-2-1772, 52-2-1773, 52-2-1774, 52-2-1775, 52-2-1776, 52-2-1778, 52-2-2208, 52-2-2209, 52-2-2229, 52-2-2246, 52-2-2248, 52-2-3068, 52-2-3640, 52-2-3641, 52-2-3645, 52-2-3646; and
- Significant man made features, including the abandoned Maldon-Dombarton railway corridor, unsealed roads, drainage culverts, dams/reservoirs or associated works and survey control marks.

Any other mine subsidence impacts identified in addition to the aspects below will be managed and mitigated generally in accordance with **Appendix 4** of the Area 3 Modification Consent.

In summary, subsidence impacts on natural features are expected to be minor and not result in any significant impact on the environment. All potential impacts can be managed effectively and methods for the monitoring and management of the SMP Area are provided in **Volume 2** of the SMP.

Table 11.1 - Predicted Mine Subsidence Impacts on Natural Features within Area 3B

Description of Item	Key Potential Impacts	Avoidance and Mitigation	Predicted Impact
Cliffs	• Isolated rock falls estimated to occur along ~10% of the cliff lines.	No cliffs are directly mined under. Monitoring during subsidence. Signage and fencing where they present safety risks. Communication strategy to stakeholders where they present safety risks.	Isolated rock falls may occur where cliffs are fractured or bedding planes or existing joints occur. The incidence of rock falls is expected to be low. Large scale cliff instabilities are not expected to occur.
Steep slopes	• Some impacts are possible if slopes are marginally stable. • Large cracks or compressive ridges. No significant diversion of surface water flow direction or increase in soil erosion/sedimentation of waterways.	Monitoring during subsidence. Signage and fencing where they present safety risks. Communication strategy to stakeholders where they present safety risks. Minor sediment control works such as fencing.	Impacts to steep slopes are most likely to occur in the form of surface cracks. If left untreated erosion may occur, however mitigation and remediation measures will be employed where required. Habitats can be affected by the cracking of soils, however, it is unlikely that cracking or erosion would have a significant impact on the environment.
Man Made Features	• Some surface cracking posing safe access constraints.	Monitoring, measurement and reporting during active subsidence. Signage and fencing where they present safety risks. Communication strategy prepared for stakeholders where they present safety	The maximum predicted conventional strains for the drainage culverts could be of sufficient magnitude to result in the cracking of surface features such as roads and concrete culverts. Any impacted features could be readily repaired or, where required, replaced.

Description of Item	Key Potential Impacts	Avoidance and Mitigation	Predicted Impact
		risks. Fill cracks with appropriate material in consultation with infrastructure owner and install temporary erosion and sediment controls where appropriate.	
Swamps	• No change in hydrology; ecological function of swamps or erosion of swamp surfaces.	Monitoring before, during and after active subsidence.	The predicted changes in grade are smaller than the natural surface gradients within the swamps. There are no overall predicted reversals of grade within the extents of these swamps resulting from mining.
Terrestrial Fauna and Flora including Endangered Ecological Communities	• Impacts on fauna are possible due to reduced flow and pool water levels in creeks. • Proposal assessed as likely to have a significant local impact on three frog and one dragonfly species	Monitoring during subsidence. No secondary extraction under Wongawilli Creek to avoid fracturing resulting in loss of surface flow. Commitment to avoid significant impacts to major natural features in Area 3B.	Terrestrial flora and fauna are likely to be impacted where subsidence modifies water flow, pool retention time and/or water quality along Wongawilli Creek and its tributaries, Donalds Castle Creek and drainage lines. Flora could be adversely affected by the emission of gas at the surface. It is possible but unlikely, that strata gas emissions at the surface would result in vegetation dieback due to the extraction of the proposed longwall. Emission of gases has not been a major issue in the past, since such emissions tend to be short lived and the consequences are generally minor and readily managed. To date only one gas release resulting from mining has been

