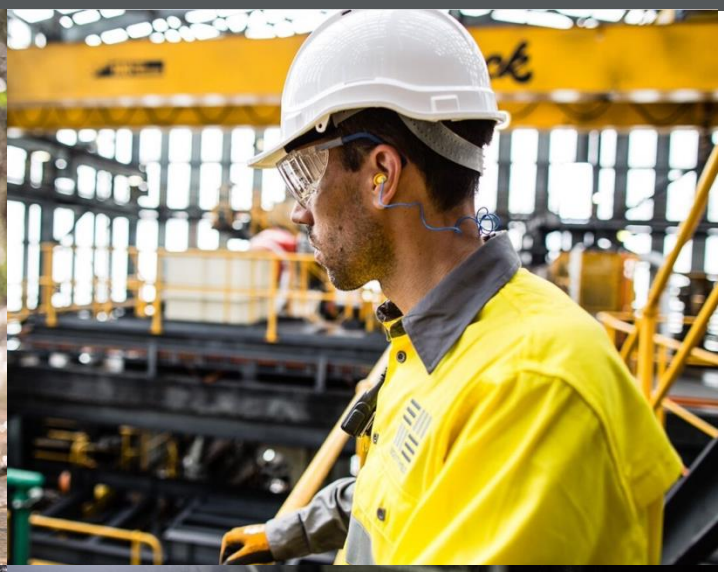
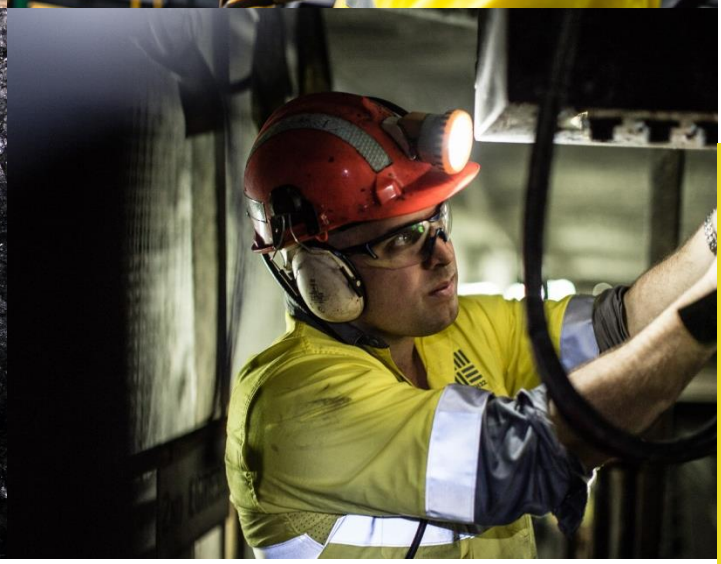
SOUTH32

Illawarra Coal
End of Panel Report



Dendrobium Area 3B Longwall 14 End of Panel Report

September 2019

EXECUTIVE SUMMARY

This End of Panel (EoP) report has been prepared in accordance with Schedule 3 Condition 9 of the Dendrobium Development Consent (DA 60-03-2001). The EoP report outlines the measured and observed impacts during the extraction of Dendrobium Area 3B (DA3B) Longwall 14, and presents monitoring results and analyses compared to relevant impact assessment criteria and predictions in the DA3B Subsidence Management Plan (SMP).

Dendrobium Longwall 14 is located within Consolidated Coal Lease 768. Extraction of Longwall 14 commenced on 22 May 2018 and was completed on 26 February 2019, and is the sixth panel to be extracted in DA3B, with an extracted length of 1969 metres (m), a void width of 305 m (including first workings) and a cutting height of between 3.7 and 3.9 m.

The extraction of underground coal reserves from DA3B provides benefits at international, national, state and local levels. Illawarra Metallurgical Coal (IMC) provides coking coal to BlueScope Steel for its steelmaking production, and for export to overseas customers.

South32 IMC provides 60% of BlueScope Steel's coking coal requirements. Mining operations at Dendrobium Mine represents continuing significant capital and operating investments in the Southern Coalfield of New South Wales.

Continuing benefits occur through continuity of employment, expendable income, export earnings and government revenue. From the operations of Dendrobium Mine, IMC paid approximately $36.95 Million in government royalties during the 2017/2018 financial year, and $44.65 Million during the 2018/2019 financial year.

Subsidence movements resulting from the extraction of Longwall 14 were monitored along lines and points within the Subsidence Management Plan (SMP) Area.

The maximum measured total closure at each of the Wongawilli Creek closure lines are equal to or less than the predictions after the completion of Longwall 14.

The maximum measured total closure at the Avon Dam closure lines are less than predicted after the completion of Longwall 14.

The measured total vertical subsidence and closure for the WC21 cross lines are less than the predicted values at the completion of Longwall 14.

The measured total vertical subsidence and closure for the WC15 cross lines are less than or similar to the predicted values at the completion of Longwall 14.

The maximum measured total movements across LA4A and LA4B are less than the predicted values at the completion of Longwall 14.

The maximum measured total vertical subsidence and closure at swamp crosslines SW4-Line, SW10-Line, SW11-Line, SW13-Line and SW23-Line are all less than the predicted values. The measured vertical subsidence movements range between 66 % and 75 % of the predicted values. The measured closures (excluding the SW11-Line) range from less than 20 % to 45 % of the predicted values. An opening of less than 20 millimetres (mm) was measured at the SW11-Line.

During the extraction of LW14, twenty-eight new surface impacts were identified. These impacts are labelled as "*DA3B_Longwall 14_001*" to "*DA3B_Longwall 14_028*". Fourteen of these impacts were observed on natural features. The remaining fourteen impacts were observed on built features such as fire roads and other access tracks, which were remediated (or observed as self-remediated) in accordance with Corrective Management Actions (CMAs). An additional three new LW13 impacts were also identified during the extraction of LW14.

At Wongawilli Creek (FR6), a Trigger Action Response Plan (TARP) Level 1 was recorded for Electrical Conductivity (EC) and a TARP Level 2 was recorded for Dissolved Oxygen (DO). At Donalds Castle Creek (FR6*)*, a TARP Level 3 was recorded EC.

The effects of mining subsidence on surface water hydrology was assessed by comparing observed stream flow characteristics for each monitored sub-catchment against predictions of streamflow from a calibrated rainfall-runoff model. There were five TARP triggers observed for sub-catchment yield change: Donalds Castle Creek (DCS2; Level 3); DC13 (DC13S1; Level 2); WC21 (WC21S1; Level 3); WC15 (WC15S1; Level 1) and LA4 (LA4S1; Level 1).

The average daily inflow to DA3B during Longwall 14 extraction was 4.21 megalitres per day (ML/day) which represents approximately 72 % of total mine inflow for the period. The average water balance for DA3B during the extraction of Longwall 14 is approximately 10 % lower than for LW13 (4.68 ML/day).

Seepage losses from Lake Avon*,* estimated using a local scale numerical model, was approximately 0.44 ML/day following the extraction of Longwall 14. The estimate is of a similar magnitude to those from regional numerical modelling and within the tolerable loss limit of 1 ML/day prescribed by the NSW Dams Safety Committee (DSC).

Longwall 14 undermined and/or passed within 400 m of shallow groundwater and soil moisture sites within four swamps: Swamps 11, 13, 14 and 23. Soil moisture and shallow groundwater responses in these swamps varied due to their proximity to mined longwalls and climatic conditions. Given the low rainfall conditions in 2017 and 2018 and strong depletion in soil moisture levels across the plateau (including reference sites), the degree of groundwater and soil moisture impact will not be clear without further monitoring over several months of close to average rainfall.

The results of the Total Species Richness (TSR) analysis demonstrate the response to mining at individual swamps is complex with Swamp 15A(2) and Swamp 15B showing a decline and subsequent increase in TSR following mining and changes in shallow groundwater. Meanwhile Swamp 1A, Swamp 1B and Swamp 5 displayed no significant decline in TSR despite observed changes in shallow groundwater availability.

When accounting for yearly effects, a statistically significant change in species composition post-mining was detected at Swamp 15B and Swamp 15A(2). As with TSR, these changes were observed immediately following mining and have continued at Swamp 15B and Swamp 15A(2) for at least four years post-mining.

The analysis of ALS survey data was used to assess the extent of upland swamps and their composite vegetation communities. The data indicates that the extent of all upland swamps (impact and control swamps) within the study area has decreased from the 2014 baseline, including a substantial decrease during 2018.

A reduction in habitat of the Littlejohn's Tree Frog was observed within streams impacted by subsidence.

Reductions in aquatic habitat for over 2 years at WC21 and Donalds Castle Creek constitute a Level 3 TARP trigger. No TARPs have been triggered with respect to Wongawilli Creek as there has not been a loss in aquatic habitat for longer than 1 year.

Two out of the five Aboriginal archaeology sites had observable impacts from subsidence movements related to the extraction of Longwall 14.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ATTACHMENTS

Attachment A – Dendrobium Area 3B SMP Approval

Attachment B – Subsidence Monitoring Report (MSEC)

Attachment C1 – Landscape Report (ICEFT)

Attachment C2 – Longwall 14 Impact Reports (ICEFT)

Attachment D – Surface Water and Shallow Groundwater Assessment (HGEO) (To be provided in final report)

Attachment E1 – Groundwater Assessment (HGEO)

Attachment E2 – Groundwater Assessment: EC Hydrographs (HGEO)

Attachment F – Terrestrial Ecology Assessment (Biosis)

Attachment G – Aquatic Ecology Assessment (Cardno)

Attachment H – Heritage Assessment (Niche)

1 INTRODUCTION

1.1 Approval and Legislative Requirements

Dendrobium Longwall 14 is located within Consolidated Coal Lease 768 and is the sixth panel to be extracted in DA3B. Extraction of Longwall 14 commenced on 22 May 2018 and was completed on 26 February 2019. The extracted longwall had a length of 1969 m; a void width of 305 m (including first workings); and a cutting height of between 3.7 and 3.9 m.

This EoP report has been prepared in accordance with Schedule 3 Condition 9 of the Development Consent (DA60-03-2001 – MOD 8) (Table 1). The EoP report outlines the measured and observed impacts of Longwall 14 and analyses the monitoring results compared to relevant impact assessment criteria and predictions made in the SMP and associated management plans and reports.

The DA3B SMP was approved by Department of Trade and Investment, Regional Infrastructure and Services NSW (DTI) on the 5 February 2013 and the Department of Planning and Environment (DP&E) on the 6 February 2013. Subsequent approval for the Longwalls 14 - 15 SMP was granted on the 16 December 2016 by DP&E, which is provided as **Attachment A**.

Schedule 3 Conditions 9 and 10 of the Development Consent are provided in Table 1.

Table 1: Approval conditions excerpt from the Dendrobium Development Consent (DA60-03-2001 – MOD 8).

Development Consent Approval Condition	Relevant Section in EoP Report
Schedule 3 of Development Consent DA60-03-2001 – MOD 8 **9.** Within 4 months of the completion of each longwall panel, or as otherwise permitted by the Director-General, the Applicant shall: 1. prepare an end-of-panel report – reporting all subsidence effects (both individual and cumulative) for the panel and comparing subsidence effects with predictions; – describing in detail all subsidence impacts (both individual and cumulative) for the panel; – discussing the environmental consequences for watercourses, swamps, water yield, water quality, aquatic ecology, terrestrial ecology, groundwater, cliffs and steep slopes; and – comparing subsidence impacts and environmental consequences with predictions; and 2. Submit the report to the Department, DPI, SCA, DECC, DWE and any other relevant agency to the satisfaction of the Director-General	*Sections 4 to 8, Attachments B to F* *The AEMR (July to June) is submitted in August each year*

10. The Applicant shall include a comprehensive summary, analysis and discussion of the results of monitoring of subsidence effects, subsidence impacts and environmental consequences in each AEMR	

The impact predictions for Longwall 14 are described in the following reports:

- South32, December 2016 - DA3B Longwalls 14 – 15 SMP;
- South32, October 2017 – DA3B Watercourse Impact Monitoring Management and Contingency Plan (WIMMCP), Revision 1.6; and
- South32, October 2017 – DA3B Swamp Impact, Monitoring, Management and Contingency Plan, Revision 1.6.

Impacts have been reported by the Illawarra Coal Environmental Field Team (ICEFT) and specialist consultants during and following mining.

1.2 Economic Benefits

The extraction of underground coal reserves from DA3B provides benefits at international, national, state and local levels. IMC provides coking coal to BlueScope Steel for its steelmaking production, and for export to overseas customers.

South32 IMC provides 60% of BlueScope Steel's coking coal requirements. Mining operations at Dendrobium Mine represents continuing significant capital and operating investments in the Southern Coalfield of New South Wales.

Continuing benefits occur through continuity of employment, expendable income, export earnings and government revenue. From the operations of Dendrobium Mine, IMC paid approximately $36.95 Million in government royalties during the 2017/2018 financial year, and $44.65 Million during the 2018/2019 financial year.

1.3 Stakeholder Consultation

Provision of monitoring data and ongoing information to the community has been undertaken during the extraction of DA3B. Information on South32 operations is provided to the community through the following mechanisms:

- Community information sheets and letter box drops;
- Media releases and other media activities;
- General community surveys and reports;
- Dendrobium Community Newsletter – distributed to the community;

- Internet site http://www.south32.net/our-operations/australia/illawarra-coal/regulatory-document;
- Dendrobium Community Consultative Committee (DCCC) Meetings;
- Landholder relations program;
- Annual review reports; and
- Information days.

IMC aims to mitigate the potential impacts subsidence may cause on individuals through various means outlined in Table 2.

Table 2: Social Impact Variables Associated with Subsidence

Potential Impact	Monitoring Variables	Mechanism
Subsidence Impacts	• Level of community concern relating to subsidence • Awareness of subsidence, its effects and management • Level of perceived community risk associated with subsidence • Level of satisfaction with the company's subsidence management practices • The extent to which the community attributes environmental, social and economic change within the community to mining activities	• The DCCC meetings including presentations and explanations of how and why subsidence occurs, and its potential impacts • A biennial telephone survey of residents in the communities in which IMC operates. The survey aims to determine the community's perception of the company's overall performance

2 PREDICTED AND OBSERVED SUBSIDENCE

Subsidence movements resulting from the extraction of Longwall 14 were monitored along lines and points within the SMP Area. A comparison of the observed and predicted movements has been prepared by Mine Subsidence Engineering Consultants (MSEC) and is included as **Attachment B**.

Monitoring points and lines associated with Longwall 14 include (Figure 1):

- Wongawilli Creek Closure Lines;
- Donalds Castle Creek Cross lines;
- Avon Dam Closure Lines;
- Wongawilli and Lake Avon Tributary Cross Lines;
- Swamp Cross Lines;
- DA3B 3D and Avon Dam 3D Monitoring Points; and
- Airborne Laser Scans (ALS) of the area.

The predicted subsidence at the location of surface features have been derived from the predicted subsidence contours illustrated in Report No. MSEC865. The predicted closures are based on a combination of the conventional and valley related movements, taking the equivalent heights within half-depths of cover from the valley bases.

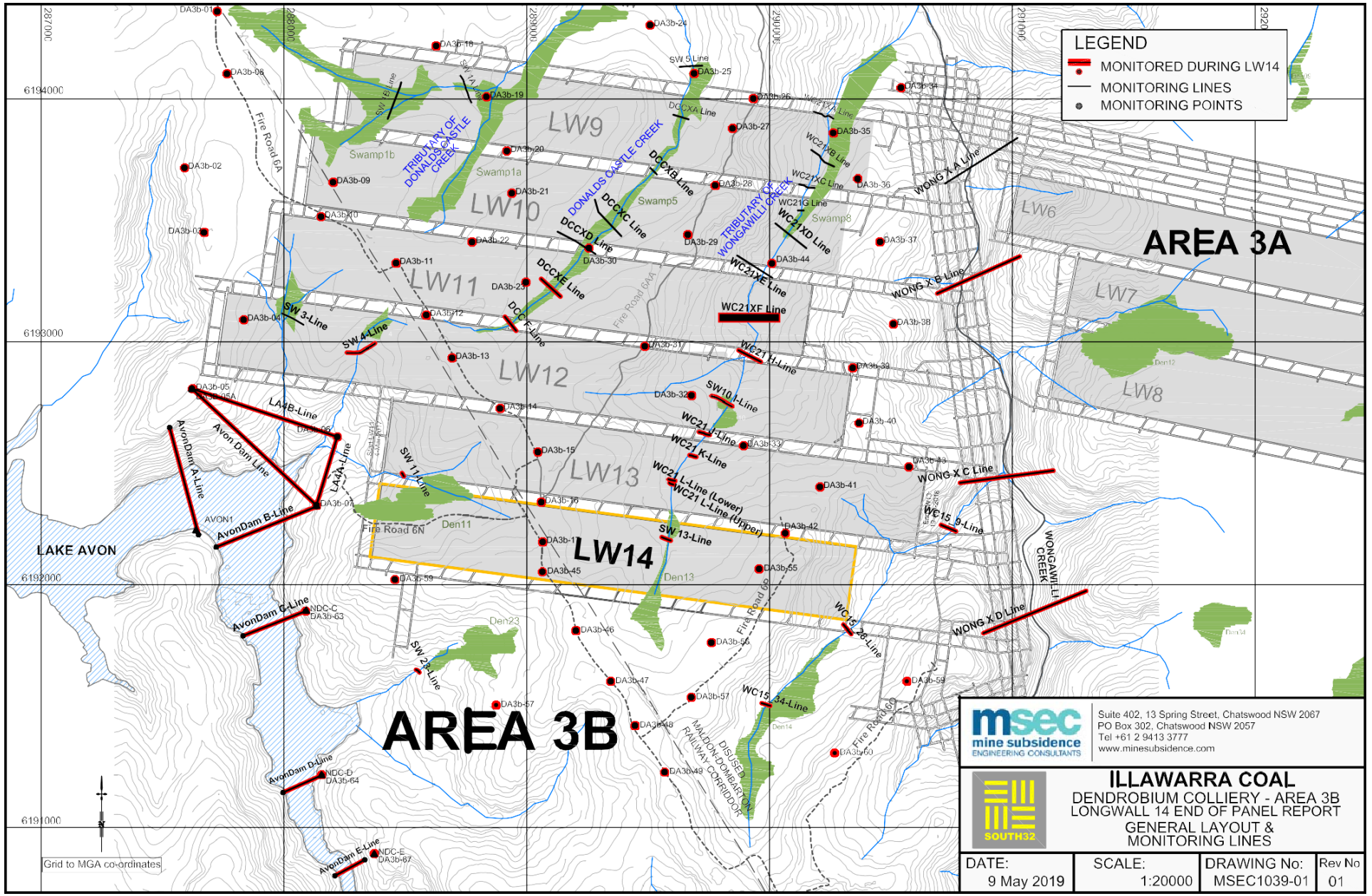


Figure 1: Overview of subsidence monitoring sites, comprised of monitoring lines and monitoring points.

