DENDROBIUM
AREA 3B

OCTOBER 2017




LONGWALL 16 SUBSIDENCE MANAGEMENT PLAN

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Review History

Revision	Description of Changes	Date	Approved
1	New Document	October 2017	GB

1 INTRODUCTION

1.1 PROJECT BACKGROUND

Illawarra Coal (IC) operates underground coal mining operations at Dendrobium Mine, located in the Southern Coalfield of New South Wales. Longwalls from the Wongawilli Seam are currently being extracted from Area 3B.

IC was granted Development Consent by the NSW Minister for Planning for the Dendrobium Project on 20 November 2001. In 2007 IC proposed to modify its underground coal mining operations and the NSW Department of Planning advised that the application for the modified Area 3 required a modification to the original consent. The application followed the process of s75W of the Environmental Planning and Assessment Act 1979 (EP&A Act) and required the submission of a comprehensive Environmental Assessment (Cardno 2007). The Environmental Assessment (EA) described the environmental consequences likely from the proposed mining, including diversion of flow, lowering of aquifers and changes to habitat for threatened species.

On 8 December 2008, the Minister for Planning approved a modification to DA_60-03-2001 for Dendrobium Underground Coal Mine and associated surface facilities and infrastructure under Section 75W of the EP&A Act.

On 4 October 2012 IC submitted a Subsidence Management Plan (SMP) for approval from the Director Generals (now Secretaries) of the Department of Planning and Infrastructure (now the Department of Planning and Environment, DPE) and Trade and Investment (T&I). The SMP incorporates the Watercourse Impact Monitoring Management and Contingency Plan (WIMMCP) and the Swamp Impact Monitoring Management and Contingency Plan (SIMMCP). The SMP was approved by the Secretary T&I 5 February 2013 and the Secretary DPE 6 February 2013.

1.2 SCOPE

DPE wrote to IC 25th October 2017 to request submission of a SMP for Longwall 16. This SMP has been prepared for Longwall 16 and complies with the Dendrobium Consent Schedule 3 Condition 7 and the Area 3B SMP. The proposed Longwall 16 and associated surface features (**Attachment 1**) are assessed in a revised subsidence assessment (MSEC914).

The Area 3B SMP Area is defined in accordance with Mine Subsidence Engineering Consultants (MSEC 2012), as the surface area that is likely to be affected by the proposed mining of Longwalls 9 to 18. The extent of the SMP Area has been calculated by combining the areas bounded by the following limits:

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

The SMP does not provide detailed reporting of monitoring data. These requirements are fulfilled by the EA (Cardno 2007), End of Panel Reports, Annual Environmental Management Reports (AEMR) and other reports.

1.3 OBJECTIVES

The objective of this SMP and associated documents is to:

- Describe a system to adequately manage subsidence risks in a timely manner and to demonstrate Illawarra Coal's capability to manage subsidence.
- Clearly state the objective of what is to be achieved for both systems and individual plans.
- Outline the systems used to establish monitoring mechanisms.
- Outline the systems to ensure ongoing analysis of monitoring information is used to implement management actions in a timely manner.
- Clearly define the necessary trigger levels and response actions.
- Assess the likelihood and scale of impact and any requirements for statutory approvals.
- Demonstrate preparedness for impacts outside of predictions.
- Carry out remediation works in a manner that protects to the greatest practicable extent the ecological values of the area and re-establishes the ecological values of an area to a similar state to that existing before mining.
- Monitor and report on the effectiveness of the SMP.

The Mine Plan has been optimised to maximise the extraction of the resource and minimise subsidence impacts to sensitive features. The SMP is to comply with the Dendrobium Conditions of Consent.

1.4 CONSULTATION

A number of submissions were made in relation to the Area 3B SMP, including detailed submissions from OEH (26 October, *an undated submission* and 13 December 2012) and Water NSW (December 2012 *undated*). IC provided a detailed response to submissions 20 December 2012.

The SMP and other relevant documentation are available on the IC website (*Condition 11 Schedule 8*).

2 PLAN REQUIREMENTS

Extraction of coal from Longwall 16 will be in accordance with the conditions set out in the Dendrobium Area 3 Modified Development Consent and conditions attached to relevant mining leases.

Baseline studies have been completed in Area 3B and surrounds in order to record biophysical characteristics. Monitoring is conducted in the area potentially affected by subsidence. The monitoring in these areas is based on the Before After Control Impact (BACI) design criteria.

The Area 3B monitoring and assessment programs will provide ongoing data for the areas and features potentially affected by the mining of Dendrobium Area 3B.

2.1 DENDROBIUM MODIFIED DA60-03-2001 APPROVAL

The Dendrobium Underground Coal Mine (DA 60-03-2001) modification was approved under Section 75W of the EP&A Act on 8 December 2008. **Table 2-1** lists the Conditions of Consent relevant to the Longwall 16 SMP.

Table 2-1 Dendrobium Modified DA-60-03-2001 Approval Conditions

Project Approval Condition
Condition 7 – Schedule 3 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 Secretary and the DRE. Each such SMP must: (a) integrate ongoing management of Areas 1 and 2; (b) integrate the WIMMCP and SIMMCP 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); · 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; (f) be prepared in consultation with OEH, SCA and DRE; (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 Secretary and the DRE.
Condition 8 – Schedule 3 The SMPs prepared under condition 7 for Areas 3B and 3C must: (a) include a mine plan for the relevant Area; (b) include a detailed subsidence impact assessment, clearly setting out all predicted subsidence effects, subsidence impacts and environmental consequences; (c) include a minimum of 2 years of baseline data, collected at appropriate frequency and scale, for all significant natural features; (d) identify and assess the significance of all natural features located within 600 m of the edge of secondary extraction; (e) distinguish between, clearly describe and adequately quantify all subsidence effects, subsidence impacts and environmental consequences; (f) propose limits on subsidence impacts and environmental consequences to be applied within the relevant Area; (g) be otherwise prepared in accordance with any guidelines for SMPs developed by the Department and/or DRE; (h) be approved prior to the carrying out of any underground mining operations that could cause subsidence in the relevant Area; and (i) be implemented to the satisfaction of the Secretary and the DRE.

2.2 DENDROBIUM AREA 3B SMP

The Dendrobium Mine Area 3B SMP performance measures are outlined below.

Performance Measures for Area 3B

11. The Applicant must ensure that the development does not cause any exceedance of the performance measures in Table 1, to the satisfaction of the Secretary.

Waterfall WC-WF54

- *Negligible environmental consequences including:*
  - *no rock fall occurs at the waterfall or from its overhang;*
  - *no impacts on the structural integrity of the waterfall, its overhang and its pool;*
  - *negligible cracking in Wongawilli Creek within 30m of the waterfall; and*
  - *negligible diversion of water from the lip of the waterfall.*

Wongawilli Creek and Donalds Castle Creek

- *Minor environmental consequences including:*
  - *minor fracturing, gas release and iron staining; and*
  - *minor impacts on water flows, water levels and water quality.*

Swamps 1a, 1b, 5, 8, 11, 14 and 23

- *Minor environmental consequences including:*
  - *negligible erosion of the surface of the swamps;*
  - *minor changes in the size of the swamps;*
  - *minor changes in the ecosystem functionality of the swamp;*
  - *no significant change to the composition or distribution of species within the swamp; and*
  - *maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.*

Swamps 3, 4, 10, 13, 35a and 35b

No significant environmental consequences beyond predictions in the Subsidence Management Plan (2012).

Avon Reservoir

- *Negligible environmental consequences including:*
  - *negligible reduction in the quality or quantity of surface water inflows to the reservoir;*
  - *negligible reduction in the quality or quantity of groundwater inflows to the reservoir; and*
  - *negligible leakage from the reservoir to the underground mine workings.*

2.3 LEASES AND LICENCES

The following licences and permits may be applicable to IC's operations in Dendrobium Area 3B:

- Dendrobium Mining Lease CCL 768;
- Environmental Protection Licence (EPL) 3241 which applies to the Dendrobium Mine. A copy of the licence can be accessed at the EPA website via the following link http://www.environment.nsw.gov.au/poeo;
- Dendrobium Mining Operations Plan (MOP) FY 2016 to FY 2022;
- Relevant OH&S and HSEC approvals; and

- Any additional leases, licences or approvals resulting from the Dendrobium Approval.

2.4 OBSERVATIONAL AND PHOTO POINT MONITORING

IC has conducted ongoing observational and photo point monitoring in the Dendrobium area since 2001 (see Area 3B WIMMCP and SIMMCP).

The IC Environmental Field Team is continuing to undertake a structured monitoring assessment, including:

- Water: location, volume and flow characteristics;
- Significant features: swamps, rockbars, pools and flow channels;
- Vegetation: location, species, height and observed health; and
- Sediment: composition, depth and moisture.

Observations of any surface water and vegetation health for prominent species are made at observation sites. Where surface water is present within a swamp or a watercourse the data collected includes water quality parameters (using a monitoring probe) and water levels from installed benchmarks established at the pool. Observations of any surface flow are also made during monitoring.

This data is used to compare differences in site conditions of swamps and watercourses before and after mining. Sites that will not be mined under are also monitored to provide a comparison of sites mined under and sites not mined under during different climatic conditions.

2.5 SURFACE WATER LEVELS AND FLOWS

Pool water levels in swamps and streams are measured using installed benchmarks in impact sites and reference sites (see Area 3B WIMMCP and SIMMCP). Water level/flow gauges and data loggers are installed at key stream flow monitoring sites. Data has been collected since 2003 and has been compiled within monitoring and field inspection reports, End of Panel Reports and Annual Environmental Management Reports. Pool water level and flow monitoring sites have been established in Dendrobium Area 3B for monitoring before, during and after mining.

Pool water levels are measured monthly before and after mining, on a weekly basis during active subsidence and in response to any identified impacts. Water level measurements will be undertaken relative to benchmarks installed on rocks or other stable features on the edge of the pools.

This data is used to compare differences in pool water level within swamps and streams before and after mining. Sites that will not be mined under are also monitored to provide a comparison of mined and not mined under sites during different climatic conditions.