Description of Item	Key Potential Impacts	Avoidance and Mitigation	Predicted Impact
			observed in the Dendrobium mining areas.
Aquatic Fauna and Flora	• Impacts on fauna are possible due to reduced flow and pool water levels in streams. Impacts on vegetation expected to be very small.	No secondary extraction under Wongawilli Creek to avoid major fracturing and loss of surface flow. Commitment to avoiding significant impacts to major natural features in Area 3B.	Aquatic flora and fauna are likely to be impacted where subsidence modifies water flow, pool retention time and/or water quality along Wongawilli Creek and its tributaries, Donalds Castle Creek and drainage lines.
<u>Creeks</u> 1. Does not cause subsidence impacts at Wongawilli Creek other than 'minor impacts' (such as minor fracturing, gas release, iron staining, and minor impacts on water flows, water levels, water quality); and 2. Does not result in reduction (other than negligible reduction) in the quality or quantity of surface water inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek.			
Wongawilli Creek	• Fracturing in the bed of Wongawilli Creek not predicted to result in reduced pool water levels.	No secondary extraction under Wongawilli Creek to avoid fracturing which results in pool water loss. Commitment to avoid significant impacts to major natural features in Area 3B.	Possible minor fracturing in the bed of Wongawilli Creek. Any fracturing that does occur in the bed of the creek is expected to be isolated and not result in reduced pool water levels. Fracturing will occur in the bedrock along Donalds Castle Creek and the drainage lines which are proposed to be directly mined beneath. Flow diversion may occur, however the likelihood of this occurring throughout the entire mining area is considered

Description of Item	Key Potential Impacts	Avoidance and Mitigation	Predicted Impact
			low.
1st and 2nd Order Watercourses (Flow)	• Fracturing of the beds of 1st and 2nd order streams and diversion of flows.	No secondary extraction under Wongawilli Creek reducing subsidence movements in the more deeply incised parts of the tributaries. Commitment to avoid significant impacts to major natural features in Areas 3B.	Possible localised increased levels of ponding or flooding may occur where slopes are reversed as a result of tilt. Fracturing of the beds of 1st and 2nd order streams, diversion of flows and reduced pool water levels. Any changes will be restricted to small areas and are not expected to result in any significant impacts.
1st and 2nd Order Watercourses (water quality)	• Impacts on water quality are possible due to reduced flow and/or increased interaction of ground and surface water. These impacts are likely to include reduced oxygen, higher dissolved ions and precipitates. There is also a possibility of lower pH and lower temperature variation as a result of groundwater inflows.	No secondary extraction under Wongawilli Creek reducing subsidence movements in the more deeply incised parts of the tributaries. Commitment to avoid significant impacts to major natural features in Area 3B.	Fracturing of the beds of 1st and 2nd order streams. Any sub-bed diversion hydrologic and geochemical effects will be restricted to small areas and are not expected to result in any significant impacts.
<u>Ground Water</u> Does not result in reduction (other than negligible reduction) in the quality or quantity of ground water inflows to Lake Cordeaux or Lake Avon			
Groundwater Quality, Quantity and Levels	• Impacts on groundwater are possible due to increased interaction of groundwater with existing and freshly created	Monitoring during subsidence. No secondary extraction under Wongawilli Creek to avoid major	Some induced seepages and diverted baseflows from Lakes Avon and Cordeaux.

Description of Item	Key Potential Impacts	Avoidance and Mitigation	Predicted Impact
	fractures within the rock and soil mass. These impacts are likely to include reduced oxygen, higher dissolved ions and lower pH. • Shallow groundwater systems are likely to be depressed by increased permeability as a result of fracturing.	fracturing and loss of surface flow. Commitment to avoid significant impacts to major natural features in Area 3B.	Diversion of some flows from rivers in the Northwest Catchment.
<u>Aboriginal Heritage</u> Measures to be implemented to protect Aboriginal sites generally, including measures that would be implemented to secure, analyse and record sites at risk of subsidence.			
Aboriginal Places of Cultural Significance	• Empirical data suggests the probability of impacts to a site is less than 10%.	Baseline, active subsidence and post mining monitoring. Appropriate consultation and approvals.	Empirical data suggests the probability of impacts to a site is less than 10%.

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