2.1 Wongawilli Creek Closure Lines

The closure movements across Wongawilli Creek have been measured using 2D survey techniques at the Wong X B-Line, Wong X C-Line and Wong X D-Line. The Wong X A-Line was not required to be measured at the completion of Longwall 14 due to its distance from these longwalls.

The maximum measured total closure at each of the Wongawilli Creek closure lines are similar to or less than the predictions after the completion of Longwall 14 (Figure 2).

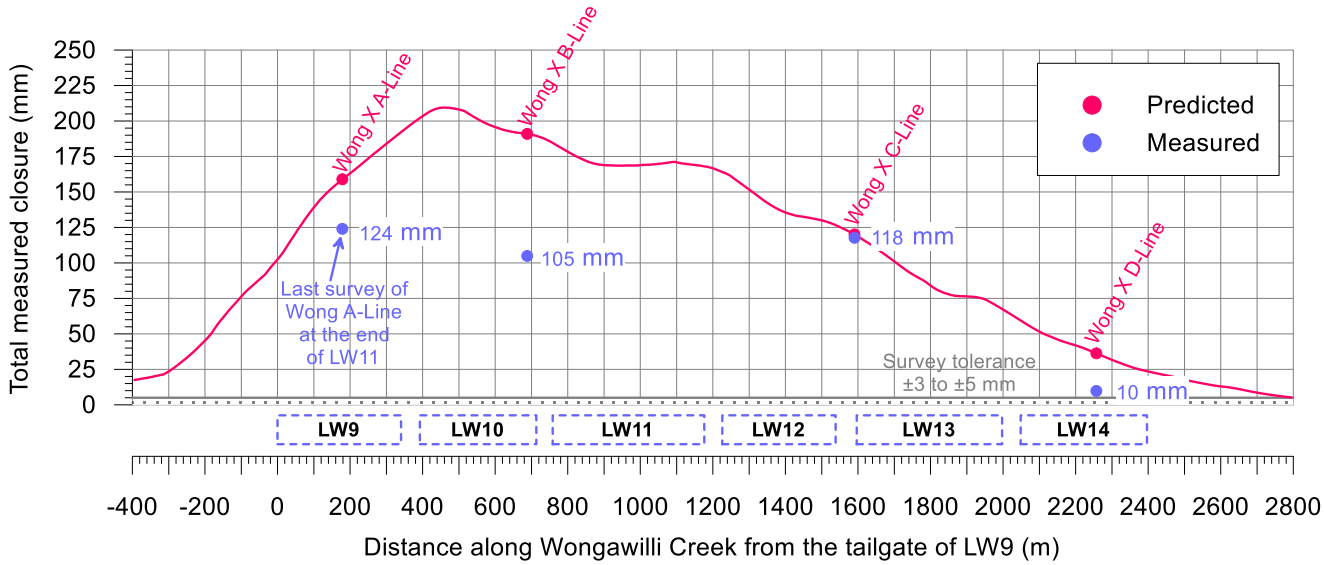


Figure 2: Measured and predicted total closure along Wongawilli Creek after the extraction of Longwall 14. (Source: Attachment B).

2.2 Donalds Castle Creek Cross Lines

The mine subsidence movements across Donalds Castle Creek were measured using 2D survey techniques at the DCCXE-Line and DCCXF-Line. The DCCXA-Line, DCCXB-Line, DCCXC-Line and DCCXD-Line were not required to be measured during Longwall 14 due to their distances from this longwall.

There were small reductions in the total closures measured at the DCCXE-Line and DCCXF-Line due to the extraction of Longwall 14. Only small changes were observed at these monitoring lines as they are located more than 700 m from the active longwall.

The measured total vertical subsidence and closure for the DCCXE-Line and DCCXF-Line are less than the predicted values at the end of Longwall 14. The ratios of the maximum measured to maximum predicted total vertical subsidence are 0.98 for the DCCXE-Line and 0.66 for the DCCXF-Line. The ratios of the maximum measured to maximum predicted total closure are 0.97 for the DCCXE-Line and 0.44 for the DCCXF-Line. It is considered, therefore, that the ground movements measured using Donalds Castle Creek cross lines are less than or consistent with predicted movements.

2.3 Avon Dam Closure Lines

The baseline surveys of Avon Dam closure lines were carried out prior to the commencement of Longwall 12 (in February 2016) and, therefore, the closure lines have measured the accumulated movements due to the extraction of Longwall 12, Longwall 13 and Longwall 14 only.

The maximum measured cumulative closures at the Avon Dam closure lines are less than the predicted closures after the completion of Longwall 14. The extraction of Longwall 14 has only resulted in a small increase in the closure measured at the A-Line and small increases in the openings measured at each of the other monitoring lines (Figure 3).

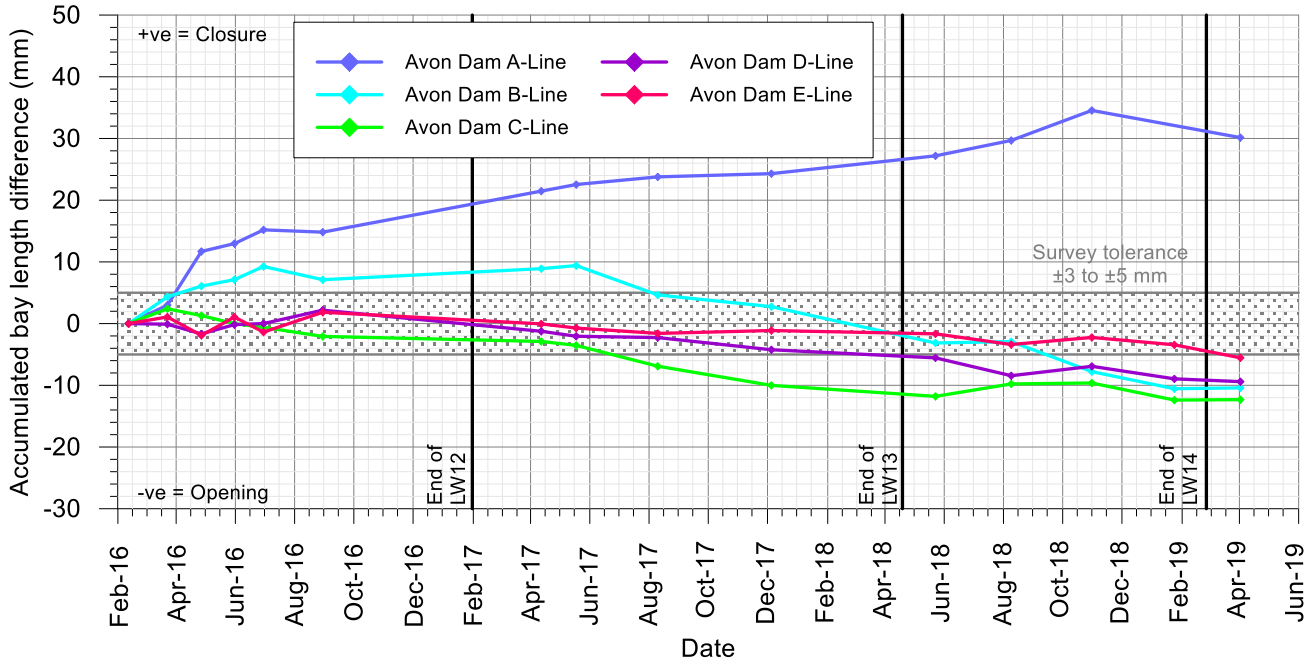


Figure 3: Measured closure for the *Avon Dam* closure lines. (Source: Attachment B).

2.4 Wongawilli Creek Tributaries and Lake Avon Tributary Cross Lines

Mine subsidence movements across *WC21*, a tributary to Wongawilli Creek, have been measured with 2D survey techniques at the WC21 F-Line, WC21 H-Line, WC21 I-Line, WC21 J-Line, WC21 K-Line, WC21 L-Line (lower) and WC21 L-Line (upper). The WC21 A-Line, B-Line, C-Line, D-Line, E-Line and G-Line were not required to be measured during Longwall 14.

The measured total vertical subsidence and closure for the WC21 cross lines are less than the predicted values at the completion of Longwall 14 (Figure 4). The measured vertical subsidence movements range between 52 % and 73 % of the predicted values, with an average of 61 %. The measured closures range between 17 % and 94 % of the predicted values, with an average of 49 %. It is considered, therefore, that the ground movements measured along WC21 are generally consistent with or less than the predicted movements.

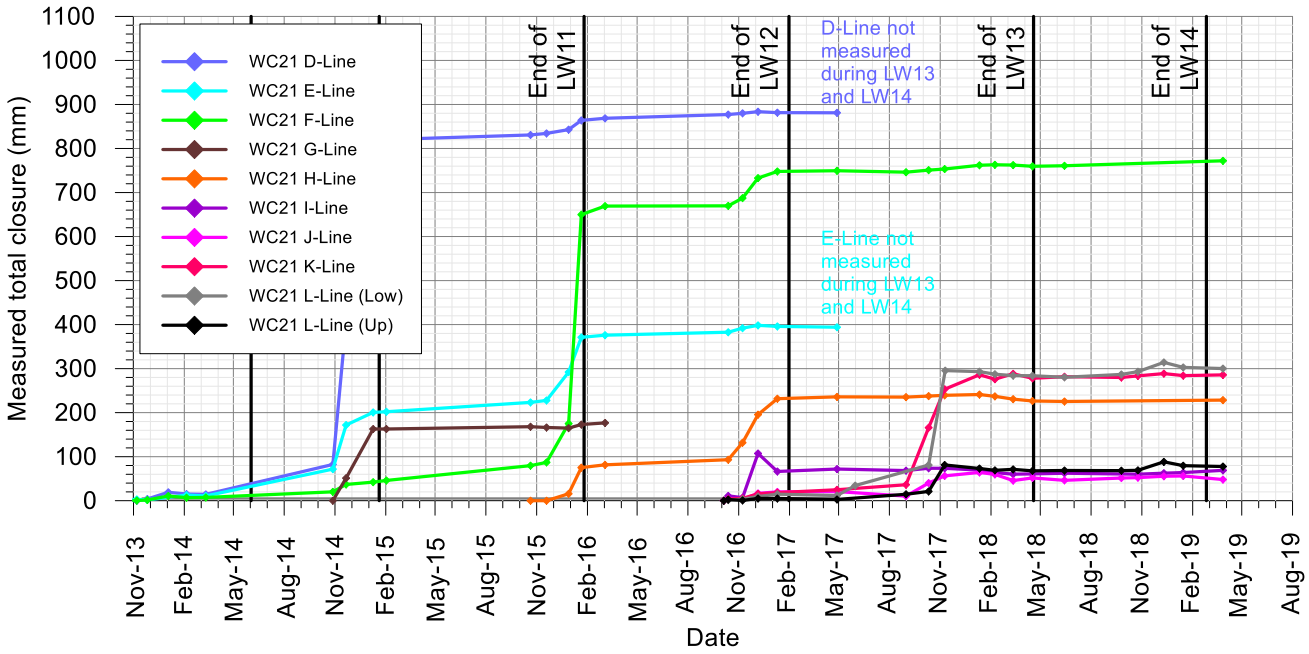


Figure 4: Measured total closure for WC21 cross lines. (Source: Attachment B).

The mine subsidence movements across WC15 (a tributary to Wongawilli Creek) have been measured using 2D survey techniques at the WC15 RB9-Line, WC15 RB28-Line and WC15 RB34-Line (Figure 5). These monitoring lines were established in December 2018 during the mining of Longwall 14. Low level net uplift in the order of the survey tolerance for absolute height were measured at each of the WC15 RB9-Line, WC15 RB28-Line and WC15 RB34-Line. The closure measured at the WC15 RB28-Line was similar to the predicted value. Only low-level closure movements similar to the order of survey tolerance were measured at the WC15 RB9-Line and WC15 RB34-Line.

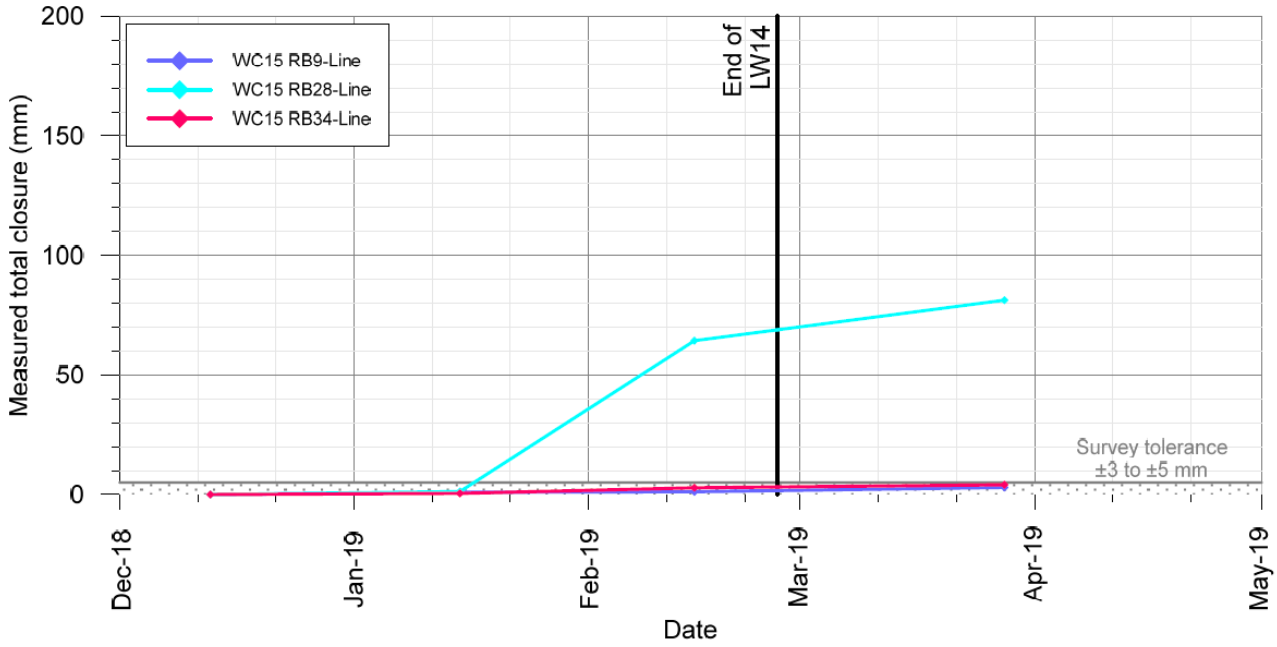


Figure 5: Measured incremental closure for the WC15 cross lines. (Source: Attachment B).

The closure across Avon Dam and two tributaries to Avon Dam (LA4A and LA4B), were measured with 2D survey technique (Figure 6). The base survey was carried out on 26 February 2013, prior to the commencement of Longwall 9. The maximum measured total movements across LA4A, LA4B and the Avon Dam are less than the predicted values at the completion of Longwall 14. It is considered that the ground movements measured using these monitoring lines are consistent with the predictions.

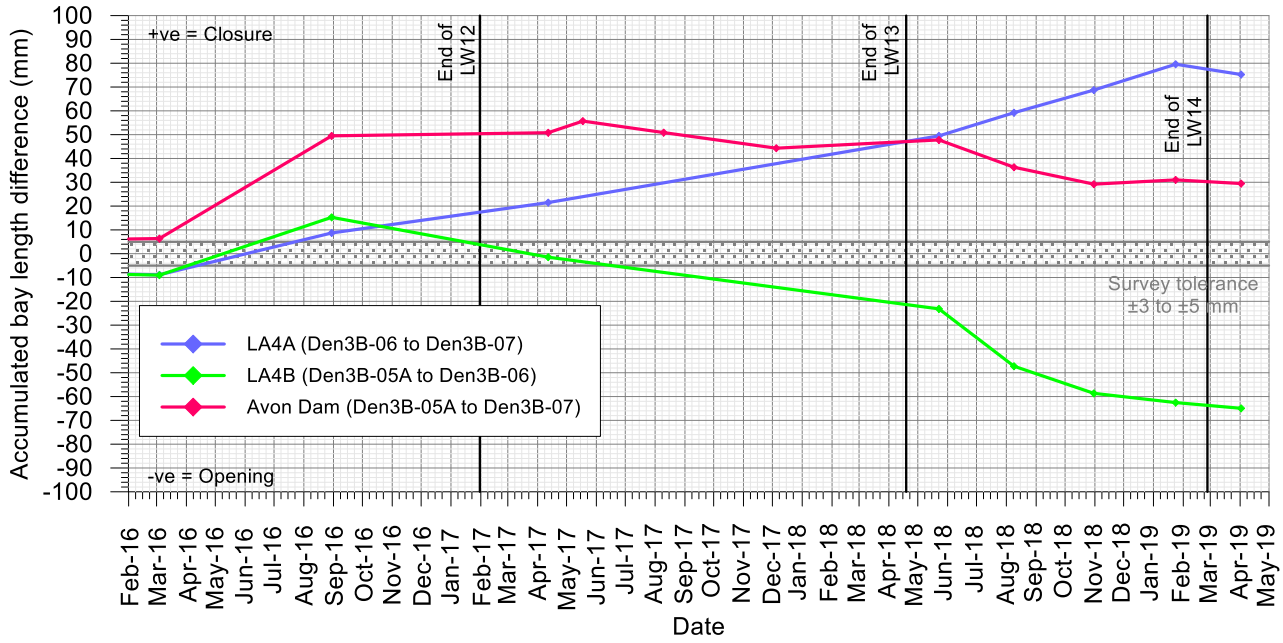


Figure 6: Measured accumulated closure for Tributaries LA4A, LA4B and the Avon Dam. (Source: Attachment B).