2.6 NEAR SURFACE GROUNDWATER AND SOIL MOISTURE

Shallow groundwater piezometers have been installed within and around several swamps and associated watercourses in Area 3 (see Area 3B WIMMCP and SIMMCP). This data is used to compare differences in shallow groundwater levels within swamps, streams and hill-slope aquifers before and after mining. Sites that will not be mined under are also monitored to provide a comparison of sites mined under and not mined under during different climatic conditions.

The piezometric monitoring directed at shallow groundwater levels is supplemented with monitoring of soil moisture profiles.

The shallow groundwater piezometers and soil moisture probe data is compared with the Cumulative Monthly Rainfall Residuals (a key parameter for interpreting temporal soil and shallow groundwater data). Comparisons of the Cumulative Monthly Rainfall Residuals against mean monthly water heads in shallow groundwater piezometers and soil moisture profiles will take into account the known distribution of rainfall isohyets (contours of equal annual precipitation) in the local region (these being denser and less smooth closer to the Illawarra Escarpment and much wider proceeding northwest).

2.7 WATER QUALITY

Monitoring undertaken by IC since 2003 (see Area 3B WIMMCP and SIMMCP) includes water quality monitoring of parameters such as pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and laboratory tested analytes (DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si).

The key field parameters of DO, pH, EC and ORP for monitoring sites within Dendrobium Area 3B will be analysed to identify any changes in water quality resulting from the mining. Pools and streams away from mining are monitored to allow for a comparison against sites not influenced by mining.

Pools within streams will be measured monthly before and following mining, weekly during active subsidence and in response to any observed impacts.

The water chemistry, algae and level of water in Avon Reservoir will be monitored as a basis for comparison to the mine water. The locations of the samples and the testing procedure have been developed in consultation with the Dams Safety Committee (DSC) and Water NSW.

2.8 SLOPES AND GRADIENTS

Slopes within Area 3B have been mapped and are identified on Drawing 9 in MSEC (2012). Monitoring of landscape features such as cliffs, slopes and rock outcrop is undertaken in Area 3B (see Area 3B WIMMCP).

Monitoring of these sites allows for the measurement of any changes to the surface including soil cracking, erosion and/or sedimentation impacts resulting from subsidence.

The inspection and monitoring includes:

- Monitoring sites based on an assessment of risk of impact where pre-mining measurements have been undertaken and reported;
- Areas of steep slopes that are en route or near monitoring sites;
- Rock outcrops that are en route or near monitoring sites;
- Any other sites where impacts have been previously observed that warrant follow-up inspection (i.e. rockfalls and soil cracking); and
- The general areas above the current mining location at the time of inspection.

Steep slopes are monitored throughout the mining period and until any necessary rehabilitation is complete. Slopes and gradients are monitored prior to mining as well as monthly during active subsidence. The monitoring is undertaken at six monthly intervals for two years following completion of mining.

2.9 ERODIBILITY

Most of the surface of Area 3B has been identified as highly weathered Hawkesbury Sandstone outcrops and Sandstone derived-soils. This soil landscape has been identified to have high to extreme erosion susceptibilities to concentrated flows. This results in potential flow on effects to slope stability and erosion from any cracking resulting from subsidence. Landscape monitoring of slopes is undertaken in Area 3B to identify any erosion of the surface (see Area 3B WIMMCP and SIMMCP).

An extensive survey network has been implemented which includes relative and absolute horizontal and vertical movements. Additional sites will be added to the monitoring program prior to subsidence movements impacting the sites.

Due to terrain, vegetation and access restrictions, the primary method of identifying any erosion over Area 3B will be Airborne Laser Scanning (ALS). This technique has proven to be successful in generating topographic models of subsidence over entire longwalls and mining domains and will also provide identification of any erosion. The maximum areas, length and depth of erosion will be measured by standard survey methods.

Base surveys over Area 3B using ALS were completed in December 2005, with a verification base survey performed in 2013, immediately prior to the commencement of Longwall 9 extraction. Subsidence landscape models using the same methodology after the completion of subsidence at each longwall will provide a new (subsided) baseline surface dataset. For a period of up to ten years after mining repeat ALS datasets and surface modelling will be completed to identify new or increases in existing erosion. Erosion will be quantified by comparison of the immediate post subsidence landscape model with the long-term monitoring model. Targeted ALS scans will be completed where erosion is observed via the observational and landscape monitoring programs or after significant events such as bushfire and flooding.

Inspections of the mining area will be undertaken at regular intervals, during active subsidence. In addition to erosion, these observations aim to identify any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, and slope and gradient changes.

2.10 FLORA, FAUNA AND ECOSYSTEM FUNCTION

Terrestrial flora and vegetation communities in the Study Area are described in the SMP Terrestrial Ecology Assessment (Niche 2012). Aquatic flora and fauna in the Study Area are described in the SMP Aquatic Ecology Assessment (Cardno Ecology Lab 2012).

A monitoring program designed to detect potential impacts to ecology and ecosystem function from subsidence has been implemented for Area 3B (see Area 3B WIMMCP and SIMMCP). The monitoring program is based on a BACI design with sampling undertaken at impact and control locations prior to the commencement of extraction, during extraction and after extraction.

Over two years of baseline data is available for Area 3B and this data indicates that the habitat in this area is relatively undisturbed. There is sufficient baseline data to enable the detection of changes to ecology associated with mining related impacts.

The study focuses on flora, fauna and ecosystem function of swamps and watercourses and is measured via the following attributes:

- The size of the swamps and the groundwater dependent communities contributing to the swamps;
- The composition and distribution of species within the swamps;
- RCE including a photographic record of each stream assessment site;
- Water quality, including pH, DO, ORP, temperature, turbidity and EC;
- Aquatic macrophytes, including presence, species composition and total area of coverage;
- Aquatic macroinvertebrates using the AusRivAS sampling protocol and artificial aquatic macroinvertebrate collectors;
- Fish presence and numbers using backpack electro fisher and/or baited traps; and

- Presence of threatened species (including Macquarie perch, Littlejohn's tree frog, Giant burrowing frog, Adams emerald dragonfly, Giant dragonfly and Sydney hawk dragonfly).

Observation data will also be collected as part of the monitoring program. Locations where significant changes have been observed (e.g. drainage of pools) will be mapped, documented and reported.

2.11 POOLS AND CONTROLLING ROCKBARS

Dendrobium Mine lies in the southern part of the Permo-Triassic Sydney Basin. The geology mainly comprises sedimentary sandstones, shales and claystones, which have been intruded by igneous sills.

The sandstone units vary in thickness from a few metres to as much as 120m. 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.

Extensive geomorphological mapping has been completed for Dendrobium Area 3, including the location of pools and rockbars (see Area 3B WIMMCP and SIMMCP).

The largest watercourse within the Study Area is Wongawilli Creek which is located between Areas 3A and 3B. The headwaters of Wongawilli Creek are located along a drainage divide separating surface runoff and shallow groundwater outflow runoff from Native Dog Creek and Lake Avon to the west.

2.12 REPORTING

End of Panel Reports are prepared in accordance with *Condition 9 Schedule 3* of the Dendrobium Area 3 Modification Approval. Results from the monitoring program are included in the End of Panel Report and in the AEMR. These reports detail the outcomes of monitoring undertaken; provide results of visual inspections, and determine whether performance indicators have been exceeded.

Monitoring results will be reviewed monthly by the IC Subsidence Management Committee. However, if the findings of monitoring are deemed to warrant an immediate response, the Principal Approvals will initiate that response.

Monitoring results are included in the Annual Reporting requirement under *Condition 5 Schedule 8* in accordance with the Dendrobium Area 3 Modification Approval and are made publicly available in accordance with *Condition 11 Schedule 8.*

3 PERFORMANCE MEASURES AND INDICATORS

Performance measures and indicators have been derived from the Dendrobium modified Consent (2008) and the Area 3B SMP Approval (2016). These performance measures are presented in **Table 3-1** and will be applied to the Dendrobium Area 3B mining area.

Table 3-1 Subsidence Impact Performance Measures

Dendrobium Modified Development Consent
• Operations shall 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 and water quality); • Operations will 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.

Area 3B SMP Approval

11. The Applicant must ensure that the development does not cause any exceedance of the performance measures in Table 1, to the satisfaction of the Secretary.

Waterfall WC-WF54

- Negligible environmental consequences including:
  - no rock fall occurs at the waterfall or from its overhang;
  - no impacts on the structural integrity of the waterfall, its overhang and its pool;
  - negligible cracking in Wongawilli Creek within 30m of the waterfall; and
  - negligible diversion of water from the lip of the waterfall.

Wongawilli Creek and Donalds Castle Creek

- Minor environmental consequences including:
  - minor fracturing, gas release and iron staining; and
  - minor impacts on water flows, water levels and water quality.

Swamps 1a, 1b, 5, 8, 11, 14 and 23

- Minor environmental consequences including:
  - negligible erosion of the surface of the swamps;
  - minor changes in the size of the swamps;
  - minor changes in the ecosystem functionality of the swamp;
  - no significant change to the composition or distribution of species within the swamp; and
  - maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.

Swamps 3, 4, 10, 13, 35a and 35b

No significant environmental consequences beyond predictions in the Subsidence Management Plan (2012).

Avon Reservoir

- Negligible environmental consequences including:
  - negligible reduction in the quality or quantity of surface water inflows to the reservoir;
  - negligible reduction in the quality or quantity of groundwater inflows to the reservoir; and
  - negligible leakage from the reservoir to the underground mine workings.

A detailed list of performance measures and triggers is included in the TARPs (see Area 3B WIMMCP and SIMMCP).

3.1 IMPACT MECHANISMS

Subsidence is an unavoidable consequence of longwall mining and includes vertical and horizontal movement of the land surface. Subsidence effects include surface and sub-surface cracking, buckling, dilation and tilting. These effects can result in changes to the hydrology of watercourses.

There are two broad mechanisms by which subsidence could cause changes in hydrology and water quality:

- The bedrock below the watercourse or groundwater dependent community fractures as a consequence of strains and water drains into the fracture zone. The extent and permanence of these changes relate to the size of the fracture zone (increase in porosity/storage) and whether the fractures are connected to a deeper aquifer, the mine workings or bedding shear pathway to the surface lower in the catchment. Surface water diverted through freshly fractured sandstone and/or groundwater that returns to the surface through the fracture network may contain increases in iron concentrations and other minerals.
- Tilting, cracking, desiccation and/or changes in vegetation health result in concentration of runoff and erosion which alters water distribution in the watercourse or groundwater dependent community.