2.5 Swamp Cross Lines

The mine subsidence movements across swamps have been measured using 2D survey techniques at the SW4-Line, SW10-Line, SW11-Line, SW13-Line and SW23-Line.

The maximum measured total vertical subsidence and closure at the SW4-Line, SW10-Line, SW11-Line, SW13-Line and SW23-Line are all less than the predicted values. The measured vertical subsidence movements range between 66 % and 75 % of the predicted values. The measured closure (excluding the SW11-Line) ranges from less than 20 % to 45 % of the predicted values. An opening of less than 20 mm was measured at the SW11-Line. Thus, the subsidence movements measured using swamp cross lines are generally consistent with or less than the predicted subsidence movements.

2.6 Dendrobium Area 3B 3D and the Avon Dam 3D monitoring points

The far-field horizontal movements near Longwall 14 have been measured using DA3B 3D monitoring points and the Avon Dam 3D monitoring points (Figure 1). The accuracies of the measured absolute positions (i.e. Eastings and Northings) are in the order of ±20 mm.

The vectors of incremental horizontal movement are typically orientated towards Longwall 14 and skewed towards the east, i.e. towards the longwall finishing end (Figure 7). The greatest movements have been measured directly above Longwall 14 and, to lesser extents, above the previously extracted Longwall 13. Only low level incremental horizontal movements have been measured outside the extents of the mining area.

The comparison between the maximum measured incremental horizontal movements at the DA3B 3D and Avon Dam 3D monitoring points with those previously measured in Dendrobium Area 1 (DA1 3D) and Dendrobium Area 2 (DA2 3D), Dendrobium Area 3A (DA3A 3D), as well as other collieries in the Southern Coalfield, is provided in Figure 8. The mean and the 95 % confidence level for the 3D monitoring data at Dendrobium Mine are also shown in Figure 8.

The measured incremental horizontal movements resulting from the extraction of Longwall 14 (i.e. dark grey diamonds and circles) are typically within the range of those measured at similar distances from previously extracted longwalls at Dendrobium Mine (i.e. blue, cyan, green, brown, orange, red, magenta and purple diamonds) and elsewhere in the Southern Coalfield (i.e. grey triangles).

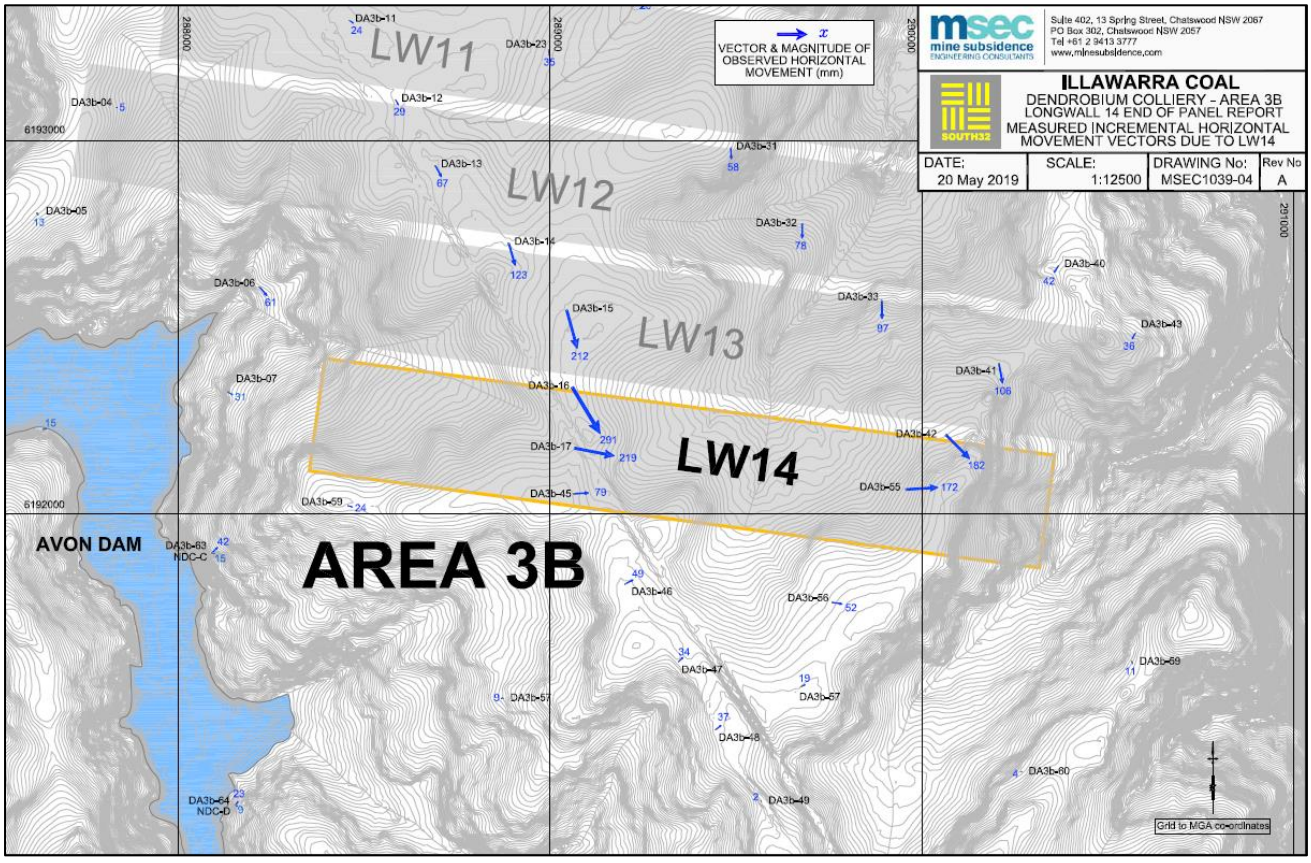


Figure 7: Incremental horizontal movement vectors following the extraction of Longwall 14. (Source: Attachment B).

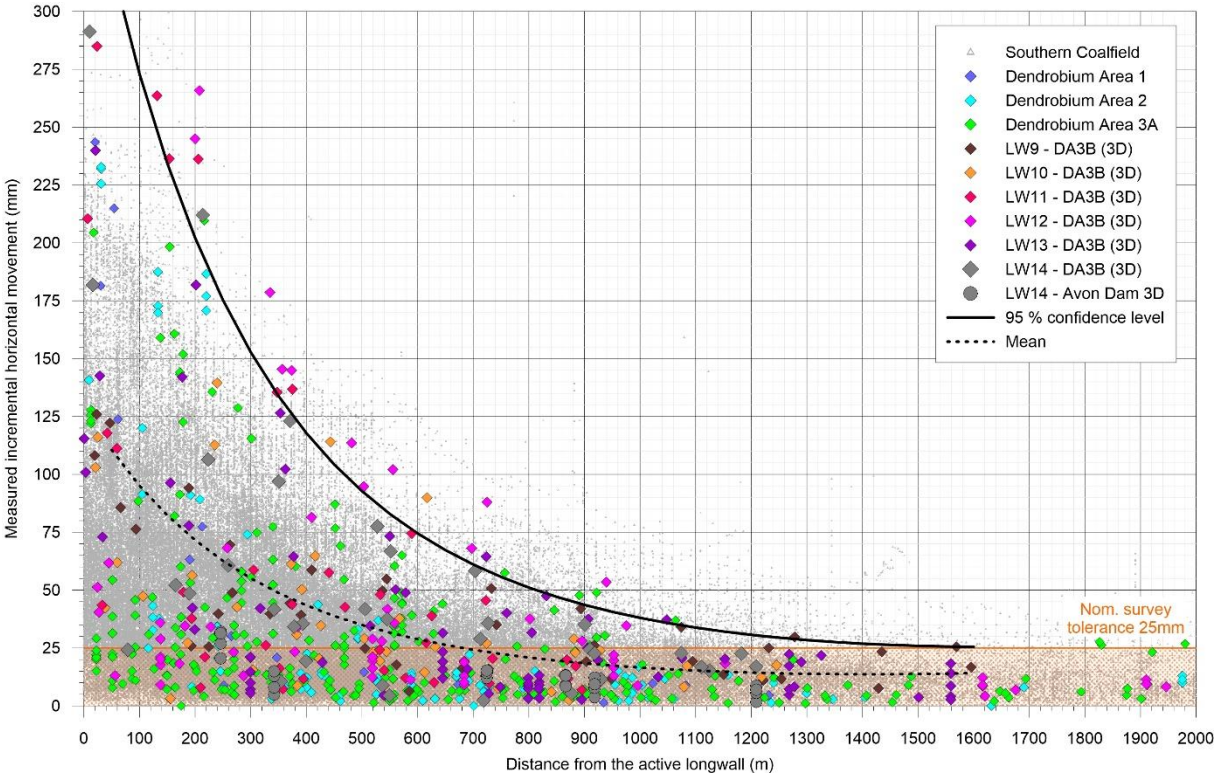


Figure 8: Measured incremental horizontal movements at Dendrobium Mine. (Source: Attachment B).

2.7 Airborne Laser Scanner (ALS) / LiDAR Surveys

The changes in surface level due to the extraction of Longwall 9 to Longwall 14 have been measured using Airborne Laser Scanning (ALS) surveys. The initial surface level contours have been determined from the base survey carried out in January 2013, prior to the extraction of Longwall 9. The post mining surface level contours have been determined from the subsequent surveys carried out in February 2014 after Longwall 9, in January 2015 after Longwall 10, in April 2016 after Longwall 11, in March 2017 after Longwall 12, in May 2018 after Longwall 13 and in March 2019 after Longwall 14.The changes in surface level were determined by calculating the differences between pre-mining surface levels and post-mining surface levels, incrementally (Figure 9), and cumulatively (Figure 10).

The profiles of the measured changes in surface level reasonably match the predicted profiles of vertical subsidence along each of the cross-sections and long-section (Figure 11, Figure 12, Figure 13 and Figure 14). The maximum measured changes in surface level above each of the longwalls are less than the maximum predicted values. Also, the measured changes in surface level above each of the chain pillars are similar to, but slightly less, than the predicted values in these locations.

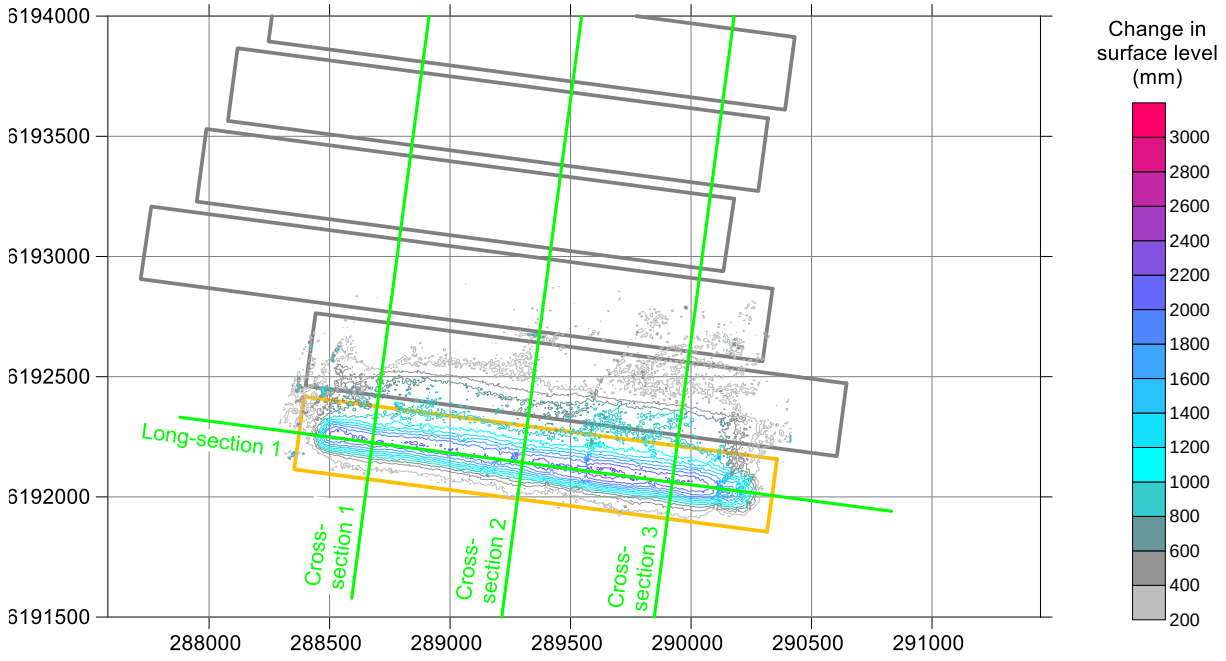


Figure 9: Measured incremental changes in surface level due to the extraction of Longwall 14. (Source: Attachment B).

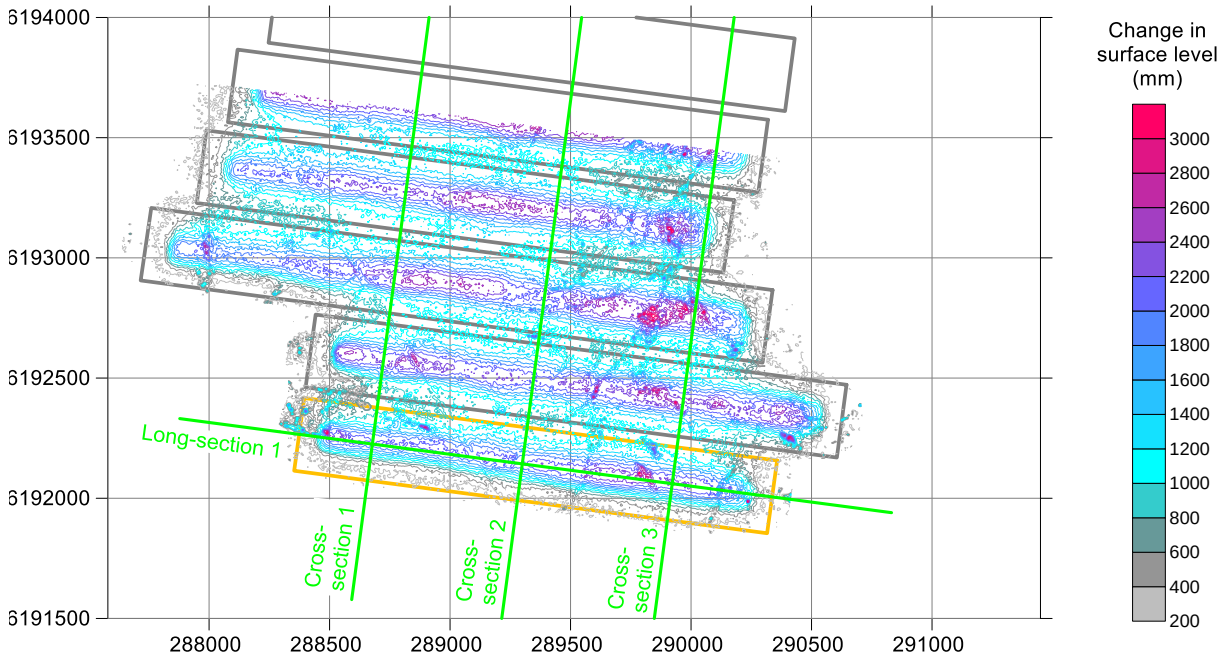


Figure 10: Measured cumulative changes in surface level due to the extraction of Longwalls 9 to 14. (Source: Attachment B).

The measured change in surface level along Long-section 1 (

Figure **14**) is greater than the predicted vertical subsidence above the commencing end of Longwall 14 (i.e. left side of figure). However, this may be partly due to the effects of the horizontal movements and sloping terrain on the ALS surveys. The ground directly above the commencing end of Longwall 14 has moved towards the

longwall (i.e. following the extraction face). The natural surface dips towards the west in this location (i.e. towards Lake Avon).

The mining-induced horizontal movement, therefore, results in the measured changes in level at a fixed position to be greater than the true vertical subsidence above the commencing end of Longwall 14. There are localised areas outside of the longwalls where the measured changes in surface level exceed the predicted vertical subsidence. However, these are artefacts of the ALS surveys and are not real movements. It is considered that the subsidence movements measured using the ALS surveys are consistent with the predicted subsidence movements.

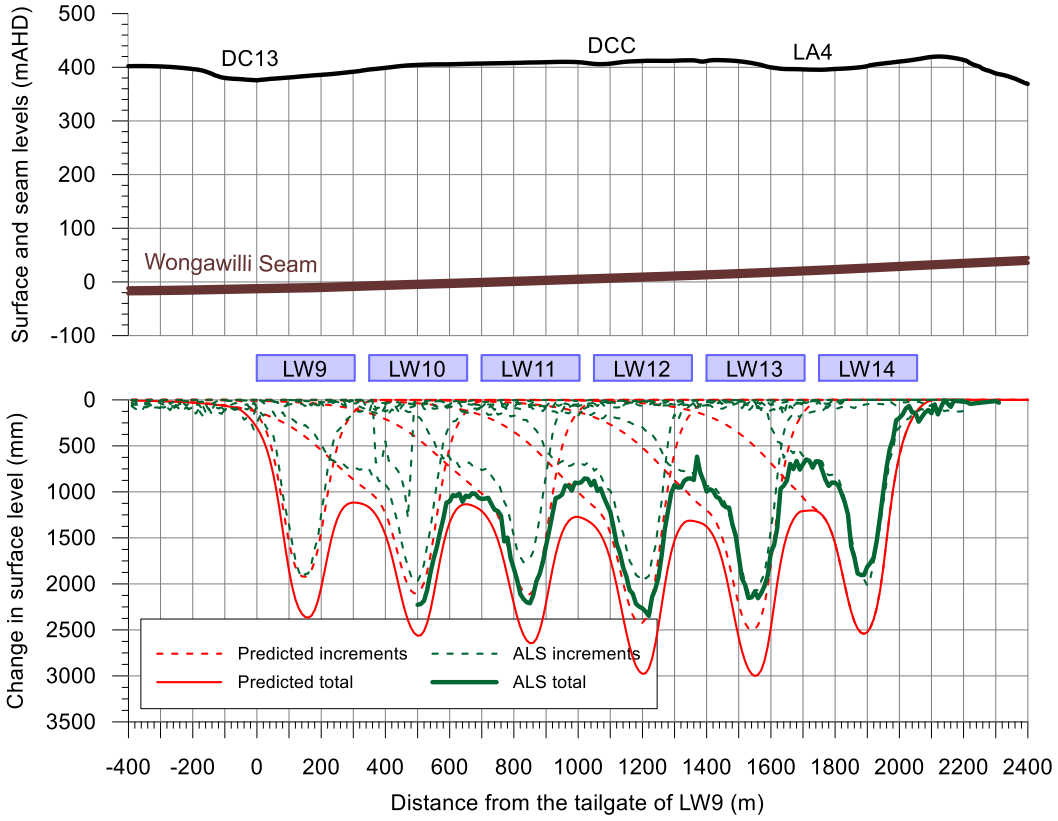


Figure 11: Measured changes in surface level and predicted vertical subsidence along Cross-section 1. (Source: Attachment B).

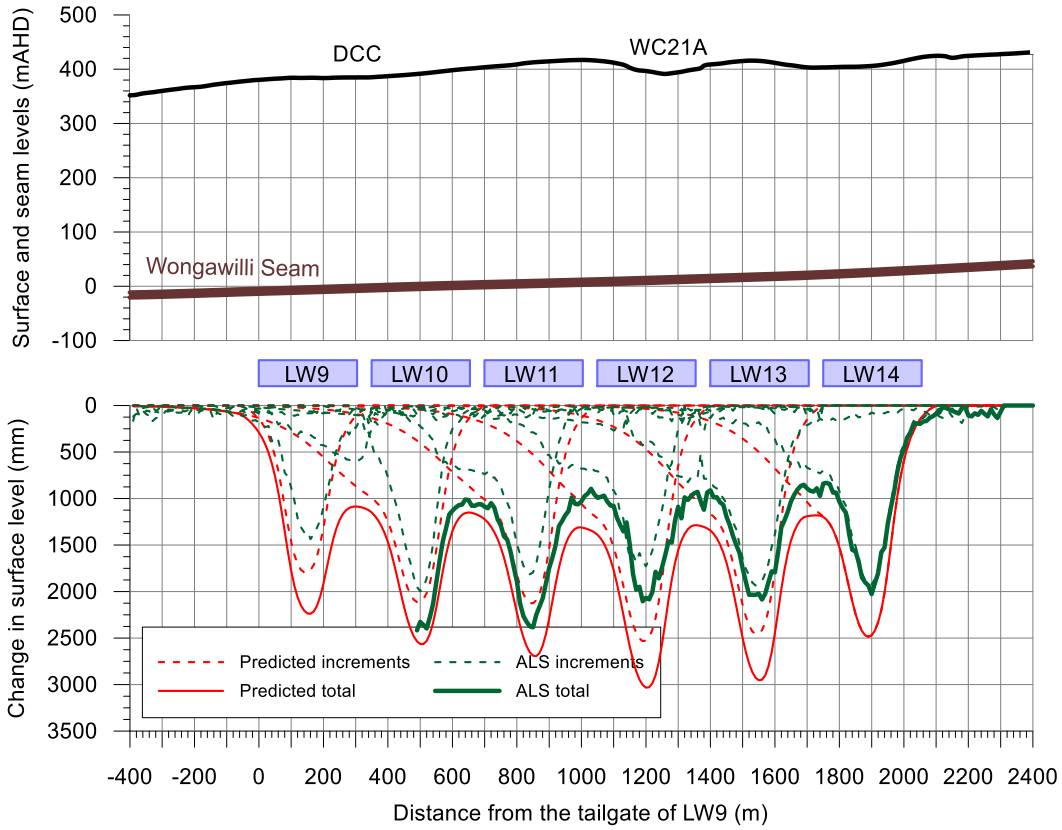


Figure 12: Measured changes in surface level and predicted vertical subsidence along Cross-section 2. (Source: Attachment B).

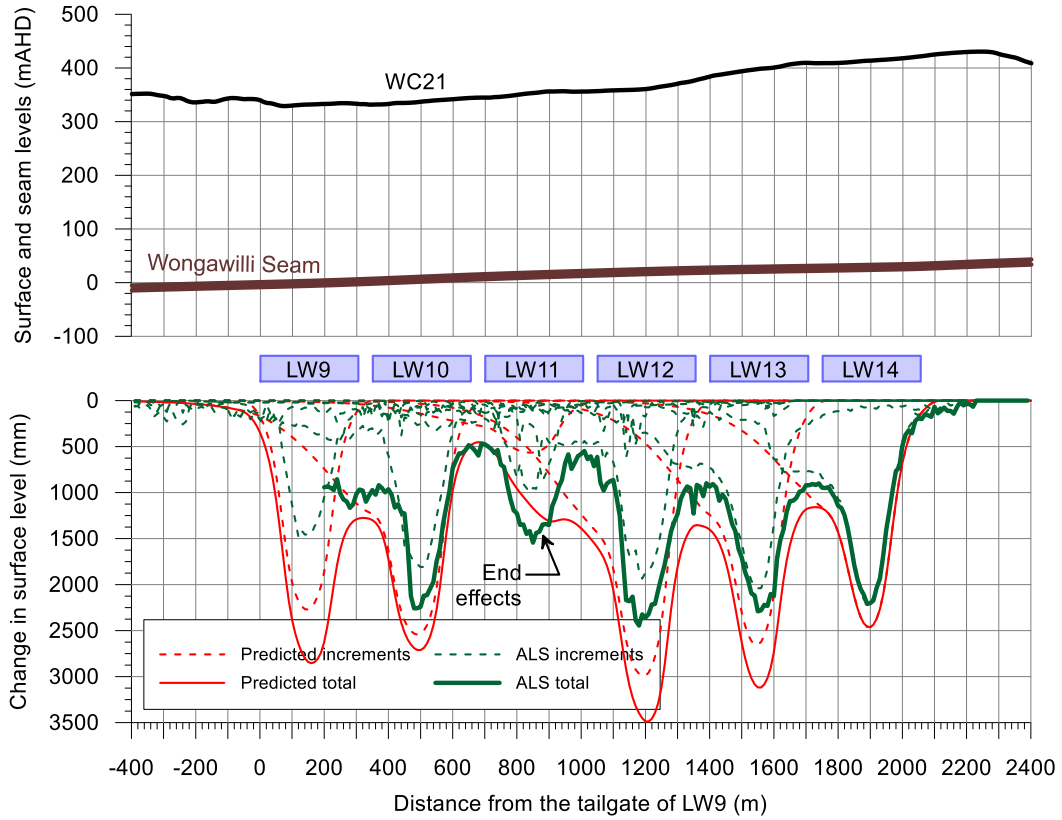


Figure 13: Measured changes in surface level and predicted vertical subsidence along Cross-section 3. (Source: Attachment B).

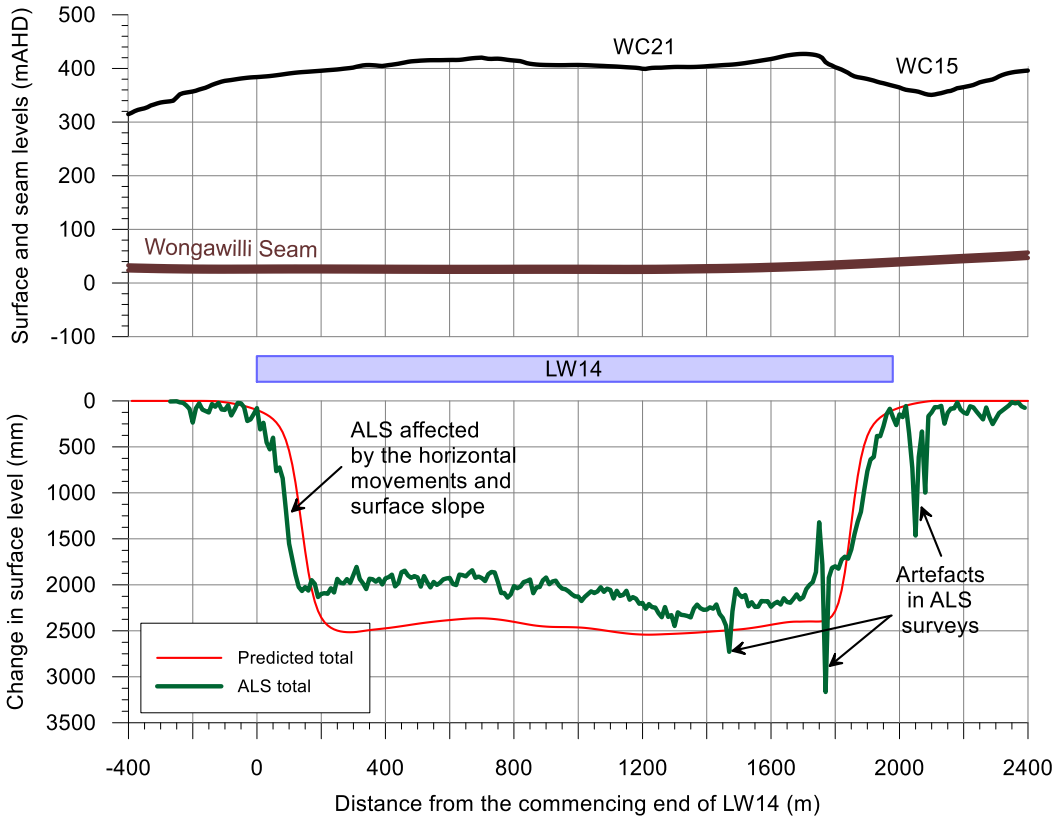


Figure 14: Measured changes in surface level and predicted vertical subsidence along Long section 1. (Source: Attachment B).

3 IMPACTS TO NATURAL FEATURES

During the extraction of Longwall 14, 28 new surface impacts were identified. These impacts are labelled as *DA3B_LW14_001* to *DA3B_LW14_028*. Three additional Longwall 13 impacts were identified; these impacts are labelled as *DA3B_LW13_044* to *DA3B_LW13_046*. Updates are provided for three existing Longwall 13 impacts; these impacts are labelled as *DA3B_LW13_035 (Update)*, *DA3B_LW13_042 (Update)* and *DA3B_LW14_043 (Update)*. Impacts *DA3B_LW14_026 to DA3B_LW14_028* are not included in the Longwall 14 End of Panel Landscape Report (**Attachment C1**) as they were identified following its finalisation. Other triggers are addressed in their respective sections, with further detail in the attached specialist assessments.

The monitoring program for Longwall 14 was conducted in accordance with the SMP, WIMMCP and SIMMCP. The monitoring program is outlined in Section 6. The results of the ICEFT monitoring are provided in **Attachment C1**; the impact reports submitted during the extraction of Longwall 14 are provided in **Attachment C2**. The results of monitoring undertaken by specialist consultants are provided in **Attachments D to H**. Figure 17 illustrates the location of surface impacts identified during the extraction of Longwall 14.

3.1 Landscape Features

Subsidence includes vertical and horizontal movement of the land surface, which can result in surface and subsurface cracking, uplifting, buckling, dilation and tilting. These impacts can affect watercourse hydrology and morphology, swamp hydrology and ecological function, and other landscape features by means of surface cracking, which can lead to erosion and rock falls. Potential mine subsidence impacts within DA3B are discussed in the DA3B SMP, WIMMCP and SIMMCP.

An overview of impacts observed during the extraction of Longwall 14 is provided in the following sections. For specific details on the impacts, refer to the relevant impact reports (**Attachment C2**).

3.1.1 Impacts to First and Second Order Streams

Nine first and second order streams were monitored as part of the Longwall 14 monitoring program; LA3, LA4, LA4B, LA4A, LA4A1, WC21, WC15, WC15A and WC15A1. Impacts observed at these streams during Longwall 14 are described in Table 3, with Photos 1 – 14 showing the impacts recorded.

Table 3: Summary of impacts to first and second order streams.

Site ID	Easting	Northing	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_LW14_016 Photo 1	290345	6191835	Rock Fracturing, Uplift and Rock Displacement	*WC15*	21/01/2019	2	Multiple fractures, uplift and dislodged sections of rock on *WC15*. The longest fracture is up to 4.0 m long and 0.03 m wide.	24/01/2019
DA3B_LW14_017 Photo 2	290276	6191786	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fracturing has a maximum measurable length of 0.8m, a maximum width of 0.025 m and a maximum measurable depth of 0.17 m.	21/02/2019
DA3B_LW14_018 Photo 3	290282	6191791	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 0.7 m, a maximum width of 0.015 m and a maximum measurable depth of 0.10 m.	21/02/2019
DA3B_LW14_019 Photo 4	290312	6191805	Rock Fracturing and Uplift	*WC15*	20/02/2019	1	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 4.5 m, a maximum width of 0.05 m, a maximum measurable depth of 0.7 m.	21/02/19
DA3B_LW14_020 Photo 5	290334	6191828	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 1.3 m, a maximum width of 0.05 m and a maximum measurable depth of 1.13 m.	21/02/19
DA3B_LW14_021 Photo 6	290416	6191943	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fractures have a maximum measurable length of 1.1 m and a maximum width of 0.01 m.	21/02/19
DA3B_LW14_022 Photo 7	290283	6192052	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 2.9 m, and a maximum width of 0.05 m.	21/02/19
DA3B_LW14_023 Photo 8	290398	6191907	Rock Fracturing	*WC15*	1/04/2019	1	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 0.35 m, and a maximum width of 0.001 m.	3/04/19
DA3B_LW13_035 *(Update)* Photo 9	290406	6191915	Rock Fracturing	*WC15*	23/04/2018	2	Additional fracturing with flow diversion was observed on *WC15*. The largest fracture is up to 3.7 m long, with the widest fracture up to 0.02 m wide.	27/04/2018 24/01/2019
DA3B_LW13_042 *(Update)* Photo 10	290772	6192286	Rock Fracturing	*WC15*	16/05/2018	2	Additional fracturing and rock fragmentation were observed at WC15. The new rock fracturing has a	17/05/2018 3/04/2019

Site ID	Easting	Northing	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
							maximum measurable length of 0.2 m and a maximum width of 0.002 m.	
DA3B_LW13_043 *(Update)* Photo 11	288106	6192537	Rock Fracturing & Rock Fall & Iron Staining	*LA4*	16/05/2018	2	Rock fracturing to *LA4*. The additional fracturing has a maximum length of 1.5 m and a maximum width of 0.01 m. An increase of iron staining was also identified evident.	17/05/2018 06/08/2018
DA3B_LW13_044 Photo 12	288180	6192634	Rock Fracturing	*LA4B*	26/07/2018	2	Rock fracturing to the base of a step on tributary *LA4B*. Maximum length of 1.7 m, horizontal depth of 1.05 m and a width of 0.1 m.	08/08/2018
DA3B_LW13_045 Photo 13	290819	6192330	Rock Fracturing	WC15	8/07/2018	2	Rock fracture across a rock bar on tributary *WC15*. The fracture is approximately 0.3 m long, 0.03 m wide and 0.03 m at the deepest measurable point.	08/08/2018
DA3B_LW13_046 Photo 14	290887	6192408	Rock Fracturing	WC15	1/04/2019	1	Rock fracturing to the base of a step on tributary *WC15*. Maximum length of 1.2 m, and a width of 0.02 m.	3/04/2018

Photo 1: *DA3B_LW14_016*, looking at fracturing and dislodged rock segments. Taken on 21/01/2019.

Photo 2: *DA3B_LW14_017*, looking at a section of rock fracturing. Taken 20/02/2019.

Photo 3: *DA3B_LW14_018,* looking at the width of the fracturing. Taken 20/02/2019.

Photo 4: *DA3B_LW14_019,* looking at a section of rock fracturing. Taken 20/02/2019.

Photo 5: *DA3B_LW14_020*, looking at the extent of the rock fracturing. Taken 20/02/2019.

Photo 6: *DA3B_LW14_021*, looking at the section of rock fracturing. Taken 20/02/2019.

Photo 7: *DA3B_LW14_022*, looking at the section of rock fracturing. Taken 20/02/2019.

Photo 8: *DA3B_LW14_023*, looking at a section of rock fracturing. Taken 01/04/2019.

Photo 9: *DA3B_LW13_035,* fracturing and uplift on rockbar. Taken on 21/01/2019.

Photo 10: *DA3B_LW13_042*, looking at largest section of rock fragmentation. Taken 01/04/2019.

Photo 11: *DA3B_LW13_043*, looking at a section of rock fracturing and uplift. Taken 6/12/2018.

Photo 12: *DA3b_LW13_044,* looking at a section of rock fracturing. Taken 26/07/18.

Photo 13: *DA3b_LW13_045,* Looking at the rock fracturing. Taken 8/07/18.

Photo 14: *DA3B_LW13_046*, looking at the extent of the rock fracturing. Taken 01/04/2019.

3.1.2 Impacts to Other Landscape Features

Impacts recorded on steep slopes, steps and general landscape features are presented below (Table 4).