Changes to hydrology and water quality can result in environmental consequences. The likelihood and timing of these consequences relate to the size and duration of the effect. The environmental consequences which could relate to changes in hydrology and water quality include:

- Species composition change and/or changes in vegetation communities.
- Loss of aquatic ecology and/or changes in aquatic habitat resulting from a reduction of surface water quality and/or flows and standing pools.
- Water-borne inputs to Lake Avon and Cordeaux River such as erosive export of fine sands and clays and/or ferruginous precipitates.
- Reduced inflows into Lake Avon and Cordeaux River.
- Increased rates or frequency of erosion events.
- Increased extent or frequency of fire events resulting in the organic components of the swamp soil profile to burn during intense bushfires.

3.2 CONNECTIVITY TO THE MINE WORKINGS

The fracture zone comprises in-situ material lying immediately above the caved zone which have sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation (Singh and Kendorski, 1981; Forster, 1995). Where the panel width-to-depth ratio is high and the depth of cover is shallow, the fracture zone would extend from the seam to the surface. Where the panel width-to-depth ratio is low, and where the depth of cover is high, the fracture zone would not extend from the seam to the surface.

The possible height of the fracture zone is dependent upon the angle of break, the width of the panel, the thickness of seam extracted and the spanning capacity of a competent stratum at the top of the fracture zone (MSEC 2012). Based on mining geometry, the height of the fracture zone equals the panel width, minus the span, divided by twice the tangent of the angle of break.

It should be noted that the height of the fracture zone should be viewed in the context of fracturing only and should not be directly associated with an increase in vertical permeability. There are numerous models for the height of fracturing and height of desaturation. A review of these matters was conducted for the Bulli Seam Operations Project Response to PAC deliberations (Hebblewhite 2010).

The Regional Groundwater Models at Dendrobium uses site specific data to determine the height of desaturation. Dendrobium monitors in excess of 1,000 piezometers in ~100 boreholes and has analysed many thousands of samples for field parameters, laboratory analysis, algae and isotopes.

The results of water analysis and the interpretation of the height of connective fracturing was peer reviewed by Parson Brinckerhoff (2012). The peer review states that "the use of standard hydrogeochemical tools clearly demonstrated the geochemical difference between water from the Wongawilli Coal Seam and goaf, and the overlying sandstone formations and surface water from Lake Cordeaux". Although the report acknowledged limitations of the available data, this review is based on one of the most comprehensive datasets available in the Southern Coalfield. On the basis of the available data and the Parson Brinckerhoff (2012) review it is considered that the height of desaturation used by Heritage Computing (2009 & 2011) is conservative.

In January 2015 SRK Consulting conducted a detailed independent review of the Dendrobium water chemistry data, to:

- Assess the level of detail, quality of science, depth and technical appropriateness of the water chemistry data.
- Evaluate associated interpretations in relation to underground operations of Dendrobium Mine, with specific focus on how these address the question of hydraulic connectivity between the mined areas and the reservoirs.

Based on the review SRK concluded that the observed geochemical trends are not consistent with a high degree of hydraulic connectivity between the underground workings and the surface water bodies.

As reported in Coffey (2012) most of the change in aquifer properties occurs within the collapsed zone. Changes in aquifer properties above the collapsed zone are less severe and largely restricted to increases in storativity. Groundwater drawdown due to sudden storativity increases will ultimately impact the surface, either directly (as seepage from watercourses or lakes to satisfy the drawdown), or by intercepting baseflow.

Predictions of fracture zone dimensions for Dendrobium (MSEC 2012 and Coffey 2012) refer to geotechnical fracturing behaviour, and are not necessarily directly related to a groundwater responses resulting from increased vertical permeability.

Parson Brinckerhoff and IC have completed testing to characterise the pre and post mining permeability above Longwall 9, the first longwall in a new domain, not affected by previous mining. After Longwall 9 mined under the site it was tested to quantify the change to vertical and horizontal permeability of the strata, including the Bulgo and Hawkesbury Sandstones and the Bald Hill Claystone. The testing involved core, packer and borehole interference testing, groundwater flow and tracer testing.

Mining of Longwall 9 resulted in a significant increase in subsurface fracturing compared with pre-mining. Down-hole camera surveys identified a number of open horizontal and inclined fractures with apertures of several centimetres. Groundwater ingress was noted at several open fractures.

Most post-mining test bores showed decreases in groundwater level and strong downward hydraulic gradients, particularly in the lower Bulgo Sandstone. Significantly however, groundwater levels in the shallow Hawkesbury Sandstone remained perched at the study site.

Horizontal hydraulic conductivity increased between one to three orders of magnitude due to mine subsidence and strata fracturing. Increases in hydraulic conductivity are observed in every geological unit, but are greatest below the base of the Hawkesbury Sandstone.

In contrast to pre-mining testing in which no breakthrough was observed, horizontal tracer testing after the passage of Longwall 9 resulted in breakthrough in about 40 minutes. This indicates a bulk hydraulic conductivity in the order of 10m/day; at least two orders of magnitude higher than pre-mining conditions.

No breakthrough in tracer was observed in either the pre-mining or the post-mining tests of the Bald Hill Claystone and this indicates that the vertical conductance at the research site was below the detection limit of the test, estimated to be approximately 0.7m/day.

Activated carbon samplers deployed in streams adjacent to the research site detected no breakthrough of tracer and therefore there is no evidence of preferential flow paths either existing or induced between the research site and adjacent streams.

Sampling of water from the underground mine suggests there is no strong connection between the shallow water bearing zones and the goaf.

Although current observations do not allow a precise definition of the height of intense fracturing using any criteria (and the boundaries are gradational in any case), most evidence suggests that the zone of most intense and vertically connected fracturing in Area 3B extends into the Bulgo Sandstone.

Estimates for the height of fracturing at Dendrobium based on published methods range from 122m to 357m. This range in estimates is large and presents a challenge to those wishing to model hydrogeological impacts of mining on a regional scale based on mine site data.

The pre- and post-mining investigations carried out in this research study provide important constraints on the extent of mining related disturbance and its effect on groundwater systems.

In August 2015 HydroSimulations' completed an assessment of the estimated height of connected fracturing at Dendrobium. The assessment included:

- The effects of longwall mining and subsidence on overburden strata;
- A summary of previous research in relation to estimating the extent of the deformed strata above longwall mining, both in general and at Dendrobium;
- Revised estimates of the height of connected fracturing for Dendrobium longwalls using the Ditton 'Geology Model' (Ditton and Merrick, 2014) and the Tammetta (2013) method.

The assessment concluded that the Ditton 'Geology model', as outlined in Ditton and Merrick (2014), is the most appropriate method for estimating the vertical extent of connected fracturing above longwalls at Dendrobium. This is supported by the research above Longwall 9 by Parsons Brinkerhoff (2015) and earlier studies by GHD (2007) and Heritage Computing (2011).

A review of methods for estimating the height of fracturing above longwall panels at Dendrobium Mine was commissioned by DPE, and carried out by geotechnical consultants Pells Sullivan Meynink (PSM). The PSM report was finalised in June 2017 and made available to South32 on 7 September 2017.

Recommendations by PSM regarding additional monitoring and research to add to our understanding of the catchment are generally sensible and many of these have already been acted on.

The PSM report appears to be limited by the fact that they may not have had access to all data or may simply have lacked time to check all available data and literature. Importantly, the analysis of mine water chemistry (water fingerprinting) is not given due regard. Scientific method should always consider multiple lines of evidence where these are available.

HysroSimulations believe there is a flaw in PSM's hydrogeological conceptual model, which leads to some errors in their conclusions about the extent of connective fracturing. PSM seems to have assumed vertical connected fracturing on the strength of pressure reductions at piezometers, when pressure reductions could occur due to several factors, including increased horizontal permeability, increased porosity or increasing downward hydraulic gradient due to depressurisation in the goaf.

The Regional Groundwater Model for Dendrobium Mine is currently being revised and this revision will consider the findings of the PSM report. HydroSimulations state that regardless of the method used to assess fracturing, they believe the current groundwater modelling approach is sound.

3.3 SURFACE FRACTURING

Based on the predicted systematic and non-systematic subsidence movements (MSEC 2012 and 2015) the bedrock below the watercourses are likely to fracture as a consequence of subsidence induced strains.

Surface flows captured by the surface subsidence fracture network resulting from valley related movements which do not connect to a deeper aquifer or the mine workings will re-emerge further downstream (see **Section 3.2**). This prediction is based on an assessment of the depth of valley closure induced vertical fracturing from the surface and measurements of water balance during the modelled periods of recessional, baseflow and small storm unit hydrograph periods downstream of mining areas.

Monitoring from Dendrobium Mine indicates the surface fracture network over the goaf connects to or is concurrent with the fracture network which propagates from the seam to the surface. In this instance the diversion of surface flow to deep strata or the mine relates to vertical permeability increases associated with this fracturing.

The effects of mining on surface water flow following the completion of Longwall 12 was modelled and assessed in the Longwall 12 End of Panel Report. The assessment indicates that headwater catchments to WC21S1, DC13S1, DCS2, are affected by mining, as is the tributary LA4 of Lake Avon. Effects are possible, but not definitive at Donalds Castle Upper and effects are not observed in the downstream catchment at Wongawilli Creek Lower (WWL).

This suggests that, within the limitations of the monitoring, some or all flow lost in Wongawilli Creek headwater catchments is returned downgradient. Modelling also suggests that high flows in the mined under catchments are less affected than the lower, recession-limb flows.

3.4 POTENTIAL FOR EROSION

Tilting, cracking, desiccation and/or changes in vegetation health could result in erosion of sediments within the mining area. The likelihood and timing of these consequences relate to the size and duration of the effect.

Subsidence predictions were carried out to assess the potential impacts of longwall mining in Area 3B. The assessment indicated that the levels of impact on the natural features were likely to be similar to the impacts observed within Area 3A and Area 3B to date. A summary of the maximum predicted values of subsidence, tilt and strain at the watercourses is provided in **Section** Error! Reference source not found..