Table 4: Summary of Impacts to other landscape features

Site ID	Easting	Northing	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_LW14_015 Photo 15	288070	6192528	Rock Fracturing and Rockfall	*Step/ledge of Lake Avon*	5/12/2018	1	Rockfall and rock fracturing on *Lake Avon* rock ledge. The rock fracturing has a maximum length of 1.8 m, a maximum width of 0.01 m and a maximum depth of 0.29 m. The rock fall is approximately 4 m x 1.5 m x 0.5 m.	18/12/2018
DA3B_LW14_024 Photo 16	290133	6191978	Rock Fracturing & Rock Fall & Soil Cracking	*A3b-SS9-Pt2 (Steep Slope)*	9/04/2019	1	Rock fracturing, rockfall and soil cracking at SLMMP site '*A3b-SS9-Pt2'.* The rock fracturing has a maximum measurable length of 0.3 m, a width of 0.04 m and a measurable depth of 0.21 m.	10/04/2019
DA3B_LW14_025 Photo 17	290115	6192041	Rock Fracturing	*Steep Slope/Step*	9/04/2019	1	Rock fracturing and displacement at a steep slope/step between *WC15* and *Fire road 6P*. The rock fracturing has a maximum measurable length 5.15 m, a maximum width of 0.015 m and a maximum measurable depth of 0.4 m.	10/04/2019
DA3B_LW14_026 Photo 18	290101	6191958	Rock Fracturing & Movement	*Steep Slope/Step*	10/05/2019	2	Rock fracturing and displacement at a steep slope/step between *WC15* and *Fire road 6P.* The movement between the rock and soil has resulted in a fracture with a maximum measurable length of 22 m, a width of 0.13 m and a measurable depth of less than 5 m.	16/05/2019
DA3B_LW14_027 Photo 19	290238	6191984	Rock Fracturing	*Steep Slope/Step*	10/05/2019	1	Rock fracturing at cultural heritage site '*Site 1 – DB 1*'. The impact is comprised of two rock fractures with the largest having a maximum measurable length of 1 m, and a maximum width of 0.03 m.	16/05/2019
DA3B_LW14_028 Photo 20	290103	6192021	Rock Fracturing	*Sandstone outcrop*	10/05/2019	1	Rock fracturing at sandstone outcrop between *WC15* and *Fire road 6P.* The impact is comprised of two rock fractures with the largest having a maximum measurable length of 0.75 m, and a maximum width of 0.015 m.	16/05/2019

Photo 15: *DA3B_LW14_015*, looking at the rockfall. Taken 5/12/2018.

Photo 16: *A3B_LW14_024*, looking at a section of rock fracturing. Taken 09/04/2019.

Photo 17: *DA3B_LW14_025*, looking at a section of the rock fracturing. Taken 09/04/2019.

Photo 18: DA3B_LW14_026, looking at the width of the fracturing. Taken 10/05/2019.

Photo 19: DA3B_LW14_027, looking at a section of rock fracturing. Taken 10/05/2019.

Photo 20: DA3B_LW14_028, looking at a section of rock fracturing. Taken 10/05/2019.

3.2 Surface Water Quality

The monitoring of water quality parameters provides a means of detecting and assessing the effects of streambed fracturing or induction of ferruginous springs. Monitoring includes measurement of field parameters such as pH, EC, DO, oxygen reduction potential (ORP) and a suite of laboratory-tested analytes. At Wongawilli Creek (FR6), a Level 1 TARP trigger was recorded for EC and a Level 2 TARP trigger was recorded for DO (Table 5). At Donalds Castle Creek (FR6) a Level 3 TARP trigger was recorded for EC (Table 5).

Table 5: Summary of water quality TARP triggers during the extraction of DA3B Longwalls.

Monitoring Site	Observation	LW9	LW10	LW11	LW12	LW13	LW14
Rainfall rate, (Average = 1032mm/year.)		1352	1293	1287	805	1015	864
Wongawilli Creek (FR6)	EC				1	3	1
	DO			2	1	2	2
Donalds Castle Creek (FR6)	EC						3
	DO	1	1	1	2		

Dry conditions during 2017 - 2018 resulted in elevated EC at many sites due to evaporative concentration of dissolved salts in residual pools. Since late 2018, EC at most sites has returned to within the baseline range.

Water quality at Donalds Castle Creek was highly variable over the reporting period, with EC increasing significantly during the latter part of 2018 and early 2019, coinciding with an increase in monthly rainfall and streamflow. EC at Donalds Castle Creek (FR6) triggered the TARP threshold on twelve occasions. The EC increase was accompanied by a sharp decline in water pH but did not trigger the pH TARP.

A longitudinal survey of water quality in pools along Donalds Castle Creek identified the highest EC values in DC_Pool 9 (647 µS/cm), located 320 m downstream of the confluence between Donalds Castle Creek and tributary *DC13*. An increase in EC was accompanied by a decrease in pH and DO (e.g. DC_Pool 19 and DC_Pool 20) and an increase in concentration of dissolved metals (Fe, Mn, Al, Zn) above baseline levels (DC13 Pool 2b and DC Pool 22).

It is likely that mine subsidence and stream diversions have contributed to the water quality effects in the upper Donalds Castle Creek reaches, as predicted in the SMP. At the furthest downstream monitoring point, DCL3, EC was slightly higher than baseline conditions over the last two years, and pH was similar to baseline. Given the dry conditions over that period is it not clear whether the changes in water quality at the downstream location are related to mining.

At Wongawilli Creek (FR6) monitoring site, triggering of the EC and DO TARPs is likely related to the dry conditions during 2018 and are not considered to reflect a mining impact. EC returned to baseline levels during 2019 in response to higher rainfall.

Further details are presented in **Attachment D.**

3.3 Surface Water Hydrology

The effects of mining subsidence on surface water hydrology is assessed by comparing observed stream flow characteristics for each monitored sub-catchment against predictions of streamflow from a calibrated rainfall-runoff model, specifically, the industry-standard Australian Water Balance Model (AWBM; Walter Boughton, 2009). The assessment consists of calibrating the rainfall-runoff model to observed pre-mining flows and then reviewing whether flows have diverged from the model in the post-mining period. Differences in the pre and post-mining conditions are then highlighted and used to infer and quantify any effects that mining has had on the catchment.

Post-mining conditions are then highlighted and used to infer and quantify any effects that mining has had on the catchment. Furthermore, the most recent iteration of the model, used for the Longwall 13 assessment, has been modified to include the added functionality of allowing for evaporative losses from the shallow water table.

The assessment approach and TARP are defined in Attachment 1 of the WIMMP (South32 2015a). The Catchment Water Balance TARP is described in the WIMMCP as:

- **Level 1:** a change in measured discharge (between pre- and post-mining) **6-12 %** less than average annual precipitation;
- **Level 2:** a change in measured discharge (between pre- and post-mining) **12-18 %** less than average annual precipitation;
- **Level 3:** a change in measured discharge (between pre- and post-mining) **>18 %** less than average annual precipitation.

Table 6 : Summary of surface water flow yield changes from baseline following the extraction of Longwall 14.

Catchment	Site	TARP Trigger	Yield Change Following the Extraction of Longwall 14	Comments
Donalds Castle Creek	DCS2	Level 3	-20%	Evidence that undermining by Longwall 9 affected the sub-catchment yield, and this continues through Longwalls 10-13; as well as during Longwall 14. During Longwalls 13 and 14 the effects have occurred across the full range of flows.

Catchment	Site	TARP Trigger	Yield Change Following the Extraction of Longwall 14	Comments
	DC13S1	Level 2	-17 %	Stream flow characteristics and sub-catchment yield as measured at DC13S1 show effects that are attributable to undermining and subsidence along the watercourse midway through Longwall 9. The effect continues through Longwalls 10-14. Cease-to-flow conditions have occurred about 17% of the time since undermining, while the model suggested that under the pre-mining case this would have been about 2% of the time.
	DCU	No Trigger	+2 %	There is no clear evidence that undermining by has affected the pattern of flow, although some recession flows at DCU through Longwalls 12-13 may indicate some reduction. Cease to flow conditions have increased by about 7%.
Wongawilli Creek	WWL	No Trigger	-4 %	There is no evidence that undermining has affected recession behaviour or reduced sub-catchment flow / yield.
	WC21S1	Level 3	-24 %	The evidence is that recent undermining by Longwalls 10-13, and now LW14 has modified the patterns of flow in this tributary. This is supported by field observation of the creek being dry upstream of the gauge. Since undermining occurred, the creek at the gauging station has had cease to flow conditions about 18% of the time.
	WC15S1	Level 1	-10 %	Surface fracturing was recorded in tributary WC15 during Longwall 13 and Longwall 14, and flow characteristics at the downstream gauge have declined. Mining effects are now discernible.
Lake Avon	LA4S1	Level 1	-6 %	Flows in LA4 were affected by LW12 and effects have persisted since then.

Further details are presented in **Attachment D.**

3.4 Deep Groundwater Hydrology

Groundwater monitoring at Dendrobium Mine is conducted in accordance with the "Dendrobium Mine Area 3B SMP Groundwater Management Plan" (South32 2012) and the DA3B Subsidence Management Plan (South32 2018a). The aims of the Groundwater Management Plan are to:

- Monitor groundwater levels and quality, commencing at least one year prior to mining affecting the system;
- Project potential groundwater changes during mining (short term) and post-mining (long term) with particular attention to the effect of changes to groundwater regime, impact on the catchment yield and interaction with the stored waters;
- Identify hydraulic characteristics of overlying and intercepted groundwater systems, and determine changes to groundwater systems due to coal extraction and dewatering operations;
- Report any pumping tests and groundwater/surface water simulation studies; and
- Collect water level data from all agreed groundwater-monitoring locations.

Further details are presented in **Attachment E.**

3.4.1 Mine Water Balance

The System Control and Data Acquisition (SCADA) system calculates a daily mine Water Balance. The Water Balance is an accurate measure of all water that enters, circulates and leaves the mine, including via air moisture and coal moisture content. Mine water seepage (groundwater inflow), which cannot be directly measured, is determined by mass balance for each goaf and is therefore known to a reasonable accuracy. Key metrics of the Mine Water Balance are reported against TARP levels to the DSC.

The average daily inflow to DA3B during Longwall 14 extraction was 4.21 ML/day which represents approximately 72 % of total mine inflow for the period. The average water balance for Area 3B during Longwall 14 is approximately 10 % lower than the previous longwall (4.68 ML/day; Longwall 13).

Groundwater ingress to DA3B has increased steadily since the start of mining (2013), initially correlating with the total area mined. However, the rate of increase has declined (flattened) during the mining of Longwalls 12 and 13 and the water balance decreased during the extraction of Longwall 14 (Figure 15). This overall trend reflects a declining groundwater inflow per unit area mined due to progressive depressurisation of the surrounding strata by previous mining (a decline in driving head). As of Longwall 12, peaks in inflow to DA3B appear to correlate with periods of high rainfall with a lag time of between two and three months. Prior to Longwall 12, the influence of rainfall on the water balance was less distinct. The decline in groundwater inflow to DA3B during Longwall 14 is likely to be due partly to the unusually dry conditions during extraction.

The presence of modern water in mine inflow is monitored by analysing tritium. Samples are collected from goaf inflow and the roadway development stage seepage water samples. The results are reported monthly to the DSC.

Tritium is an isotope of hydrogen (3H), which decays exponentially according to its half-life (12.32 years) and is typically only detectable in surface water samples and in groundwater that recharged within 4 to 5 half-lives (50 to 70 years). Detection of tritium above deep groundwater baseline levels in mine inflow samples would indicate a component of modern water in the sample (as it does for samples from Area 2). As of September 2018, there is no detectable component of modern water in DA3B inflow. The laboratory processing time for high precision tritium analysis can be more than 6 months and therefore results for some samples collected in the latter part of Longwall 14 are pending.

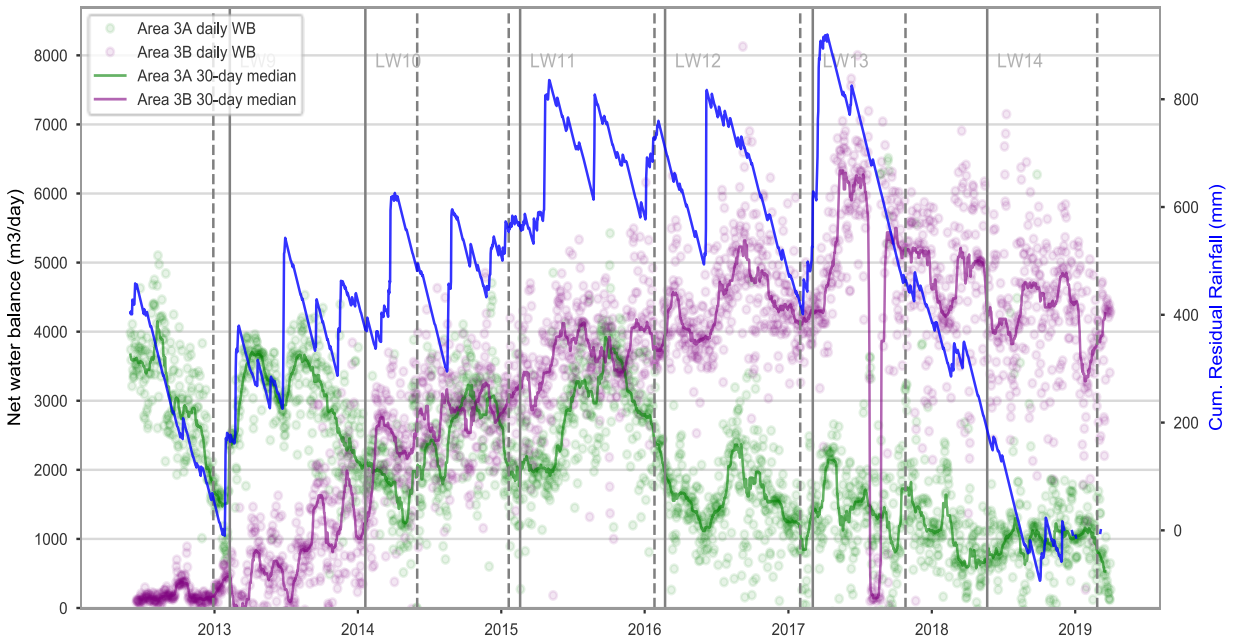


Figure 15: Groundwater inflow in to DA3A and DA3B.

3.4.2 Deep Groundwater Levels

Mining of Longwall 14 resulted in continued depressurisation of the target coal seam and overlying strata. The observed changes in groundwater levels are in line with, or less then numerical model predictions that support mining approvals.

As expected, the greatest depressurisation is within the Wongawilli Coal Seam, and decreases with height above the seam. Groundwater drawdown in the Scarborough and Bulgo Sandstones is most pronounced near the mined longwalls and to the northeast and south of DA3B. Drawdown decreases to the northwest with distance from DA3B.

Observations at monitoring bores installed above mined longwalls indicate that the Hawkesbury Sandstone undergoes fracturing to the ground surface, accompanied by depressurisation of most strata.

There is evidence that drainage of the Hawkesbury Sandstone above goafs is not complete in all areas and some perched groundwater horizons remain.

Piezometers located to the north and west of the longwall footprint show a gradual decline in groundwater pressures in most strata with the rate of decline increasing with depth and proximity to the longwall.

Those observations are consistent with the gradual expansion of a drawdown cone away from the mine and are in line with numerical modelling predictions. Piezometers located to the south of the active longwalls in DA3B show more pronounced depressurisation in the mid to deep stratigraphic levels with some strata pressures dropping to zero well in advance of the longwall. It is likely that those piezometers are affected by depressurisation from the Elouera mine to the south, as well as drawdown from Dendrobium.

3.4.3 DSC Monitoring – Loss of baseflow to Lake Avon

Between 2015 and 2018, a series of monitoring bores were installed along the barrier zone between Lake Avon Reservoir and DA3B. Observations at these bores indicate depressurisation of the upper Colo Vale Sandstone in response to longwall extraction, and variable drawdown in the Hawkesbury Sandstone. A hydraulic gradient towards the lake is preserved in the Hawkesbury Sandstone at S2313, whereas at S2314 and S2376 the hydraulic gradient is locally reversed towards the mine, implying movement of groundwater from the lake to the mine. The Dendrobium Regional Groundwater Model (2016) estimates that seepage loss between Lake Avon and Longwalls 12 to 16 would be less than 0.28 ML/day (or 0.17 ML/day/km of shoreline adjacent to extracted longwalls). This estimate is consistent with numerical modelling predictions.

The numerical model developed by Hydrosimulations in 2014 and updated in 2016 was assessed to be accurate with respect to estimated groundwater levels within the Hawkesbury Sandstone at the end of Longwall 14. The model overestimates drawdown in the Bulgo and Scarborough Sandstones and is therefore conservative.

Seepage losses from Lake Avon was estimated using a local scale numerical model at approximately 0.44 ML per day following the extraction of Longwall 14. The estimate is of a similar magnitude to those from regional numerical modelling and is within the tolerable loss limit of 1 ML/day prescribed by the DSC.

3.4.4 Groundwater Chemistry

Previous reviews have shown that there is no clear spatial pattern in the distribution of groundwater quality in Hawkesbury Sandstone and Bulgo Sandstone bores. Groundwater salinity (EC) for samples collected from monitoring bores in DA3A and DA3B tends to increase with depth.

A notable change is seen in the most recent sampling from S1886 (DEN94) where samples from all three depths (at 22 m, 30 m, and 38 m) show EC field measurements that are up to 200 µS/cm higher than last sampling round. Laboratory measured EC for all three samples are within the historical range, suggesting that the field EC measurements are in error. Given the proximity of this bore to Lake Cordeaux Reservoir, it is recommended that the bore is resampled as soon as practical. The average EC for all samples collected are: 168 µS/cm for

the Hawkesbury Sandstone (n = 314), 559 µS/cm for the Bulgo Sandstone (n = 82) and 556 µS/cm for the Scarborough Sandstone (n = 115).

3.5 Impacts to Upland Swamps

3.5.1 Shallow Groundwater and Soil Moisture

Trigger levels for changes to groundwater at surface and near-surface monitoring sites at DA3B swamps have been established within the SIMMCP for DA3B (South32 2015a). Shallow groundwater level and soil moisture characteristics have been identified as an indicator of potential changes in ecosystem functionality of Upland Swamps.

Changes to groundwater are reported when measurements of water level drop below baseline levels or when rates of recession exceed those recorded during baseline monitoring. Groundwater level hydrographs for each shallow piezometer are presented in **Attachment D**. Each hydrograph is plotted together with ground elevation and the elevation of the piezometer base, longwall timing, rainfall trend ("rainfall CRM"), and the dates that longwalls pass under (if relevant) a piezometer. Assessment of mining effects is based on these hydrographs.

The soil moisture TARP has been assessed by comparing the average moisture content of the soil profile during the longwall assessment period against that of the baseline period. If the average soil moisture level drops below the minimum level recorded during the baseline period, a TARP is triggered.

Both shallow groundwater levels and soil moisture levels in reference swamps were anomalously low during the assessment period in response to very low rainfall conditions in 2017-2018. Some reference sites showed no or limited saturation of swamp sediments for 12 months or more for the first time since the start of monitoring (e.g. Swamps 85, 86 and 87).

Longwall 14 mined under and/or passed within 400 m of shallow groundwater and soil moisture sites within four swamps: Swamps 11, 13, 14 and 23. It was predicted that these swamps would be affected by mine subsidence due to mining in DA3B (South32 2015a). Shallow groundwater and soil moisture assessments for these swamps are summarised in Table 7 and Table 8.

Trigger levels are assessed differently by the ICEFT and HGEO. The ICEFT report triggers when groundwater or moisture decrease below the baseline level during the mining period whilst the HGEO assessment is conducted following the completion of Longwall 14 and considers other factors such as longer-term climatic conditions and reference swamp comparisons.

Further details are presented in **Attachment D.**

Table 7: Summary of shallow groundwater level TARP status at Longwall 14 impact sites.

Swamp	Longwall	Sensors and TARP triggers			Comment	ICEFT TARP Level	HGEO TARP Level
		Not Triggered	Triggered	Not within mine influence			
11	LW13 LW14		S11_S01 S11_S02 S11_S05		Soil moisture at all sensors dropped to lowest levels following Longwall 13 and Longwall 14. Likely mining effect exacerbated by dry conditions.	Level 3	Level 3
13	LW14		S13_S01 S13_S02 S13_S03		Soil moisture at all sensors dropped to lowest levels following Longwall 13 and Longwall 14. Likely mining effect exacerbated by dry conditions.	Level 3	Level 3
14	LW16			S14_S02 S14_S01	Not yet mined under; No change after passage of Longwall 14.	No Trigger	No Trigger
23	LW15			S23_S01, S23_S02	Not yet mined under; soil moisture dropped below baseline prior to Longwall 14 passing.	Level 1	No Trigger

Table 8: Summary of soil moisture level TARP status at Longwall 14 impact sites.

SWAMP	TARP SITES	RELEVANT LONGWALLS	PIEZOMETERS WITH AN OBSERVED RESPONSE			OBSERVED BEHAVIOUR	COMMENT	ICEFT TARP LEVEL	HGEO TARP LEVEL
			YES	UNCLEAR	NO				
11	3	LW13, LW14	11_H1 11_H2 11_H3			All three piezometers show mostly desaturated conditions following the passage of LW14 with only brief periods of saturation following rainfall events.	Partially mined under by Longwall 13 and by Longwall 14.	Level 1	Level 3
13	1	LW14		13_01		Groundwater level below the piezometer base since early 2018; Possible impact but similar to reference swamps.	Partially mined under by Longwall 13 and by Longwall 14.	Level 3	Unclear
14	2	LW15, LW16			14_01 14_02	No evidence for change to the shallow groundwater relative to reference sites.	Yet to be mined under; Longwall 14 passed within 400m, Jan 2018.	Level 2	No Trigger
23	2	LW15, LW16			23_01 23_02	Groundwater level below piezometer base since early 2018; Similar to reference swamps.	Yet to be mined under; Longwall 14 passed within 400m, May 2018.	No Trigger	No Trigger

3.5.2 Erosion in Upland Swamps

The SIMMCP (South32 2018a) describes the monitoring and assessment to determine any areas of erosion in swamps resulting from mining. Tilting, cracking, desiccation and/or changes in vegetation health could result in the concentration of runoff and erosion, which intern could alter water distribution in the swamp. TARPs have been established within the SIMMCP (South32 2018a) (See Appendix A: Table 22).

Impact assessment of Upland Swamp erosion includes analyses of ALS results, combined with infield observations. Locally increased changes in surface level contours were apparent near Swamp 23. However, these inferred movements were not visible in the incremental changes in surface level, indicating that these effects occurred prior to the mining of Longwall 14. A site inspection of the area identified a fallen tree and flattened vegetation that could partly account for these apparent changes in surface level. The variable vegetation distribution within the swamp can also affect the ALS surveys by making it more difficult to filter out the non-ground laser strikes. Other apparent localised movements are also likely to be due to the effects of the horizontal movements and sloping terrain on the ALS surveys.

3.6 Terrestrial Ecology

Biosis Pty Ltd was commissioned by IMC to undertake terrestrial ecology monitoring for the Dendrobium Mine in accordance with the Flora and Fauna Environmental Management Program (Biosis 2003) and as required by the Dendrobium Mine Development Consent. The Dendrobium Terrestrial Ecology Monitoring Program commenced in 2003 and is expected to continue throughout the duration of mining activities and for a period after the completion of mining within each area. The aim of the program is to determine whether subsidence effects associated with longwall mining result in impacts to terrestrial ecology. A Before-After Control-Impact (BACI) experimental design has been established and implemented. The BACI design investigates the temporal changes at sites that have been mined beneath (Before-After) compared with change at control sites that have not been mined beneath (Control-Impact). The terrestrial ecology monitoring program focuses on ecological features considered to be at risk of impact from subsidence effects, namely those values reliant on shallow groundwater or surface water. The following ecological features are monitored as part of the program:

- Vegetation communities (species and diversity) within Upland Swamps in DA3A and DA3B.
- Littlejohn's Tree Frog (*Litoria littlejohni*) along selected streams that provide suitable habitat in DA3A and DA3B.

Further details of the methodology used by Biosis for the Terrestrial Ecology Assessment can be found in **Attachment F**.

3.6.1 Terrestrial Flora

The latest terrestrial ecology (flora) assessment includes the 2018 monitoring period and includes monitoring and analysis of seven Upland Swamp sites as post-mining sites (Swamp 15B (S15B), Swamp 15A(2) (S15A(2)),

Swamp 1A (S1A), Swamp 1B (S1B), Swamp 5 (S5), Swamp 11 (S11), Swamp 13 (S13)). Swamp 14 and Swamp 23 were added to the program in 2017 to commence pre-mine baseline monitoring. Parameters analysed include TSR, species composition and swamp extent (i.e. the extent of groundwater dependent swamp sub-communities).

3.6.1.1 Upland Swamp Total Species Richness

The results of the TSR analysis demonstrate the response to mining at individual swamps is complex with Swamp 15A(2) and Swamp 15B showing a decline and subsequent increase in TSR following mining and changes in shallow groundwater. At Swamp 15A(2), the decline in TSR post-mining was not statistically significantly to TSR pre-mining and at control swamps immediately after mining but by 2013 became statistically significantly, with the level of significance continuing to increase. This trend towards an increasing difference between TSR compared with TSR before mining and at control swamps is suggestive of a lag-effect, whereby the impacts of mining have been gradual, accumulating over time.

Swamp 1A, Swamp 1B and Swamp 5 displayed no significant decline in TSR despite observed changes in shallow groundwater availability. Table 9 summarises the swamp TSR assessment against the TARP.

3.6.1.2 Upland Swamp Species Composition

Yearly changes in species composition were detected in most sites, regardless of area or treatment. Such trends are indicative of natural turnover of species within upland swamps in response to seasonal and annual variability in climate, competition, disturbance and edaphic factors including nutrient availability.

When accounting for yearly effects, a statistically significant change in species composition post-mining was detected at Swamp 15B and Swamp 15A(2). As with TSR, these changes were observed immediately following mining and have continued at Swamp 15B and Swamp 15A(2) for at least four years post-mining. Swamp 1A, Swamp 1B and Swamp 5 displayed no statistically significant decline in species composition. Table 9 summarises the swamp species composition assessment against the TARP.

3.6.1.1 Upland Swamp Extent

The analysis of ALS survey data was used to assess the extent of upland swamps and their composite vegetation communities. It has detected that the extent of all upland swamps (impact and control swamps) monitored has decreased from the 2014 baseline substantially during 2018. Table 10 summarises the Swamp size and ecosystem functionality assessment against the TARPS.

The results of the 2018 ALS data analysis have identified continued declines in the extent of vegetation communities that comprise upland swamps, recorded in 2017. These are MU43 (Tee-tree Thicket) and MU44c (Sedgeland). Declines in the extent of MU44c, while triggering a Level 1 TARP, require further investigation to determine why this community is increasing in extent at some swamps and decreasing at others. MU44b (Sedgeland-Heath Complex) was also identified as being reduced in extent at a number of impact sites in 2018.

The overall extent of the smaller control swamps (*S89, S91, S92 and S93*) remained relatively stable during the 2014 to 2017 period, but show small but more marked decreases in the 2018 data relative to the other years. The changes observed in impact swamp total areas appear to be comparable to those observed at the control swamps, indicating that catchment scale conditions, rather than mining impacts are driving the reduction in total swamp area.

Table 9: DA3A and DA3B Swamp Monitoring – Terrestrial Flora: TSR and Species Composition TARP summary.

Swamp Name	Predicted Impact	TARP Trigger Level	Results and TARP Justification	Recommendations
DA3A Landscape Monitoring - Terrestrial Flora and Fauna TARP (12 November 2012)				
Swamp 15B	Level 1, 2 or 3 TARP.	Level 2 triggered	A statistically significant difference in TSR at Swamp 15B was detected (following being mined beneath from 2012 through to 2018) at the α=0.1 level. This difference was detected during a period of stability at control swamps over three consecutive years (2013 to 2015), which was followed by an increase in TSR between 2015 and 2016 at these control swamps. A statistically significant (p-values < = 0.05) change in species composition was detected at S15B during at all but one of the six post-mining time periods examined, indicating a Level 2 TARP has been triggered. No CMAs have been initiated, therefore a Level 3 trigger cannot be assessed.	Continue monitoring *S15B* in spring and autumn each year. Consult with technical specialists to identify need and type of CMA required and implement any agreed CMA.
Swamp 15A(2)	Level 1, 2 or 3 TARP.	Level 2 triggered	No significant decline in TSR was detected at S15A(2) at the p=0.05 level. A statistically significant (p-values < = 0.05) change in species composition was detected at S15A(2) during all of the post-mining time periods examined, indicating a Level 2 TARP has been triggered. No CMAs have been initiated, therefore a Level 3 trigger cannot be assessed.	Continue monitoring S15A(2) in spring and autumn each year and investigate reasons for the TARP trigger. Consult with technical specialists to identify need and type of CMA required and implement any agreed CMA.

Swamp Name	Predicted Impact	TARP Trigger Level	Results and TARP Justification	Recommendations
DA3B Swamp Monitoring – Terrestrial Flora: Composition and Distribution of Species (dated 12 October 2015)				
Swamp 1A	Level 1, 2 or 3 TARP.	No TARP trigger	TSR within S1A showed no statistically significant decline when compared to control sites. Additionally, no statistically significant decline in species composition was found post-mining at S1A.	Due to the detection of decreased groundwater and incidental observations of Needlebush yellowing, continued monitoring of S1A is recommended.
Swamp 1B	Level 1, 2 or 3 TARP.	No TARP trigger	TSR within S1B showed no statistically significant decline when compared to control sites. Additionally, no statistically significant decline in species composition was found post-mining at S1B.	Due to the detection of decreased groundwater, continued monitoring of S1B is recommended.
Swamp 5	Level 1, 2 or 3 TARP.	No TARP trigger	TSR within S5 showed no statistically significant decline when compared to control sites. Additionally, no statistically significant decline in species composition was found post-mining at S5.	Due to the detection of decreased groundwater and soil moisture along with the yellowing of Needlebush, continued monitoring of S5 is recommended.

Table 10: DA3B Swamp Monitoring – Terrestrial Flora: Swamp Size and Ecosystem Functionality (Illawarra Coal 2015b).

Swamp Name	Predicted Impact	TARP Trigger Level	Results and TARP Justification	Recommendations
Swamp 15B (not included in DA3B TARP)	No prediction made in EIS.	None	N/A	Continue monitoring in 2019.
Swamp 1A	Level 1, 2 or 3 TARP.	Swamp Size: Level 1 TARP triggered.	Two years of decline in total swamp extent greater than the mean (±SE) decline of the control group.	Continue monitoring in 2019. Ground truth swamp extent and swamp vegetation community extent in 2019.

Swamp Name	Predicted Impact	TARP Trigger Level	Results and TARP Justification	Recommendations
		Ecosystem Function: Level 2 TARP triggered.	Trending decline in the extent of subcommunity MU43 for three consecutive monitoring periods greater than the mean (±SE) decline of MU43 in the control group. Trending decline in the extent of subcommunity MU42 and MU44b for two consecutive monitoring periods greater than the mean (±SE) decline of MU42 and MU44b in the control group.	Investigate practical remediation measures or offset if remediation deemed to be ineffective after 5 years.
Swamp 1B	Level 1, 2 or 3 TARP.	Swamp Size: Level 1 TARP triggered. Ecosystem Function: Level 1 TARP triggered.	Two years of decline in total swamp extent greater than the mean (±SE) decline of the control group. Trending decline in the extent of subcommunity MU43 and MU44b for two consecutive monitoring periods greater than the mean (±SE) decline in the MU42 and MU43 control group.	Continue monitoring in 2019. Ground truth swamp extent and swamp vegetation community extent in 2019. Investigate practical remediation measures or offset if remediation deemed to be ineffective after 5 years.
Swamp 5	Level 1, 2 or 3 TARP.	Swamp Size: No TARP triggered. Ecosystem Function: Level 2 TARP triggered.	One year of decline in total swamp extent not greater than the mean (±SE) decline of the control group. Trending decline in the extent of subcommunity MU43 for three consecutive monitoring periods greater than the mean (±SE) decline in the control group.	Continue monitoring in 2019. Ground truth swamp extent and swamp vegetation community extent in 2019. Investigate practical remediation measures or offset if remediation deemed to be ineffective after 5 years.
Swamp 8	Level 1, 2 or 3 TARP.	Swamp Size: No TARP triggered. Ecosystem Function: No TARP triggered.	One year of decline in total swamp extent not greater than the mean (±SE) decline of the control group. One year of trending decline in the extent of MU42 over the monitoring period.	Continue monitoring in 2019. Ground truth swamp extent and swamp vegetation community extent in 2019.

3.6.2 Terrestrial Fauna – Littlejohn's Tree Frog Assessment

Monitoring of Littlejohn's Tree Frog transects was undertaken at five locations within DA3A during winter; 6CDL, SC10 (two sections), SC10C and WC17. As a result of impacts to SC10C and WC17 observed for consecutive years in 2015 and 2016, monitoring of streams within Dendrobium Area 3A continued in 2017 through 2018. During 2018, a total of six watercourses were monitored for Littlejohn's Tree Frog as part of the DA3B program; continued monitoring at DC(1), DC13, LA4A, WC15, WC21 as well as the addition of LA2 to the program to commence two years of pre-mine baseline monitoring.

It was predicted that mining within DA3A and DA3B would have a significant impact to one or more local populations of Littlejohn's Tree Frog (Biosis 2007b; Niche 2012). Analysis of adult Littlejohn's Tree Frog standardised abundance for the combined DA3A and DA3B programs indicates that the abundance of adult frogs is lower at impact sites than control sites. Due to the catchment wide dry conditions experienced in 2018, the continuation of this trend is more difficult to determine for this year and the ability to confidently identify any new impacts may also be limited due to the decreased detection numbers across control sites.

There was a decrease in detection of adult Littlejohn's Tree Frog across all sites in 2017 compared to 2016 by approximately 32 %, and tadpoles by 84 %. In 2018, there was a decrease in detection of adult Littlejohn's Tree Frog across all sites compared to 2017 by approximately 24 %, tadpoles by 21 % and egg mass also by 21 %. It has been noted that 2016 was an excellent year for breeding due to high levels of rainfall, and frog numbers recorded in 2016 were much higher than previous years. Detection of Littlejohn's Tree Frog in 2017 and 2018 was comparable to detection in 2015.

Since commencement of threatened frog monitoring in DA3A and DA3B, the abundance of all life stages detected has varied substantially year to year, at both impact and control sites. This is most likely due to movement of individuals amongst sites, as well as differences in environmental conditions (e.g. rainfall frequency, rainfall intensity, temperature) at the time of survey. Environmental conditions such as rainfall can influence both detectability of individuals (adults may not be active if conditions are not suitable), as well as the timing of breeding events relative to survey. Conducting amphibian surveys at one time-point during the breeding season only provides a snapshot of frog abundance at that particular time, contributing to variation seen across years. However, there is no visually discernible trend in either year or mining status (pre/post mining) in either mining areas (DA3A and DA3B).

Further monitoring of breeding pools conducted in summer 2016/2017 confirmed that, at several of these sites, identified breeding pools contained sufficient water to support the laying of egg clutches in winter. However, these pools did not retain water for a sufficient period into summer for individuals to successfully reach metamorphosis. This represents a reduction in the available Littlejohn's Tree Frog breeding habitat within both DA3A and DA3B.

In response to the impacts to DC(1), DC13 and WC21 (Table 11), water level monitoring and tadpole surveys were undertaken during summer 2016/2017 to determine if metamorphosis was occurring along streams where reductions in habitat were detected (Biosis 2017b).

Continuing tadpole development at DC13, WC21 and DC(1) varied based on the availability of sustained water levels within potholes and pools throughout the key development stages following the 2016 winter breeding season. Due to a limited number of breeding pools that contain water for a sufficient time to allow for full development to metamorphosis and adults, the risk of losing a generation of a local population of Littlejohn's Tree Frogs at these sites has increased as a result of mining impacts. Continued monitoring and CMAs are recommended in Biosis (2017b) and Table 11.

Table 11: Assessment of Littlejohn's Tree Frog monitoring results at impact sites, within DA3A and DA3B, against DA3A and DA3B TARPs.