Tilting of sufficient magnitude could change the catchment area of a watercourse or concentrate runoff leading to scour and erosion.

The likelihood of change in drainage line alignment is considered in MSEC (2012, 2015 and 2017). The assessment takes into account the nature of the drainage channel and whether the predicted tilt is significant when compared to the existing slopes.

Landscape monitoring commenced in 2004 for Dendrobium Area 1. This monitoring program has been continued and updated throughout the mining period for Areas 2, 3A and 3B. The monitoring includes inspections of watercourses at regular intervals prior to mining, during active subsidence and following the completion of subsidence movements. In addition to erosion (increased incision and/or widening), these observations target any surface cracking, surface water loss, soil moisture changes, vegetation condition changes, slope and gradient changes and the condition of rockbars.

The observed impacts on natural features above Area 3B to date are generally consistent with those predicted in the assessments undertaken prior to mining.

In Area 3B, one surface impact (cracking) has been observed in swamps. To date there has been no instance of erosion resulting from this cracking. No erosion of the surface of the swamps as a result of mining observed to date. For Area 3B to completion of Longwall 12, 83 surface impacts have been identified. Many of these are very minor impacts and of very limited environmental consequence. For example, 94% of the cracking identified at the surface has a width of less than 100mm. To date there has been no instance of erosion resulting from this cracking (Illawarra Coal 2017).

3.5 POTENTIAL FOR AQUATIC ECOLOGY CHANGES

Where there are changes to watercourse hydrology that are large and persistent there is likely to be an aquatic ecology response. Aquatic species which do not have life-cycles adapted to temporary loss of aquatic habitat are likely to be relatively susceptible to changes in pool water level. In comparison, riparian vegetation is likely to be relatively resilient to short term changes in groundwater level and soil moisture, demonstrated by the persistence of these vegetation communities during extended periods of drought.

A monitoring program is in place to detect mining-related subsidence impacts to the condition of aquatic ecology. The monitoring program is based on a Before, After, Control, Impact (BACI) design that provides a measure of natural spatial and temporal variability in key aquatic ecology indicators at potential impact and control sites before, during and after mining. This enables changes in the mining area to be distinguished from changes due to natural variability.

The monitoring program focuses on the following key indicators:

- Habitat condition, assessed using the Riparian, Channel and Environmental (RCE) Inventory method and by establishing a photographic record through time;
- Aquatic macroinvertebrates sampled in accordance with the Australian River Assessment System (AUSRIVAS);
- Aquatic macroinvertebrates sampled quantitatively using artificial collectors;
- Sampling of fish using bait traps and backpack electrofishing; and
- Limited in situ water quality sampling is undertaken to assist with interpretation of trends in the above indicators.

Monitoring is undertaken within Wongawilli Creek, WC21 (a tributary of Wongawilli Creek) and Donalds Castle Creek, and at comparable Control sites established on Wongawilli, Sandy, Donalds Castle and Kentish creeks. Univariate and multivariate statistical analyses has been conducted on the AUSRIVAS sampling and artificial collectors. Surveys and reporting have been completed in 2010, 2011, 2013, 2014 and 2015, with additional surveys being undertaken late 2017.

Physical impacts in Lake Avon tributary LA4B, including fracturing and flow diversion has resulted in a reduction in aquatic habitat.

Wongawilli Creek was surveyed in April 2017 and there does not appear to be any change to aquatic habitat along this stream.

WC21 has been mined beneath by Longwalls 9 to 12 with fracturing of bedrock, flow diversions and associated reductions in pool water levels and flow. During the April 2017 fieldwork, aquatic ecology site X2 consisted of a few small and disconnected pools. Site 6, downstream from mining had surface flow.

Water was also observed in site X3, located approximately 80m downstream from Longwall 12, during the April 2017 survey. A reduction in water level at this location was identified during Longwall 12 however it coincided with an extended dry period. Additional monitoring will determine the further response to Longwall 12.

There was no evidence of any change to macroinvertebrate and fish data at the site further downstream on WC21 (Site 6) following extraction of Longwalls 9 to 12 (Longwall 12 End of Panel Report), further suggesting that impacts observed in WC21 are localised to the areas directly affected by habitat loss. Monitoring of this site will continue throughout 2017 as part of the ongoing monitoring program.

3.6 POTENTIAL FOR VEGETATION CHANGES

In the Southern Coalfield, impacts to riparian vegetation as a result of subsidence are minor in occurrence. Furthermore, no impacts to riparian vegetation have been observed in Dendrobium Mine to date (Niche 2012). Previous examples of impacts include: dieback of riparian vegetation as a result of subsidence of the Cataract River during the 1990s (Eco Logical Australia, 2004 in TEC 2997), and small localised changes to riparian vegetation along a section of the Waratah Rivulet (Helensburgh Coal 2007).

Where there are changes to swamp hydrology that are large and persistent there is likely to be a vegetation response. Swamp vegetation is likely to be relatively resilient to short term changes in groundwater level and soil moisture, demonstrated by the persistence of the swamp vegetation communities during extended periods of drought. For this reason, any response to changes in swamp hydrology are likely to be over a medium to longer period. Vegetation change may be observed in the rates of species composition change and/or changes in vegetation communities over and above what is measured in nearby swamps due to natural variation.

Flora monitoring in swamps includes collection of data on species abundance within thirty 0.5m x 0.5m quadrats along a 15m transect. Data is also collected from a number of control sites, to allow comparison both pre-and post-mining with control sites as a part of a Before – After - Control – Impact (BACI) experimental design.

Eleven years of post-mining monitoring is available for Dendrobium Area 2, 7 to 13 years in Dendrobium Area 3A and 4 years in Dendrobium Area 3B. Monitoring includes a minimum of two years baseline surveys for pre-impact sites within Area 2 and Area 3. Monitoring of control sites has been occurring for a minimum of three years for Dendrobium Area 3B and up to a maximum of 11 years for Area 2.

The program includes monitoring and analysis of six upland swamp sites as post-mining sites (Swamp 1 (S1), Swamp 15B (S15B), Swamp 15A(2) (S15A(2)), Swamp 1A (S1A), Swamp 1B (S1B) and Swamp 5 (S5)). The remaining swamps were monitored and analysed as controls or pre-mining sites. Parameters analysed include Total Species Richness (TSR) and species composition as well as swamp size and the extent of groundwater dependent swamp sub-communities.

A statistically significant decline in Total Species Richness (TSR) was detected at Swamp 1 (Dendrobium Area 2) and Swamp 15B (Dendrobium 3A). Declines in TSR were observed immediately following each site being mined beneath and have continued for at least four years post-mining. Yearly changes in species composition were detected in most sites, regardless of area or treatment. This variation is due to natural turnover of species and is to be expected with changes in rainfall, temperature, natural succession and other seasonal factors. When accounting for the yearly effects, a statistically significant change in species composition in post-mining data to pre-mining data was found at Swamp 1 (Dendrobium Area 2), Swamp 15B (Dendrobium 3A) and Swamp 15A(2) (Dendrobium 3A). The change detected at Swamp 1 however was detected for a four year period post-mining between 2007 and 2010, however in recent years (2010 to 2016), the change in species composition when compared to pre-mining data was not apparent.

Analysis of LiDAR data indicates the extent of upland swamps has declined at all control and impact swamps in Dendrobium 3A and 3B when compared to the baseline year of 2012. Results indicate that no swamp size TARP trigger levels have been met for impact swamps in Dendrobium Area 3B as the observed decline in swamp extent from 2015 to 2016 was preceded by an increase in swamp extent from 2014 to 2015.

Change in the extent of upland swamp sub-communities from 2012 through to 2016 was similar to the trend observed for total swamp extent. An exception to this trend was Swamp 1A and Swamp 5 where three consecutive years of decline of the sub-community Upland Swamps: Banksia Thicket (Swamp 5 only) and Upland Swamps: Tea-Tree Thicket (Swamp 1A and Swamp 5) were recorded. These declines were greater than the mean (±SE) decline in the control group, indicating a Level 2 ecosystem functionality TARP trigger at these swamps.

Caution is urged when interpreting the results of the swamp size and ecosystem functionality LiDAR monitoring given that a number of factors unrelated to mining-induced impacts may drive some of the observed decreases in swamp size and extent of groundwater dependent sub-communities. Changes in swamp size and extent of groundwater dependent communities observed at each swamp may be the result of responses to natural phenomena such as recent and long-term climate conditions, fire patterns and stochastic events (e.g. storm damage).

Monitoring is continuing to further define any vegetation changes likely to result from reduced groundwater levels.

3.7 POTENTIAL FOR RAW WATER QUALITY CHANGES

From several years of monitoring there has been no evidence of short or long term impacts to water quality or drinking water quality in Lake Avon, despite tributaries of the lake being directly undermined by Elouera Colliery and Dendrobium Mine longwalls, causing 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.

Based on 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 Lake Avon or Cordeaux River.

Any water-borne inputs to Lake Avon and Cordeaux River would likely be restricted to a possible erosive export of fine sands and clays and/or ferruginous precipitates near the mouths of minor creeks designated LA2, LA3, LA4 and LA5 (Lake Avon) during mining of Area 3B. It is predicted that these water-borne inputs will result in negligible environmental consequences.

These creeks are all remote from their respective dam off-takes and outflows. Such zones would be localised around the point of input to the Lake and would be unlikely to have any detrimental effect on local freshwater ecology and unable to affect bulk water supply quality.

3.8 ACHIEVEMENT OF PERFORMANCE MEASURES

Longwall mining can result in surface cracking, heaving, buckling and stepping at the surface. Surface deformations can also develop as the result of downslope movements where longwalls are extracted beneath steep slopes. In these cases, the downslope movements can result in the development of tension cracks at the tops of the steep slopes and compression ridges at the bottoms of the steep slopes. Fracturing of bedrock can also occur in the bases of stream valleys due to the compressive strains associated with valley closure movements. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, geomorphology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

A number of large surface cracks were observed at the commencing end of Longwall 3 in Area 2 at Dendrobium Mine. The depth of cover at the commencing end of Longwall 3 was as shallow as 145m, which is less than that above Longwalls 9 to 18 in Area 3B, which varies between 310m and 450m. It is expected, therefore, that the widths of surface cracking resulting from the extraction in Area 3B would be generally less than that observed above the commencing end of Longwall 3.

The experience gained from mining in Dendrobium Areas 1, 2 and 3A indicate that mining-induced fracturing in bedrock and rockbars are commonly found in sections of streams that are located directly above extracted longwalls. However, minor fracturing has also been observed in some locations beyond extracted longwall goaf edges, the majority of which have been within the limit of conventional subsidence or associated with valley closure.

Mining has been occurring for a number of years beneath swamps and this allows an opportunity to do some relatively simple back analysis of impacts to these features over the long-term. This approach has the disadvantage of a relatively simple experimental design whereby only obvious changes as a result of the mining are likely to be identified.

Subsidence predictions for swamps in historic mining areas were reviewed as part of the Bulli Seam Project Environmental Assessment (Resource Strategies 2009). Field investigations were carried out in these swamps to assess impacts and consequences from various levels of back-predicted levels of subsidence movement. This data was used to inform the assessment of risk of impacts and environmental consequences for the Bulli Seam Operation Project. A summary of the review findings is provided below.

Back predictions have been undertaken for 34 swamps previously subject to subsidence in the Southern Coalfield. The back predictions indicate that six of these swamps would have been subject to closure values of greater than 200mm, namely:

- Swamp STC-S4 (221mm predicted closure) at West Cliff;
- Swamp STC-S1c (276mm predicted closure) at West Cliff;
- Swamp STC-S1a (278mm predicted closure) at West Cliff;
- Swamp 12 (335mm predicted closure) at Dendrobium;
- Swamp STC-S1b (461mm predicted closure) at West Cliff; and
- Swamp STC-S2 (542mm predicted closure) at West Cliff.

Site inspections have been conducted of the swamps listed above. An additional ten swamps predicted to have been previously subject to less than 200mm valley closure were also inspected.

The inspection methods included walking the length of the swamp and recording observations of any significant environmental impacts or consequences, for example:

- Significant subsidence-induced buckling or cracking.
- Any significant erosion or scour.
- Significant vegetation dieback on a broad scale.
- Significant desiccation of vegetation or peat materials on a broad scale.

It is recognised that there are limitations associated with the assessment. As stated above, the assessment is based on back predictions of subsidence effects, as opposed to observed (i.e. monitored) subsidence effects. However, these back predictions are being compared with predictions using the same methodology for analysis at Dendrobium, thus ensuring consistency within the comparative assessment.

Evidence of cracking and minor erosion was observed during the site inspections, however no evidence of significant environmental consequences was observed.

4 MANAGEMENT AND CONTINGENCY PLAN

This section describes the potential impacts of mine subsidence in Area 3B, together with a summary of the avoidance, minimising, mitigation and remediation measures proposed.

4.1 OBJECTIVES

The aims and objectives of the Plan include:

- Avoiding and minimising impacts to significant environmental values where possible.
- Implementing TARPs to identify, assess and responding to impacts.
- Carrying out mitigation and remediation works in a manner that protects to the greatest practicable extent the environmental values of the area.
- Achieving the Performance Measures outlined in the Area 3B SMP Approval, to the satisfaction of the Secretary.
- Monitoring and reporting effectiveness of the Plan.

To achieve these aims, monitoring, management, mitigation and remediation has been incorporated into the mining activity proposed by IC.

4.2 TRIGGER ACTION RESPONSE PLAN

The TARPs relate to identifying, assessing and responding to potential impacts to watercourses (including impacts greater than predicted) from subsidence in Dendrobium Area 3B. These TARPs have been prepared using knowledge gained from previous mining in other areas of Dendrobium. The TARPs for Area 3B are included in the SIMMCP and WIMMCP.

It should be noted that the TARPs represent actions to be taken upon reaching each defined trigger level. A Corrective Management Action (CMA) is developed in consultation with stakeholders in order to manage an observed impact in accordance with relevant approvals. The SIMMCP and WIMMCP provide a basis for the design and implementation of any mitigation and remediation.

Monitoring of environmental aspects provides key data when determining any requirement for mitigation or rehabilitation. The triggers are based on comparison of baseline and impact monitoring results. Specific triggers will continue to be reviewed and developed in consultation with key stakeholders as the impact monitoring phase matures. Where required the triggers will be reviewed and changes proposed in impact assessment reports provided to government agencies or in EoP Reports.

Level 2 and 3 TARPs result in further investigations and reporting by appropriately qualified people. Impact assessment reports will include:

- Study scope and objectives;
- Consideration of relevant aspect from this Plan;
- Analysis of trends and assessment of any impacts compared to prediction;
- Root cause analysis of any change or impact;
- Assessment of the need for contingent measures and management options;
- Any recommended changes to this Plan; and
- Appropriate consultation.

The Level 2 and 3 TARPs may require the development of site specific CMAs which include:

- A description of the impact to be managed;
- Results of specific investigations;
- Aims and objectives for any corrective actions;
- Specific actions required to mitigate/manage and timeframes for implementation;
- Roles and responsibilities;
- Gaining appropriate approvals from landholders and government agencies; and
- Reporting, consultation and communication.

4.3 AVOIDING AND MINIMISING

Mine layouts for Dendrobium Area 3B have been developed using IC's Integrated Mine Planning Process (IMPP). This process considers mining and surface impacts when designing mine layouts.

IC has assessed mining layout options for Dendrobium Area 3B against the following criteria:

- Extent, duration and nature of any 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.

Several layout alternatives for Area 3B were assessed by IC using a multi-disciplinary team including environment, community, mining and exploration expertise. These included variations in the number of longwalls and orientations, lengths, and setbacks 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 Mine 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 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 predicted impacts on major natural features and aimed to minimise these impacts within geological and other mining constraints.

No contingent mining areas containing Wongawilli Seam Coal resources with the possibility for extraction are available to IC.

The layouts at Dendrobium Mine have been modified to reduce the potential for impacts to surface features. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3B mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DPE and OEH during the consultation process. Mine plan changes result in significant business and economic impact, including:

- Reduction in coal extracted;
- Reduction in royalties to the State;
- Additional costs to the business;

- Risks to longwall production due to additional roadway development requirements; and
- Constraints on blending which can disrupt the supply of coal to meet customer requirements.

Restricting mine layout flexibility can also have the following consequences:

- Additional energy used to ventilate the mine;
- Increased safety risks such as risk of frictional ignition on the longwall due to less than optimal ventilation;
- Increased power usage, reduced fan lifespan and a requirement to install booster fans;
- Requirement for heavy secondary support density;
- Potential for horizontal stress and vertical abutment concentrations;
- The risk of strata control associated with increased roadway development and longwall install and take-off faces;
- Exposes the workforce to higher risk environments more frequently;
- Results in a large number of equipment movements and interaction with workers and infrastructure; and
- Requires specialised equipment and skilled personnel with limited availability.

The longwalls have been setback between 130m and 680m from Wongawilli Creek and minimum of 300m from Lake Avon. This reduction in extraction also reduces subsidence movements at surface features in proximity to Wongawilli Creek and Lake Avon, including the streams LA2, LA3, LA4, LA5, WC7, WC9, WC12, WC15, WC16, WC18, and Swamps 23 and 11.

Illawarra Coal proposed a 50m setback of Longwall 14 from WC15. This resulted in Longwall 14 being 333m shorter than previously proposed and will significantly reduce the levels of impact within this stream.

4.4 MITIGATION AND REHABILITATION

If the performance measures in Table 1 of the SMP Approval are not met, then following consultation with OEH, Water NSW and T&I, the Secretary of DPE may issue a direction in writing to undertake actions or measures to mitigate or remediate subsidence impacts and/or associated environmental consequences. The direction must be implemented in accordance with its terms and requirements, in consultation with the Secretary and affected agencies.

As indicated in Schedule 2 Conditions 1 and 14 of the Development Consent (Minister for Planning 2008) and Condition 13 of the Area 3B SMP Approval (Deputy Secretary DPE 2016), the mitigation and rehabilitation described in this Plan is required for the development and an integral component of the proposed mining activity. To the extent these activities are required for the development approved under the Dendrobium Mine Development Consent no other licence under the TSC Act is required in respect of those activities.

At the time of grant of the Dendrobium Development Consent there was no requirement for concurrence in respect of threatened species or ecological communities. The requirement for concurrence was, at that time, governed by section 79B of the EPA Act. At the time of grant of the Dendrobium Consent there was a requirement for consultation with the Minister administering the TSC Act and this consultation was undertaken.

4.4.1 Sealing of Rock Fractures

Where the bedrock base of any significant permanent pool or controlling rockbar within Wongawilli Creek or Donalds Castle Creeks are impacted from subsidence and where there is limited ability for these fractures to seal naturally they will be sealed with an appropriate and approved cementatious (or alternative) grout. Grouting will be focused where fractures result in diversion of flow from pools or through the controlling rockbar. Significant success has been achieved in the remediation of the Georges River where four West Cliff longwalls directly mined under the river and pool water level loss was observed.

A number of grouts are available for use including cement with various additives. These grouts can be used with or without fillers such as clean sand. Grouts can be mixed on-site and injected into a fracture network or placed by hand. Hand placed and injection grouting of large fractures were successfully implemented in the Georges River near Appin.

Such operations do have the potential to result in additional environmental impacts and are carefully planned to avoid contamination. Mixing areas will be restricted to cleared seismic lines or other open areas wherever possible. Bunds are used to contain any local spillage at mixing points. Temporary cofferdams can be built downstream of the grouting operations to collect any spillage or excess grouting materials for disposal off-site. The selection of grouting materials is based on demonstrated effectiveness and ensuring that there is no significant impact to water quality or ecology.

4.4.2 Injection Grouting

Injection grouting involves the delivery of grout through holes drilled into the bedrock targeted for rehabilitation. A variety of grouts and filler materials can be injected to fill the voids in the fractured strata intercepted by the drill holes. The intention of this grouting is to achieve a low permeability ‘layer’ below any affected pool as well as the full depth of any controlling rockbar.