Stream	Predicted Impact	TARP Trigger Level	Results and TARP Justification	Recommendations
DA3A Landscape Monitoring TARP (dated 12 November 2012)				
SC10C	Significant impacts to local populations of Littlejohn's Tree Frog.	Level 1 TARP triggered.	Due to the level of variation in the dataset and lack of replication of monitoring events each year, a statistical analysis of the data could not be completed. However, a decline in the abundance of adult frogs was observed following subsidence impacts detected at *SC10C* following extraction of Longwall 7 and Longwall 8 during 2011 and 2012 (2 years after the initial mining within the RMZ), and numbers have not recovered. The following Level 1 triggers relating to terrestrial fauna have been observed: • No significant statistical difference between BACI sites. The following triggers relating to watercourse monitoring have been observed: • Stream appearance at *SC10C*.	Continue monitoring to investigate whether CMAs for related watercourse TARPs may address some impacts to threatened frog habitats.
SC10(1)	Significant impacts to local populations of Littlejohn's Tree Frog.	No TARP levels triggered.	There has been no significant decline in Littlejohn's Tree Frogs at *SC10(1)* since mining began in 2011. Although tadpole and egg mass numbers were low in 2017, this is consistent with pre-mining records, and does not appear associated with mining impacts. The 2018 results show an increase in the detection of Littlejohn's Tree Frogs at this site, in contrast to declining numbers at the control sites during this year	Continue monitoring program.

Stream	Predicted Impact	TARP Trigger Level	Results and TARP Justification	Recommendations
			The following trigger relating to watercourse monitoring has been observed: • Iron flocculant covering all stream surfaces This represents a reduction in breeding habitat for Littlejohn's Tree Frogs.	
SC10(2)	Significant impacts to local populations of Littlejohn's Tree Frog.	No TARP levels triggered.	There has been no significant decline in Littlejohn's Tree Frogs at *SC10(2)* since mining began in 2011.	Continue monitoring program.
WC17	Significant impacts to local populations of Littlejohn's Tree Frog.	Level 1 TARP no longer triggered.	Due to the level of variation in the dataset and lack of replication of monitoring events each year, a statistical analysis of the data could not be completed. In 2017, detection of Littlejohn's Tree Frog continued to increase from previous years, with abundance records consistent with pre-mining numbers. Due to a lack of water at this site and associated control sites, it is determined that the Level 1 TARP continues not to be triggered. However future monitoring results should be examined at this site.	Continue monitoring program.
DA3B Watercourse Monitoring TARP (dated 12 October 2015)				
DC(1)	Significant impacts to local populations of	Level 1 TARP remains.	Following the 2016 survey at *DC(1)*, breeding pools (Pools 32 and 33) had a reduced water level below the pool monitoring benchmark. In order to confirm whether water remained present in pools long enough for Littlejohn's Tree Frog tadpoles and eggs to develop and metamorphose, follow up surveys were undertaken in summer 2016/2017 by Biosis. These surveys	Continue monitoring as a part of the approved terrestrial monitoring program.

Stream	Predicted Impact	TARP Trigger Level	Results and TARP Justification	Recommendations
	Littlejohn's Tree Frog.		confirmed that pool water had dried up before recorded tadpoles and eggs had sufficient time to metamorphose, resulting in zero survival, and indicating a loss of Littlejohn's Tree Frog breeding habitat within *DC1* (Biosis 2017). The Level 1 TARP was triggered in 2017. While also reflecting the impacts of dry conditions, the 2018 data is consistent with that of the 2017 findings.	
DC13	Significant impacts to local populations of Littlejohn's Tree Frog.	Level 3 TARP triggered in 2017. Level 3 TARP is considered to remain triggered in 2018.	Subsidence impacts following mining has resulted in the loss of water in pools located above Longwall 9. In 2016, subsidence impacts extended along approximately 30% of the monitoring transect. Pools located within this stretch (Pools 18A through to the transect end) provided known habitat for Littlejohn's Tree Frog during the baseline monitoring period. Pools along approximately 40% of the total length of the transects had experienced a reduction in water in 2016. Follow up monitoring in summer 2016/2017 confirmed that many of the identified breeding pools that had water in winter 2016 had experienced a significant reduction in water by summer and were considered no longer appropriate habitat for Littlejohn's Tree Frogs to survive to metamorphosis. While also reflecting the impacts of dry conditions, the 2018 data is consistent with the 2017 findings. The Level 3 Tarp is considered to remain triggered and should be reviewed in 2019.	Recommendations for reporting to the relevant authorities were made following the triggering of the Level 3 TARP in Biosis (2017). Continue monitoring as a part of the approved terrestrial monitoring program.
WC21	Significant impacts to local populations of	Level 3 TARP triggered. Level 3	A reduction in habitat for five monitoring periods (four years) has been recorded at *WC21* following the extraction of Longwall 9, Longwall 10, Longwall 11 and Longwall 12. Approximately 57% of the potential breeding habitat along this stream is experiencing a reduction in water levels (between	Recommendations for reporting to the relevant authorities were made following the triggering of the Level 3 TARP in Biosis (2017).

Stream	Predicted Impact	TARP Trigger Level	Results and TARP Justification	Recommendations
	Littlejohn's Tree Frog.	TARP is considered to remain	Pool 11 and Pool 30) including three confirmed breeding pools (observations by Biosis during monitoring in 2015). While also reflecting the impacts of dry conditions, the 2018 data is consistent with the 2017 findings. The Level 3 TARP is considered to remain triggered and should be reviewed in 2019.	Continue monitoring as a part of the approved terrestrial monitoring program.
LA4A	Significant impacts to local populations of Littlejohn's Tree Frog.	No TARP levels triggered.	No observed impacts have been detected at the one breeding pool, *LA4A-P1* along this stream. Some fracturing and flow diversion has been detected at the lower end of the transect where it becomes *LA4*; however. this has not resulted in a reduction of breeding habitat for the species.	Continue monitoring as a part of the approved terrestrial monitoring program.

3.7 Aquatic Ecology

Cardno was commissioned by South32 to undertake a review of aquatic flora and fauna in relation to the extraction of Longwall 14. Cardno has been undertaking ongoing monitoring of watercourses within the DA3B mining area including Wongawilli Creek, Donalds Castle Creek and several associated tributaries. The overall objective of the monitoring is to determine whether the extent and nature of observed impacts, primarily subsidence-induced fracturing of bedrock, diversion and loss of aquatic habitat, are consistent with the predictions made in the aquatic flora and fauna review (AFFA) (Cardno Ecology Lab 2012) and DA3B SMP (BHPBIC 2012).

The monitoring requirements recommended in the AFFA and included in the SMP incorporates a BACI sampling design to monitor mine subsidence impacts on the aquatic environment with collection of at least two years of baseline data followed by monitoring during extraction, and at least two years of post-extraction monitoring. The following indicators were monitored at impact and control sites within and outside the SMP area as a measure of aquatic health:

- Aquatic habitat condition - using a modified version of the Riparian, Channel and Environmental Inventory method (Chessman *et al.* 1997);
- Macroinvertebrates, including threatened species of dragonfly (Adams emerald dragonfly and Sydney hawk dragonfly), using AUSRIVAS and standardised artificial collectors;
- Limited in-situ water quality – using a portable probe; and
- Fish abundance using backpack electrofishing and bait traps.

Further details of the Aquatic Ecology Assessment methodology can be found in **Attachment G.**

Table 12: Summary of predicted and observed impacts to aquatic ecology associated with Longwall 14.

Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology	Observed Impacts to Aquatic Ecology
Wongawilli Creek			
Ponding, flooding and scouring of stream banks due to tilt	No significant change predicted.	No measurable effects due to tilt.	None identified by ICEFT during extraction of Longwall 14 or by Cardno at aquatic ecology monitoring sites on Wongawilli Creek in May 2019.
Fracturing of bedrock and diversion of surface flows	No significant fracturing resulting in surface water flow diversions. Minor, isolated fractures of the streambed may occur	No significant changes in the quantity or quality of permanent aquatic habitat due to fracturing of bedrock	Reductions in pool water levels and flow observed initially during extraction of Longwall 13 were present during the first 5 to 6 months of extraction of Longwall 14. These resulted in a reduction in aquatic habitat (full or partial loss of pool water) in

Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology	Observed Impacts to Aquatic Ecology
	within 400 m from the proposed Longwalls. Minor fracturing of the creek bed and subsequent diversion of flows would not have significant geochemical effects. Formation of ferruginous springs is unlikely but could occur at the margins or upslope of swamps (Ecoengineers 2011).	and diversion of surface flows.	approximately 1.4 km of *Wongawilli Creek* (around 10 % of the 12 km long creek). Loss of some aquatic biota (fish and macroinvertebrates) would likely also have occurred here. Indirect impacts to aquatic biota would include a loss of longitudinal habitat connectivity. However, impacts to the availability of aquatic habitat and to longitudinal connectivity were temporary. Water and flow returned to the affected area following rainfall events. No impacts to aquatic habitat were noted at affected water quality monitoring sites visited by Cardno in May 2019. The relatively minor changes in water quality that have been observed at FR6 are not expected to have significant impacts on aquatic biota. Potential associated impacts to aquatic macroinvertebrates will be assessed once the samples have been analysed.
Donalds Castle Creek and drainage lines (WC21, WC15 and LA4)			
Ponding, flooding and scouring of stream banks due to tilt	Reversals in grade may occur along Tributary *WC21*, adjacent to the tailgates of Longwalls 10 and 11. These could result in small increases in the levels of ponding, flooding and scouring of stream banks in highly localised areas along the tributaries. The impacts resulting from such changes are expected to be small relative to those that occur naturally during floods.	Localised changes in habitat availability and connectivity may occur along the tributaries due to tilt but will be difficult to detect because of the large variability in natural flows within these ephemeral systems.	No impacts observed due to tilt.

Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology	Observed Impacts to Aquatic Ecology
Fracturing of bedrock and diversion of surface flows	Fracturing of the bedrock is likely to occur. In ephemeral creeks with alluvial deposits, fractures are likely to be in-filled by deposits during flow events. In areas with exposed bedrock, some diversion of surface flows into underlying strata and drainage of pools may occur, particularly during low flows. It is unlikely, that this would result in a significant impact on the overall quantity or quality of water flowing from the catchment.	There is unlikely to be any significant long-term changes in the quantity, quality or connectivity of aquatic habitats. Any losses of habitat and connectivity that do occur would be minor, localised and transient.	No impacts were observed in *Donalds Castle Creek* or *WC21* during extraction of Longwall 14. Fracturing of bedrock and diversion of flows in Lake Avon drainage lines *LA4* and *LA4B* and *Wongawilli Creek* drainage line *WC15* is likely to have resulted in some minor reduction in quantity and connectivity of aquatic habitat, particularly given the abundance of first and second order stream habitat in the upper Avon and Cordeaux Catchments. Associated impacts to aquatic biota would also be expected to be minor. The relatively minor changes in water quality that have been observed in *Donalds Castle Creek* at FR6 are not expected to have significant impacts on aquatic biota.

Table 13: Summary of Aquatic Ecology TARP sites and their respective trigger levels.

TARP	Wongawilli Creek	Donalds Castle Creek	WC21
Level 1 – Reduction in aquatic habitat for 1 year	Not triggered	Triggered September 2014	Triggered December 2014
Level 2 – Reduction in aquatic habitat for 2 years following the active subsidence period (i.e. when a longwall within 400 m of a feature, such as a creek, is completed)	Not triggered	Triggered 24 October 2015	Triggered 20 January 2017
Level 3 – Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period	Not triggered	Triggered During 2017 Aquatic Ecology Surveys (Cardno 2018)	Triggered During 2017 Aquatic Ecology Surveys (Cardno 2018)

3.8 Cultural Heritage

Following the extraction of Longwall 14, an inspection of Aboriginal archaeological sites within the Longwall 14 study area (as defined in Niche 2019; **Attachment H**) was conducted by Niche on 10 May 2019 (Figure 16). Two out of the five Aboriginal archaeological sites had observable impacts from subsidence movements related to extraction of Longwall 14 (Table 14). The sandstone shelters at Browns Road Site 11 and Site 1 DB-1 have experienced diagonal and vertical cracking with block fall and exfoliation expedited with subsidence (Photo 21 to Photo 26). Art Panels have not been impacted by subsidence effects.

The Aboriginal Heritage Impact Permit (AHIP) granted to impact Aboriginal objects located within DA3B states that Browns Road Site 11 and Site 1 DB 1 are identified in Schedule C as sites that can be harmed by mining related activity under section 90 of the *National Parks and Wildlife Act 1974.*

As per the TARPS performance measures, Browns Road Site 11 and Site 1 DB 1 are considered to act on Level 1 performance measures. Upper Avon 37, DM22 and DM21 do not trigger CMA's. Future monitoring recommendations for Longwall 14 Aboriginal archaeological sites are outlined in Table 15.

Further details of the methodology and TARPS used by Niche for the Aboriginal Cultural Heritage Assessment can be found in **Attachment H**.

Table 14: Summary table of Aboriginal archaeological sites within the Longwall 14 study area.

AHIMS Number	Site Name/ AHIMS Number	Observed Changes
52-2-1626	Browns Road Site 11	This shelter had visible impacts from subsidence movements. The impact is comprised of one main area of rock fracturing. Diagonal and vertical cracking are contained to the southern end of the floor of the shelter, including block fall. No lateral movement or opening of joins were visible within the shelter site. The sandstone shelter is actively exfoliating, possibly expedited by subsidence movements. Macro vegetation was observed growing within the natural joint lines of the shelter. Further localised cracking was observed to the north of the shelter, within a shared ridgeline. Cracking within the southern floor area measured to an approximate length of 0.7 m and maximum width of 0.03 m. The site was undermined by Longwall 14 on 28 January 2019. The two art panels remain in the same condition as described in Biosis Research 2011, and 2007.
52-2-2229	Site 1-DB1	This shelter had visible impacts from subsidence. The impact is comprised of two rock fractures with the largest having a maximum measurable length of 1m, and a maximum width of 0.03 m. The fracturing is located within the back wall of the Aboriginal site *Site 1-DB1*, this site comprises of a sandstone

AHIMS Number	Site Name/ AHIMS Number	Observed Changes
		shelter containing art on the roof area. The shelter is 4.5 m in length, 2 m wide, 1.2 m high with a sanded floor. The art is not directly impacted by the fracture, which is contained to the underlying, disconnected rock. The site was undermined by Longwall 14 on 28 January 2019. Access to the site was restricted during mining due to safety concerns. The art panel remains in the same condition as described in Biosis Research 2008, and 2009.
52-2-3645	DM21	None
52-2-3646	DM22	None
52-2-1773	Upper Avon 37	None

Table 15: Recommendations for Aboriginal archaeology sites within the study area.

Recommendations	
#	**Browns Road Site 11 (AHIMS ID# 52-2-1626) and Site 1 DB 1 (AHIMS ID #52-2-2229)**
1.	Notify relevant specialists and key stakeholders (e.g. Aboriginal community groups).
2.	Continue monitoring program with condition assessment and photographic records as per TARPS.

Photo 21: Overview photo of Browns Road Site 11. Taken: 10th May 2019.

Photo 22: Subsidence cracking at the west end of the Browns Road Site 11 shelter. Taken: 10th May 2019.

Photo 23: Browns Road Site *1,* panel 1; indeterminate charcoal motifs and charcoal eel motif. Taken: 10th May 2019.

Photo 24: Overview photo of Site 1-DB1. Taken: 10th May 2019.

Photo 25: Subsidence related cracking in the north side of the Site 1-DB1 shelter. Taken: 10th May 2019.

Photo 26: Site 1-DB1, panel; indeterminate charcoal motif. Taken: 10th May 2019.

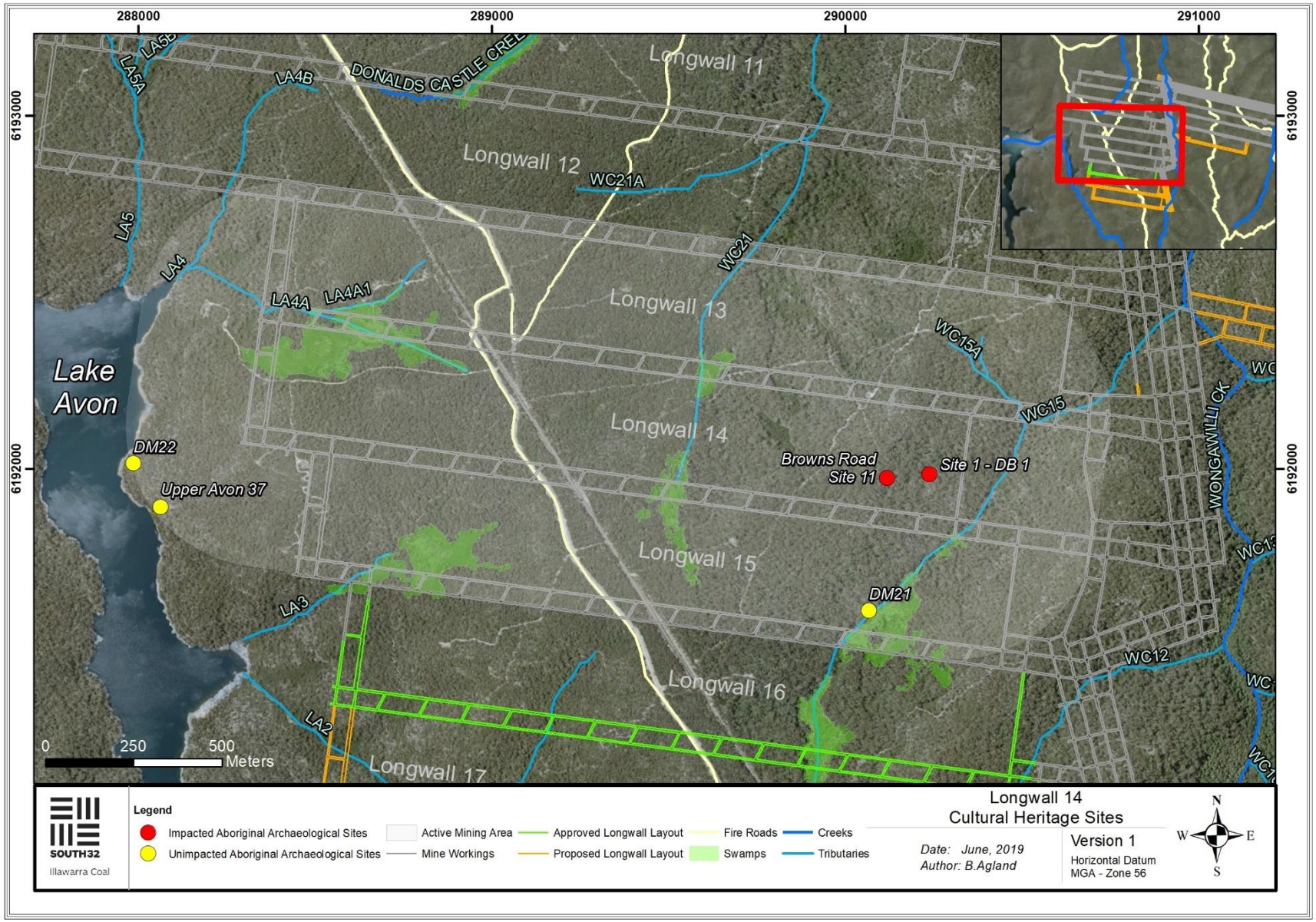


Figure 16: Aboriginal archaeological sites within the Longwall 14 study area.