Where alluvial materials overlie sandstone, grouts may be injected through grout rods to seal voids in or under the soil profile. This technique was successfully used at Pool 16 in the Georges River to rehabilitate surface flow by-pass to Pool 17. In this case 1-2m of loose sediment was grouted through using purpose built grouting pipes.

Grouting holes are drilled in a pattern, usually commencing at a grid spacing of 1m x 1m to 2m x 2m. The most efficient way to drill the holes taking into account potential environmental impact is by using handheld drills. The drills are powered by compressed air which is distributed to the work area from a compressor. The necessary equipment will be sited on cleared seismic lines or other clear areas wherever possible with hoses run out to target areas.

Grout is delivered from a small tank into the ground via mechanical packers installed at the surface. All equipment can be transported with vehicles capable of travelling on tracks similar to seismic lines. If necessary, equipment or materials can be flown to nearby tracks or open spaces by helicopter. Helicopter staging has previously occurred from Cordeaux Mine where there is appropriate logistical support. The grout is mixed and pumped according to a grout design. A grout of high viscosity will be used if vertical fracturing is believed to be present since it has a shorter setting time. A low viscosity grout will be used if cross-linking is noted during grouting. Once the grout has been installed the packers are removed and the area cleaned.

After sufficient time for the product to set the area may be in-filled with additional grouting holes that target areas of significant grout take from the previous pass. The grouting program can normally be completed with hand held equipment. Wherever possible the setup and mixing areas will be restricted to cleared seismic lines and other open areas. Bunds are used to contain any local spillage at mixing points.

Grouting volumes and locations are recorded and high volume areas identified. Once the grout take in the area is reduced and the material has set, the grouted section of the pool is isolated and tested with local or imported clean water. The rate at which the water drains is measured and compared to pre-grouting results. The grouting process is iterative; relying on monitoring of grout injection quantities, grout backpressures and measurements of water holding capacity. In the Georges River pools were sealed with two to three grout passes.

If flow diversion through a large rockbar occurs it may be more appropriate to implement alternative grouting techniques such as a deeper grout curtain which can be delivered via traditional or directional drilling technologies. Grouting should preferentially be undertaken at the completion of subsidence movements in the area to reduce the risk of the area being re-impacted. **Figure 4-1** shows grouting operations in progress within the Georges River.

(a) Drilling into the bedrock

(b) Grout pump station setup

(c) Injecting grout into bedrock via a specially designed packer system

Figure 4-1 Rockbar Grouting in the Georges River

4.4.3 Erosion Control

Erosion can occur along preferred flow paths where subsidence induced tilts increase a catchment area. To arrest this type of erosion, 'coir log dams' are installed at knick points in the channelised flow paths or at the inception of tunnel/void spaces (**Figure 4-2**).

Figure 4-2 Square Coir Logs for Knick Point Control

As the coir log dams silt up they are regularly added to by the placement of additional layers of logs until the pooled water behind the 'dams' is at or above the level of the bank of the eroded channel. The coir logs are held in place by 50mm x 50mm wooden stakes and bound together with wire (**Figure 4-3**).

The coir log dam slows the flows in the eroding drainage line such that the drainage line will silt up.

Figure 4-3 Installation of Square Coir Logs

The most important aspect of these coir dams is the positioning of the first layer of coir logs. A trench is cut into the soil so the first layer sits on the underlying substrate or so the top of the first coir log is at ground level (**Figure 4-4**).

Figure 4-4 Trenching and Positioning of the First Layer of Coir Logs and Construction of a Small Dam in a Channel

The coir log dams are constructed at intervals down the eroding flow line, the intervals being calculated on the depth of erosion and predicted peak flows and added to until the pooled water behind the 'dams' is at or above the level of the bank of the erosion. Where increased filtering of flows is required the coir logs are wrapped in fibre matting (**Figure 4-5**).

Figure 4-5 Small Coir Log Dams with Fibre Matting

4.4.4 Surface Treatments and Water Spreading

Where cracking develops in significant areas and natural infilling is not occurring, the cracks may require forking over and compacting to prevent erosion. Larger cracks may require more work to repair them, for example, mulch or other protection to prevent the development of erosion channels. Surface protection will remain in place until revegetation covers the disturbed area. In some cases, if the cracks are wider they may require gravel or sand filling up to surface level and revegetation using brush matting. Maintenance of moisture in rehabilitation areas can be enhanced by additional water spreading techniques, involving long lengths of coir logs and hessian 'sausages' linked together across the contour such that water flow builds up behind them and slowly seeps through the water spreaders (**Figure 4-6**).

Where sheet and rill erosion forms, these processes can reduce vegetation on the surface and/or be a precursor to the formation of gully and stream channel erosion. Treatment of these areas can prevent the formation of channels and maintain swamp moisture. The treatment proposed includes water spreading techniques, involving long lengths of coir logs and hessian 'sausages' linked together across the contour such that water flow builds up behind them and slowly seeps through the water spreaders

Figure 4-6 Round Coir Logs Installed to Spread Water

Erosion control and water spreading involves soft-engineering materials that are biodegradable and become integrated into the soil profile. This approach is ecologically sustainable in that all the materials used can breakdown and become part of the organic component of the soil. This also removes the requirement for any post-rehabilitation removal of structures or materials. However, rehabilitation measures have the potential to cause impact through the materials used and the disturbance associated with access. Relevant approvals will be obtained to ensure the protection of the environment as works are implemented.

4.4.5 Gas Release

A typical driver of gas release at the surface is pressure changes, dilation and/or fracturing of the rock mass and associated release to the surface, with or without groundwater flows. Grouting techniques discussed above can reduce these associated gas flows at specific sites. In all identified circumstances in the Southern Coalfield the gas releases have diminished over time. Typically this time is a number of months but it can be a number of years. Long running gas releases significantly reduce in quantity over time. Where vegetation is impacted by gas releases the areas affected will be revegetated once monitoring determines the gas releases have ceased or reduced to an extent that vegetation is no longer affected.

Very few gas releases have been observed within the Dendrobium mining area.

4.4.6 Water Quality

In Appendix A of Attachment B (see SMP, Vol.1), Ecoengineers (2012) outline mitigation measures that would be considered if unpredicted water quality impacts were detected. Any works on Water NSW land requires prior approval from Water NSW to access the land and there is a requirement for compliance with the Access Agreement between Water NSW and Illawarra Coal. These requirements ensure strict limits are placed on any impacts associated with undertaking rehabilitation works on Water NSW land.

4.4.7 Alternative Remediation Approaches

IC has successfully implemented a subsidence rehabilitation program in the Georges River where there were impacts associated with mining directly under streams. This rehabilitation focused on grouting of mining induced fractures and strata dilation to reinstate the structural integrity and water holding capacity of the bedrock. Metropolitan Colliery is currently undertaking work aimed at rehabilitating areas impacted by subsidence using Poly-urethane Resin (PUR) and other grouting materials. IC is consulting with Metropolitan Colliery in relation to these new and emerging technologies. Should rehabilitation be necessary in Dendrobium Area 3B, the best option available at the time of the rehabilitation work will be identified and with appropriate approval, implemented by IC.

Cracking due to subsidence will tend to seal as the natural processes of erosion and deposition act on them. The characteristics of the surface materials and the prevailing erosion and depositional processes of a specific area will determine the rate of infill of cracks and sealing of any fracture network.

4.4.8 Monitoring Remediation Success

Baseline studies have been completed within the Study Area in order to record biophysical characteristics of the mining area. Monitoring is conducted in the area potentially affected by subsidence from the Area 3B extraction as well as areas away from mining to act as control sites. The studies in these areas are based on the BACI design criteria.

A comprehensive monitoring program is in place for this Plan. A summary of monitoring within Dendrobium Area 3B is provided in **Section 2**. In the event that monitoring reveals impacts greater than what is authorised by the approval, modifications to the project, mitigation measures and environmental offsets would be considered to minimise impacts.

The monitoring program would remain in place prior to, during and following the implementation of any mitigation measures in Area 3B. The monitoring program is based on the BACI design with sampling undertaken at impact and control locations prior to the commencement of mitigation, during mitigation and after the completion of the mitigation actions. The monitoring locations/points for watercourses within Dendrobium Area 3B will be reviewed as required and can be modified (with agreement) accordingly.

Data will be analysed according to the BACI design. Statistical analyses between control, impact and mitigation sites will be used to determine whether there are statistically significant differences between these sites. This analysis will assist in determining the success of any mitigation or natural reduction of mining impacts over time.

Observation data will be collected as part of the monitoring program and be used to provide contextual information to the above assessment approach. Monitoring data and observations will be mapped, documented and reported.

4.5 BIODIVERSITY OFFSET STRATEGY

Where impacts are greater than predicted or not within approved levels, compensatory measures will be considered. Any compensatory measure will consider the level of impact requiring compensation, the compensatory measures available and the practicality and cost of implementing the measure.

Subject to Condition 14 of Schedule 3 of the Development Consent:

> The Applicant shall provide suitable offsets for loss of water quality or loss of water flows to Water NSW storages, clearing and other ground disturbance (including cliff falls) caused by its mining operations and/or surface activities within the mining area, unless otherwise addressed by the conditions of this consent, to the satisfaction of the Secretary. These offsets must:
>
> (a) be submitted to the Secretary for approval by 30 April 2009;
>
> (b) be prepared in consultation with Water NSW;
>
> (c) provide measures that result in a beneficial effect on water quality, water quantity, aquatic ecosystems and/or ecological integrity of Water NSW's Special Areas or water catchments.

IC transferred 33ha of land adjacent to the Cataract River to Water NSW to meet the above condition.

A biodiversity offset strategy has been developed in consultation with OEH and Water NSW for the approval of the Secretary of DPE. The Secretary DPE approved the Strategic Biodiversity Offset in accordance with Condition 15 of Schedule 2 of the Development Consent for the Dendrobium Coal Mine 16th December 2016. The Secretary also expressed satisfaction that the Strategy fulfils the requirements of the SMP for Area 3B.

4.6 RESEARCH

To assist in further understanding the impacts of subsidence and rehabilitation of swamps IC will undertake research to the satisfaction of the Secretary. The research will be directed to improving the prediction, assessment, remediation and/or avoidance of subsidence impacts and environmental consequences to swamps.

4.7 CONTINGENCY AND RESPONSE PLAN

In the event the TARP parameters are considered to have been exceeded, or are likely to be exceeded, IC will implement a Contingency Plan to manage any unpredicted impacts and their consequences.

This would involve the following actions:

- Identify and record the event.
- Notify government agencies and specialists as soon as practicable.
- Conduct site visits with stakeholders as required.
- Contract specialists to investigate and report on changes identified.
- Provide incident report to relevant agencies.
- Establish weekly monitoring frequency for the site until stabilised.
- Updates from specialists on investigation process.
- Inform relevant government agencies of investigation results.
- Develop site CMA in consultation with key stakeholders and seek approvals.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting following CMA completion.
- Review the WIMMCP and/or SIMMCP in consultation with key government agencies and seek approval for any modifications.
- Report in EoP Report and AEMR.

A site specific rehabilitation action plan detailing the location and specific works to be implemented will be prepared following the identification of mining induced degradation that exceeds the trigger levels specified in the TARPS.

The site specific rehabilitation action plan will be circulated to relevant stakeholders for comment prior to finalisation. Authority to access the land to conduct works and implement environmental controls will be approved by Water NSW.

The WIMMCP and SIMMCP describes the avoidance, mitigation and contingency measures proposed to manage impacts where predicted impacts are exceeded.

5 INCIDENTS, COMPLAINTS, EXCEEDANCES AND NON-CONFORMANCES

5.1 INCIDENTS

IC will notify DPE and any other relevant agencies of any incident associated with Area 3B operations as soon as practicable after IC becomes aware of the incident. IC will provide DPE and any relevant agencies with a report on the incident within seven days of confirmation of any event.

5.2 COMPLAINTS HANDLING

IC will:

- Provide a readily accessible contact point through a 24 hour toll-free Community Call Line (1800 102 210). The number will be displayed prominently on IC sites in a position visible by the public as well as on publications provided to the local community.
- Respond to complaints in accordance with the IC Community Complaints and Enquiry Procedure.
- Maintain good communication lines between the community and IC.
- Keep a register of any complaints, including the details of the complaint with information such as:
  - Time and date.
  - Person receiving the complaint.

- o Complainant's name and phone number.
- o Description of the complaint.
- o Area where complaint relates to.
- o Details of any response where appropriate.
- o Details of any corrective actions.

5.3 NON CONFORMANCE PROTOCOL

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

Non-conformities, corrective actions and preventative actions are managed in accordance with the following process:

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

An Annual Review will be undertaken to assess IC's compliance with all conditions of the Dendrobium Development Consent, Mining Leases and other approvals and licenses.

An independent environmental audit will be undertaken (*Condition 6 Schedule 8*) to review the adequacy of strategies, plans or programs under these approvals and if appropriate, recommend actions to improve environmental performance. The independent environmental audit will be undertaken by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Secretary of DPE.

6 PLAN ADMINISTRATION

This SMP will be administered in accordance with the requirements of the Dendrobium Environmental Management System (EMS) and the Dendrobium Area 3 Approval Conditions. A summary of the administrative requirements is provided below.

6.1 ROLES AND RESPONSIBILITIES

Statutory obligations applicable to Dendrobium operations are identified and managed via an online compliance management system (TICKIT). The online system can be accessed by the responsible IC managers from the link below.

https://illawarracoal.tod.net.au/login.

The overall responsibility for the implementation of the SMP resides with the Principal Approvals who shall be the SMP's authorising officer.

Responsibilities for environmental management in Dendrobium Area 3 and the implementation of the SMP include:

Planning Manager

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

Principal Approvals

- Authorise the SMP and any amendments thereto.
- To document any approved changes to the SMP.
- Provide regular updates to IC on the results of the SMP.
- Arrange information forums for key stakeholders as required.
- Prepare any report and maintain records required by the SMP.
- Organise and participate in assessment meetings called to review mining impacts.
- Respond to any queries or complaints made by members of the public in relation to aspects of the SMP.
- Organise audits and reviews of the SMP.
- Address any identified non-conformances, assess improvement ideas and implement if appropriate.
- Arrange implementation of any agreed actions, responses or remedial measures.
- Ensure surveys required by this SMP are conducted and record details of instances where circumstances prevent these from taking place.

Environmental Field Team Lead

- Instruct suitable person(s) in the required standards for inspections, recording and reporting and be satisfied that these standards are maintained.
- Investigate significant subsidence impacts.
- Identify and report any non-conformances with the SMP.
- Participate in assessment meetings to review subsidence impacts.

Survey Team Lead

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

Technical Experts

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

Person(s) Performing Inspections

- Inform the Environmental Field Team Lead of any non-conformances identified with the Plan, or ideas aimed at improving the SMP.
- Conduct inspections in a safe manner.

6.2 RESOURCES REQUIRED

The Planning Manager provides resources sufficient to implement this SMP.

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

The Principal Approvals shall ensure personnel and equipment are provided as required to allow the provisions of this Plan to be implemented.

6.3 TRAINING

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

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

It is the responsibility of the Principal Approvals to ensure that all persons and organisations having responsibilities under this SMP are trained and understand their responsibilities.

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

6.4 RECORD KEEPING AND CONTROL

Environmental Records are maintained in accordance with the IC document control requirements.

IC document control requirements include:

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

The SMP and other relevant documentation will be made available on the IC website.

6.5 MANAGEMENT PLAN REVIEW

A comprehensive review of the objectives and targets associated with the Dendrobium Area 3 operations is undertaken on an annual basis via the IC planning process. These reviews, which include involvement from senior management and other key site personnel, assess the performance of the mine over the previous year and develop goals and targets for the following period.

An annual review of the environmental performance of Dendrobium Area 3 operations will also be undertaken in accordance with *Condition 5 Schedule* 8. More specifically this SMP will be subject to review (and revision if necessary, to the satisfaction of the Secretary) following:

- The submission of an annual review under *Condition 5 Schedule 8.*
- The submission of an incident report under *Condition 3 Schedule 8.*
- The submission of an audit report under *Condition 6 Schedule 8.*
- Any modification to the conditions of this approval.

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

7 REFERENCES AND SUPPORTING DOCUMENTATION

ACARP, 2009. Damage Criteria and Practical Solutions for Protecting River Channels. Project Number C12016. Ken Mills SCT May 2009.

BHP Billiton Illawarra Coal, 2006. Georges River Report: Assessment of Georges River Remediation Longwalls 5A1-4. November 2006.

BHP Billiton Illawarra Coal, 2011. Understanding Swamp Conditions - Field Inspection Report - September 2010 to November 2010. BHP Billiton Illawarra Coal, April, 2011.

Biosis Research 2007. Dendrobium Area 3 Species Impact Statement, Prepared for BHP Billiton Illawarra Coal, Biosis Research Pty Ltd.

Biosis Research 2007. Dendrobium Coal Mine and Elouera Colliery Flora and Fauna Environmental Management Program, Annual Monitoring Report – Spring 2003 to Winter 2006, Biosis Research Pty Ltd.

Biosis Research, 2009. Revision of the Dendrobium Coal Mine Flora and Fauna Monitoring Program. February 2009.

Biosis Research, 2012. Elouera and Dendrobium Ecological Monitoring Program. Annual Monitoring Report Financial Year 2010/2011. August 2012.

Biosis Research, 2012. Swamp 15b TARP Assessment – Ecology. Ref:15462, 10 October 2012.

Biosis, 2014. Dendrobium Ecological Monitoring Program, Annual Report for 2012/2013 Financial Year. February 2014. Prepared for Illawarra Coal.

Biosis, 2015. Dendrobium Terrestrial Ecology Monitoring Program, Annual Report for 2014. September 2015. Prepared for Illawarra Coal.

Boughton W, 2004. The Australian water balance model. Environ Model Softw 19:943–956. doi: doi:10.1016/j.envsoft.2003.10.007.

Cardno Ecology Lab, 2012. Aquatic Flora and Fauna Assessment. Prepared for BHPBIC, February 2012.

Cardno Ecology Lab, 2012. Swamp 15b and SC10C Aquatic Flora and Fauna Review. Ref: NA49913032, 5 October 2012.

Cardno Ecology Lab, 2013. Dendrobium Area 3A Aquatic Ecology Monitoring 2008-2012. Job Number: EL1112073 Prepared for BHP Billiton – Illawarra Coal, February 2013.

Cardno Ecology Lab, 2013. Review of Sandy Creek Pools Aquatic Flora and Fauna. 25 February 2013.

Cardno Ecology Lab, 2013. SC10C Level 3 Aquatic Ecology Trigger Assessment. 11 June 2013.

Cardno Ecology Lab, 2015. Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014. 30 March 2015.

Cardno Forbes Rigby, 2007. Landscape Impact Assessment and Monitoring Site Optimisation. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Area 3A Subsidence Management Plan Longwalls 6 to 10. Prepared for BHPBIC.

Cardno Forbes Rigby, 2007. Dendrobium Area 3 Environmental Assessment. Prepared for BHPBIC.

Chafer, C., Noonan, M and Macnaught, E. 2004. The Post-Fire Measurement of Fire Severity and Intensity in the Christmas 2001 Sydney Wildfires. International Journal of Wildland Fire Vol. 13; pp. 227-240.

Chiew, F, Wang, Q. J., McConachy, F., James, R., Wright, W, and deHoedt, G. 2002. Evapotranspiration Maps for Australia. Hydrology and Water Resources Symposium, Melbourne, 20-23 May, 2002, Institution of Engineers, Australia.

Coffey, 2012. Groundwater Study Area 3B Dendrobium Coal Mine: Numerical Modelling. GEOTLCOV24507AA-AB2 2 October 2012.

Ditton, S., and Merrick, N.P. 2014. A new sub-surface fracture height prediction model for longwall mines in the NSW coalfields. Paper presented at the Australian Earth Science Convention, Newcastle, NSW.

Doherty, J. 2010. PEST: Model-Independent Parameter Estimation User Manual (5th ed.): Watermark Numerical Computing, Brisbane, Queensland, Australia.

EarthTech Engineering Pty Ltd, 2005. Thresholds for Swamp Stability. Prepared for BHPBIC, January 2005.

The Ecology Lab, 2007. Dendrobium Area 3 Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota. October 2007.

Ecoengineers, 2006. Assessment of Surface Water Chemical Effects of Mining by Elouera Colliery. January - December 2005. February 2006.

Ecoengineers, 2006. Assessment of Catchment Hydrological Effects by Mining by Elouera Colliery Stage 1: Establishment of a Practical and Theoretical Framework. August 2006.

EcoEngineers, 2007. Surface Water Quality and Hydrology Assessment to Support SMP Application for Dendrobium Area 3.

EcoEngineers, 2010. End of Panel Surface and Shallow Groundwater Impacts Assessment Dendrobium Area 2 Longwall 5. Document Reference No. 2010/01A. April 2010.

Ecoengineers, 2012. Surface Water Quality and Hydrological Assessment: Dendrobium Area 3B Subsidence Management Plan Surface and Shallow Groundwater Assessment.

Ecoengineers, 2012. Level 2 TARP Independent Review and Recommendations Swamp 15b Dendrobium Area 3A. 25 September 2012.

Ecoengineers, 2013. Level 3 TARP Independent Review and Recommendations Sandy Creek Catchment Pool 7 (Dendrobium Area 3A). 12 February 2013.

Ecoengineers, 2013. Level 2 TARP Specialist Review and Recommendations Donalds Castle Creek. 22 May 2013.

Ecoegineers, 2014. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 9. June 2014.

Ecoengineers, 2015. End of Panel Surface and Shallow Groundwater Impacts Assessment, Dendrobium Area 3B Longwall 10. February 2015.

Eco Logical Australia, 2004. The Impacts of Longwall Mining on the Upper Georges River Catchment: Report to Total Environment Centre, 2004.

Forster, 1995. Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW. Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

GHD, 2007. Dendrobium Area 3A Predicted Hydrogeologic Performance. Report for BHP Billiton, Illawarra Coal. November 2007.

GSS Environmental, 2013. Baseline and Pre-Mining Land Capability Survey. Dendrobium Mine, Area 3B. February 2013.

Hazelton P.A. and Tille P.J., 1990. Soil Landscapes of the Wollongong-Port Hacking 1:100,000 Sheet map and report, Soil Conservation Service of NSW, Sydney.

Hebblewhite, 2010. BHP Billiton Illawarra Coal: Bulli Seam Operations Project – Independent Review. 31 March 2010.

Helensburgh Coal Pty Ltd, 2007. Submission to: Independent Expert Panel - Inquiry into NSW Southern Coalfield July 2007, Helensburgh Coal Pty Ltd.

Heritage Computing, 2009. Dendrobium Colliery Groundwater Assessment: Mine Inflow Review, Conceptualisation and Preliminary Groundwater Modelling. Merrick, N.P., Heritage Computing Report HC2009/2, February 2009.

Heritage Computing, October 2011. Recalibration of the Dendrobium Local Area Groundwater Model after Completion of Longwall 6 (Area 3A). Report prepared for Illawarra Coal. Report HC2011/13.

HydroSimulations, 2014. Dendrobium Area 3B Groundwater Model Revision: Swamps, Stream Flows and Shallow Groundwater Sata. Report: HC2014/4 March 2014.

Illawarra Coal, 2014. Longwall 9 End of Panel Report.

Illawarra Coal, 2015. Longwall 10 End of Panel Report.

Kirchner, J. W. 2009. Catchments as simple dynamical systems: Catchment characterization, rainfall-runoff modelling, and doing hydrology backwards. Res., W02429.

Manly Hydraulics Laboratory, 2006. BHP Billiton Dendrobium Mine Area 2 Subsidence Environmental Management Plan Water Monitoring and Management Program. Prepared for BHPBIC. Version 1.4 January 2006.

McMahon, 2014. Dendrobium Community Consultative Committee Report: Review of Surface Water Study. An independent review of surface water hydrological modelling associated with Illawarra Coal's Dendrobium Area 3, conducted by Emeritus Professor Thomas McMahon, University of Melbourne. 4 June 2014.

MSEC, 2007. Dendrobium Mine Area 3A Longwalls 6 to 10. Report on The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of proposed Longwalls 6 to 10 in Area 3A at Dendrobium Mine in Support of the SMP and SEMP Applications. September 2007.

MSEC, 2012. Dendrobium Area 3B Subsidence Predictions and Assessments for Natural Features and Surface Infrastructure in Support of the SMP Application.

MSEC, 2015. Dendrobium Area 3B – Longwalls 12 to 18 Review of the Subsidence Predictions and Impact Assessments for Natural and Built Features in Dendrobium Area 3B based on Observed Movements and Impacts during Longwalls 9 and 10.

MSEC, 2017. Dendrobium mine – Area 3B. The Effects of the Proposed Modified Commencing Ends of Longwalls 15 to 18 in Area 3B at Dendrobium Mine on the Subsidence Predictions and Impact Assessments. MSEC914 August 2017.

Niche Environment and Heritage, 2012. Terrestrial Ecological Assessment. Prepared for BHP Billiton Illawarra Coal. February, 2012.

OEC, 2001. Environmental Impact Statement Dendrobium Coal Project. Olsen Environmental Consulting, Figtree, N.S.W.

Parkhurst. D.L., and Appelo, C.A.J. 2012. Description of Input and Examples for PHREEQC Version 3 – A Computer Program for Speciation, Batch-Reaction, One- Dimensional Transport and Inverse Geochemical Calculations. US Department of Interior/US Geological Survey.

Parson Brinckerhoff, 2012. Independent Review of Dendrobium Area 2 and 3A Hydrochemical Data. August 20012.

Parsons Brinckerhoff, 2015. Connected fracturing above longwall mining operations, Part 2: Post-longwall investigation. For BHP Billiton Illawarra Coal. Document number 2172268F-WAT-REP-002 RevB. 6 March 2015.

Petersen, 1992. The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology Vol 27, Issue 2, April 1992.

Resource Strategies, 2009. Bulli Seam Operations Environmental Assessment. Report in support of an application for the continued operations of the Appin and West Cliff Mines.

Singh & Kendorski, 1981. Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments, Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

Tammetta, P. (2013). Estimation of the height of complete groundwater drainage above mined longwall panels. Groundwater, 51(5), 723-734.

Tomkins, K.M. and Humphries, G.S. 2006. Technical report 2: Upland Swamp development and erosion on the Woronora Plateau during the Holocene. January 2006. Sydney Catchment Authority – Macquarie Collaborative Research Project.

Waddington, A.A. and Kay, D.R. 2001. Research into the Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys and Development of Management Guidelines for Undermining Cliffs. Gorges and River Systems. Final Report on ACARP Research Project C8005, March 2001.

Waddington, A.A. and Kay, D.R. 2002. Management Information handbook on the Undermining of Cliffs, Gorges and River Systems. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Zhang, L. Dawes, W.R. and Walker, G.R. 1999. Predicting the effect of Vegetation Changes on Catchment Average Water Balance. Technical Report No. 99/12, Cooperative Research Centre for Catchment Hydrology.

Attachment 1 – Approved Mine Plan DEN-01-6151 (Rev 11) and Surface Feature Plan DEN-01-6153 (Rev 6)

	MGA E	MGA N
A	288575.286	6190583.436
B	291117.188	6190240.003
C	291306.867	6190264.638
D	290853.234	6193759.291
E	290886.480	6193932.095
F	290609.402	6193981.712
G	288202.273	6194299.030
H	288156.299	6193952.162
J	287983.183	6193975.107
K	287937.205	6193628.210
L	287844.036	6193640.559
M	287798.058	6193293.663
N	287598.262	6193320.144
O	287534.520	6192839.219
P	288294.827	6192738.448
Q	288202.871	6192044.656
R	288361.447	6192023.638
S	288315.469	6191676.742
T	288484.087	6191654.393
U	288392.132	6190960.600
V	288621.250	6190930.233

LEGEND

EXISTING WORKINGS
APPROVED WORKINGS
PROPOSED WORKINGS FOR THIS APPLICATION
PROPOSED WORKINGS FOR FUTURE APPLICATIONS
OTHER PROPOSED WORKINGS
AVON DAM FSL 300m OFFSET
DAM FSL - Based on 2003 Airborne Laser Scanner and 1977 MWSDB Plan
NOTIFICATION AREA
PROPOSED EXTRACTION
APPLICATION AREA
PREVIOUS EXTRACTION APPROVALS

I hereby certify the accuracy of the plan.

....
Registered Mining Surveyor Date

I hereby accept the information on the plan.

....
Manager of Mining Engineering Date

SCALE IN METRES

0 100 200 300 400 500 600 700 800 900 1000

ENDORSEMENTS
1. Workings shown were prepared in accordance with Survey & Drafting Directions 2015.
2. Seam geolocigal information & contours supplied by Illawarra Coal Exploration Department database in May 2014.
3. All surface features supplied by consultants MSEC (Project 459) & NSW Land & Property Information Department.
4. Orthophoto supplied by AAM in 2010.

SOUTH32

Dendrobium Mine
ILLAWARRA COAL
Cordeaux Road Mount Kembla NSW 2526 Australia
ABN 85 098 744 088

	Name	Date
DRN	D.Baker	25/10/2017
REV		
APP		
SCALE	A0	1:4000

Title Dendrobium Mine Approved Plan
Longwall 16 SMP Application

DRAWING NUMBER DEN-01-6151

REV 11

ENDORSEMENTS
1. Workings shown were prepared in accordance with Survey & Drafting Directions 2015.
2. Seam geolocigal information & contours supplied by Illawarra Coal Exploration Department database in May 2014.
3. All surface features supplied by consultants MSEC (Project 459) & NSW Land & Property Information Department.
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SOUTH32

Dendrobium Mine
ILLAWARRA COAL
Cordeaux Road Mount Kembla NSW 2526 Australia
ABN 85 098 744 088

	Name	Date
DRN	D.Baker	25/10/2017
REV		
APP		
SCALE	A0	1:4000

Title **Dendrobium Mine Plan 2 - Surface Features**
Longwall 16 SMP Application

DRAWING NUMBER DEN-01-6153

REV 6