4 IMPACTS TO BUILT FEATURES

The built features in proximity to Longwall 14 are shown in (**Attachment B**); and include:

- Fire trails and four-wheel drive tracks;
- Disused Maldon – Dombarton Railway Corridor;
- Survey control marks; and
- Exploration and monitoring boreholes.

Cordeaux Dam Wall is located more than 5 km north of Longwall 14, at its closest point. The Upper Cordeaux No.2 Dam Wall is located more than 6 km south-east of Longwall 14, at its closest point. It is unlikely these dam walls would experience any measurable far-field horizontal movements resulting from Longwall 14 and, therefore, they have not been assessed further.

Fourteen impacts associated with built features were identified during the extraction of Longwall 14 (Table 17 and Table 18). These impacts consist of soil cracks and uplift on seismic trails, Fire Road 6A, Access Track 6AA (also known as Access Track 6000) and the disused Maldon – Dombarton Railway Corridor. All fourteen impacts were either remediated (by means of in-filling) or were observed as self-remediating.

Table 16: Summary of predicted impacts in comparison to observed impacts relevant to Longwall 14.

Built feature	MSEC assessed impacts	Reported impacts
Fire trails and four-wheel drive tracks	Cracking of unsealed road surfaces	Soil / surface cracking observed on or near the fire trails, seismic tracks and railway corridor, with widths ranging between approximately 7 mm and 60 mm.
Disused Maldon-Dombarton Railway	Possible fracturing of rock cuttings, spalling, and/or mobilisation of rock joints	Surface cracking and rock fracturing above Longwall 14 near the alignment of the railway corridor.
Avon Dam	Adverse impacts not anticipated	No reported impacts to the dam walls. Refer to associated groundwater report for further details.
Survey control marks	Vertical and horizontal movements which could require re-establishment	No reported damage to the survey control marks. The marks to be re-established after completion of mining, as required.

4.1 Level 1 Surface Cracking

Twelve impacts (Photo 27 to Photo 30) to built features were reported as Level 1 impacts in accordance with the DA3B SMP; specifically:

- crack at the surface, which should not result in any significant erosion or further ground movement;
- crack in a fire trail, which should not result in erosion or impede access;
- crack or fracture up to 100 mm width;
- crack or fracture up to 10 m length; and
- erosion in a localised area, which would be expected to naturally stabilise without CMA and within the period of monitoring.

Table 17: Summary of Level 1 impacts to built features.

Site ID	Easting	Northing	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_LW14_001	288548	6192249	Surface Cracking	*Fire Trail 6N*	3/07/2018	1	Soil cracking on access track, approximately 5m length, 0.02m width, 0.1m depth.	4/07/2018
DA3B_LW14_002	288653	6192281	Surface Cracking	*Fire Trail 6N*	7/07/2018	1	Five soil cracks along a 30m section of *Fire Trail 6N.* The largest crack is approximately 3m long, 0.01m wide and 0.01m at deepest measurable point.	8/08/2018
DA3B_LW14_003	288849	6192272	Surface Cracking	*Fire Trail 6N*	7/07/2018	1	Four soil cracks along a 70m section of *Fire Trail 6N*. The largest crack is approximately 4.5m long, 0.03m wide and 0.23m at deepest measurable point.	8/08/2018
DA3B_LW14_004	288944	6192270	Surface Cracking	*Fire Trail 6N*	13/08/2018	1	Five soil cracks along a 40m section of *Fire Trail 6N.* The largest crack is approximately 5 m long, 0.025m wide and 0.122m at the deepest measurable point.	29/08/2018
DA3B_LW14_005	289060	6192478	Surface Cracking	*Fire Road 6AA*	13/08/2018	1	Two soil cracks along a 10m section of *Fire Road 6AA*. The largest crack is approximately 3.3m long, 0.007m wide and 0.066m at the deepest measurable point.	29/08/2018
DA3B_LW14_006	288908	6192429	Surface Cracking	Access Track	19/08/2018	1	Two soil cracks along a 10m on an access track. The largest crack is approximately 2.1m long and 0.01m wide.	29/08/2018
DA3B_LW14_007	289061	6192371	Surface Cracking	*Fire Road 6AA*	28/08/2018	1	Singular soil crack on *Fire Road 6AA*. The soil crack is approximately 3m long, 0.01m wide and 0.07m at the deepest measurable point.	29/08/2018
DA3B_LW14_008	288998	6192286	Surface Cracking	*Fire Road 6A*	28/08/2018	1	Two soil cracks along a 20m section of *Fire Road 6A*. The largest soil crack is approximately 4.5m long, 0.02m wide and 0.15m at the deepest measurable point.	29/08/2018
DA3B_LW14_009	289022	6192242	Surface Cracking	*Fire Road 6A*	3/09/2018	1	Three soil cracks along 20 m of Fire Road 6A. The largest continuous crack is 5m long, 0.02m wide and 0.4m deep.	3/09/2018
DA3B_LW14_011	289065	6192240	Soil Cracking, Rock Fracture and Uplift	Rail Corridor	16/9/2018	1	Soil crack, rock fracture and uplift on rail corridor adjacent to Fire Road 6A.	20/09/2018

Site ID	Easting	Northing	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_LW14_012	289062	6192097	Surface Cracking	*Fire Road 6A*	16/9/2018	1	Multiple surface cracks within a 20m section. Longest crack measuring approximately 9m long, 0.01m wide and 0.03m deep.	20/09/2018
DA3B_LW14_014	289432	6192021	Surface Cracking	Access Track	13/11/2018	1	Surface cracking on access track adjacent to Swamp 13. The crack is 1.1m long, 0.06m wide and 0.15m deep.	16/11/2018

Photo 27: *DA3b_LW14_003*. Taken 7/07/18.

Photo 28: *DA3B_LW14_009*. Taken 03/09/18.

Photo 29: *DA3B_LW14_012*. Taken 16/09/18.

Photo 30: *DA3B_LW14_014*. Taken 13/11/2018.

4.2 Level 2 Surface Cracking

Two impacts (Photo 31) to built features were reported as Level 2 impacts in accordance with the DA3B SMP; specifically:

- Crack or fracture between 100 mm and 300 mm width;
- Crack in the fire trail, which could result in significant erosion or impede vehicle access; and
- Crack or fracture between 10 m and 50 m length.

Table 18: Summary of Level 2 impacts to built features.

Site ID	Easting	Northing	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_LW14_010	289038	6192227	Surface Cracking and Uplift	*Fire Road 6A*	10/09/2018	2	Continuous soil crack and uplift along Fire Trail 6A. The crack is approximately 12m long, 0.05m wide with a maximum uplift of 0.03m and 0.26m at the deepest measurable point.	20/09/2018
DA3B_LW14_013	289080	6192069	Surface Cracking	Access Track	26/09/2018	2	Surface cracking on access track adjacent to *Fire Road 6A*. The crack is approximately 14m long, 0.01m wide and 0.05m deep at the deepest measurable point.	27/09/2018

Photo 31: *DA3B_LW14_010*. Taken 10/09/18.

5 SUMMARY OF TARP TRIGGERS

A summary of TARP triggers during the extraction of Longwall 14 is presented below in Table 19; additionally, an overview of Longwall 14 surface impacts is presented in Figure 17.

Table 19: Summary of TARP Triggers during the extraction of Longwall 14.

Site ID	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_LW14_001	Surface Cracking	*Fire Trail 6N*	3/07/2018	1	Soil cracking on access track, approximately 5m length, 0.02m width, 0.1m depth.	4/07/2018
DA3B_LW14_002	Surface Cracking	*Fire Trail 6N*	7/07/2018	1	Five soil cracks along a 30m section of *Fire Trail 6N.* The largest crack is approximately 3m long, 0.01m wide and 0.01m at deepest measurable point.	8/08/2018
DA3B_LW14_003	Surface Cracking	*Fire Trail 6N*	7/07/2018	1	Four soil cracks along a 70m section of *Fire Trail 6N*. The largest crack is approximately 4.5m long, 0.03m wide and 0.23m at deepest measurable point.	8/08/2018
DA3B_LW14_004	Surface Cracking	*Fire Trail 6N*	13/08/2018	1	Five soil cracks along a 40m section of *Fire Trail 6N.* The largest crack is approximately 5 m long, 0.025m wide and 0.122m at the deepest measurable point.	29/08/2018
DA3B_LW14_005	Surface Cracking	*Fire Road 6AA*	13/08/2018	1	Two soil cracks along a 10m section of *Fire Road 6AA*. The largest crack is approximately 3.3m long, 0.007m wide and 0.066m at the deepest measurable point.	29/08/2018
DA3B_LW14_006	Surface Cracking	Access Track	19/08/2018	1	Two soil cracks along a 10m on an access track. The largest crack is approximately 2.1m long and 0.01m wide.	29/08/2018
DA3B_LW14_007	Surface Cracking	*Fire Road 6AA*	28/08/2018	1	Singular soil crack on *Fire Road 6AA*. The soil crack is approximately 3m long, 0.01m wide and 0.07m at the deepest measurable point.	29/08/2018

Site ID	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_LW14_008	Surface Cracking	*Fire Road 6A*	28/08/2018	1	Two soil cracks along a 20m section of *Fire Road 6A*. The largest soil crack is approximately 4.5m long, 0.02m wide and 0.15m at the deepest measurable point.	29/08/2018
DA3B_LW14_009	Surface Cracking	*Fire Road 6A*	3/09/2018	1	Three soil cracks along 20 m of *Fire Road 6A*. The largest continuous crack is 5m long, 0.02m wide and 0.4m deep.	3/09/2018
DA3B_LW14_010	Surface Cracking and Uplift	*Fire Road 6A*	10/09/2018	2	Continuous soil crack and uplift along Fire Trail 6A. The crack is approximately 12m long, 0.05m wide with a maximum uplift of 0.03m and 0.26m at the deepest measurable point.	20/09/2018
DA3B_LW14_011	Soil Cracking, Rock Fracture and Uplift	Rail Corridor	16/9/2018	1	Soil crack, rock fracture and uplift on rail corridor adjacent to Fire Road 6A.	20/09/2018
DA3B_LW14_012	Surface Cracking	*Fire Road 6A*	16/9/2018	1	Multiple surface cracks within a 20m section. Longest crack measuring approximately 9m long, 0.01m wide and 0.03m deep.	20/09/2018
DA3B_LW14_013	Surface Cracking	Access Track	26/09/2018	2	Surface cracking on access track adjacent to *Fire Road 6A.* The crack is approximately 14m long, 0.01m wide and 0.05m deep at the deepest measurable point.	27/09/2018
DA3B_LW14_014	Surface Cracking	Access Track	13/11/2018	1	Surface cracking on access track adjacent to Swamp 13. The crack is 1.1m long, 0.06m wide and 0.15m deep.	16/11/2018
DA3B_LW14_015	Rock Fracturing and Rockfall	*Step/ledge of Lake Avon*	5/12/2018	1	Rockfall and rock fracturing on Lake Avon rock ledge. The rock fracturing has a maximum length of 1.8m, a maximum width of 0.01m and a maximum depth of 0.29m. The rock fall is approximately 4m x 1.5m x 0.5m.	18/12/2018
DA3B_LW14_016	Rock Fracturing, Uplift and Rock Displacement	*WC15*	21/01/2019	2	Multiple fractures, uplift and dislodged sections of rock on *WC15*. The longest fracture is up to 4.0m long and 0.03m wide.	24/01/2019

Site ID	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_LW14_017	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fracturing has a maximum measurable length of 0.8m, a maximum width of 0.025m and a maximum measurable depth of 0.17m.	21/02/2019
DA3B_LW14_018	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 0.7m, a maximum width of 0.015m and a maximum measurable depth of 0.10m.	21/02/2019
DA3B_LW14_019	Rock Fracturing and Uplift	*WC15*	20/02/2019	1	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 4.5m, a maximum width of 0.05m, a maximum measurable depth of 0.7m.	21/02/19
DA3B_LW14_020	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 1.3m, a maximum width of 0.05m and a maximum measurable depth of 1.13m.	21/02/19
DA3B_LW14_021	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fractures have a maximum measurable length of 1.1m and a maximum width of 0.01m.	21/02/19
DA3B_LW14_022	Rock Fracturing	*WC15*	20/02/2019	2	Rock fracturing to *WC15*. The rock fracture has a maximum measurable length of 2.9m, and a maximum width of 0.05m.	21/02/19
DA3B_LW14_023	Rock Fracturing	*WC15*	1/04/2019	1	Rock fracturing to *WC15_Pool 22*. The rock fracture has a maximum measurable length of 0.35m, and a maximum width of 0.001m.	3/04/19
DA3B_LW14_024	Rock Fracturing & Rock Fall & Soil Cracking	*A3b-SS9-Pt2 (Steep Slope)*	9/04/2019	1	Rock fracturing, rockfall and soil cracking at SLMMP site '*A3b-SS9-Pt2'*.	10/04/2019
DA3B_LW14_025	Rock Fracturing	*Steep Slope/Step*	9/04/2019	1	Rock fracturing and displacement at a steep slope/ step between WC15 and Fire road 6P.	10/04/2019
DA3B_LW14_026	Rock Fracturing & Movement	*Steep Slope/Step*	10/05/2019	2	Rock fracturing and displacement at a steep slope/step between *WC15* and *Fire road 6P*. The movement between the rock and soil has resulted	16/05/2019

Site ID	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
					in a fracture with a maximum measurable length of 22m, a width of 0.13m and a measurable depth of less than 5m.	
DA3B_LW14_027	Rock Fracturing	*Steep Slope/Step*	10/05/2019	1	Rock fracturing at cultural heritage site 'Site 1 – DB 1'. The impact is comprised of two rock fractures with the largest having a maximum measurable length of 1m, and a maximum width of 0.03m.	16/05/2019
DA3B_LW14_028	Rock Fracturing	*Sandstone outcrop*	10/05/2019	1	Rock fracturing at sandstone outcrop between *WC15* and *Fire road 6P.* The impact is comprised of two rock fractures with the largest having a maximum measurable length of 0.75m, and a maximum width of 0.015m.	16/05/2019
DA3B_Longwall 13_035 *(Update)*	Rock Fracturing	*WC15*	23/04/2018	2	Additional fracturing with flow diversion was observed on *WC15*. The largest fracture is up to 3.7m long, with the widest fracture up to 0.02m wide.	27/04/2018 24/01/2019
DA3B_Longwall 13_042 *(Update)*	Rock Fracturing	*WC15*	16/05/2018	2	Additional fracturing and rock fragmentation was observed at WC15_Pool 22. The new rock fracturing has a maximum measurable length of 0.2m and a maximum width of 0.002m.	17/05/2018 3/04/2019
DA3B_Longwall 13_043 *(Update)*	Rock Fracturing & Rock Fall & Iron Staining	*LA4*	16/05/2018	2	Rock fracturing to *LA4_ Step 0*. The additional fracturing has a maximum length of 1.5m and a maximum width of 0.01m. An increase of iron staining was also identified evident.	17/05/2018 06/08/2018
DA3B_Longwall 13_044	Rock Fracturing	*LA4B*	26/07/2018	2	Rock fracturing to the base of a step on tributary *LA4B*. Maximum length of 1.7m, horizontal depth of 1.05m and a width of 0.1m.	08/08/2018
DA3B_Longwall 13_045	Rock Fracturing	WC15	8/07/2018	2	Rock fracture across a rock bar on tributary *WC15*. The fracture is approximately 0.3m long, 0.03m wide and 0.03m at the deepest measurable point.	08/08/2018

Site ID	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DA3B_Longwall 13_046	Rock Fracturing	WC15	1/04/2019	1	Rock fracturing to the base of a step on tributary *WC15*. Maximum length of 1.2m, and a width of 0.02m.	3/04/2018
Donalds Castle Ck (FR6)	Water Quality	*Donalds Castle Creek*	25/03/2019	3	EC trigger.	28/03/2019
Wongawilli Creek (FR6)	Water Quality	*Wongawilli Creek*	3/10/2018	2	DO trigger.	16/10/2018
Wongawilli Creek (FR6)	Water Quality	*Wongawilli Creek*	3/10/2018	1	EC trigger.	16/10/2018
S13_01	Soil Moisture	*Swamp 13*	12/10/2018	3 (ICEFT & HGEO)	Soil moisture level below baseline.	15/10/2018 16/10/2018
S13_02	Soil Moisture	*Swamp 13*	12/10/2018	3 (ICEFT & HGEO)	Soil moisture level below baseline.	15/10/2018 16/10/2018
S13_03	Soil Moisture	*Swamp 13*	12/10/2018	3 (ICEFT & HGEO)	Soil moisture level below baseline.	15/10/2018 16/10/2018
23_02	Soil Moisture	*Swamp 23*	23/09/2018	1 (ICEFT) No Trigger (HGEO)	Soil moisture level below baseline.	21/09/2018
14_02	Groundwater	*Swamp 14*	12/02/2019	2 (ICEFT) No Trigger (HGEO)	Shallow groundwater rate of recession.	13/02/2019
13_01	Groundwater	*Swamp 13*	5/12/2018	3 (ICEFT) Unclear (HGEO)	Shallow groundwater level below baseline.	06/12/2018

Site ID	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
DCS2	Catchment Yield	*Donalds Castle Creek*	N/A	3	-20 % yield change during the extraction of Longwall 14.	HGEO (August 2019)
DC13S1	Catchment Yield	*DC13*	N/A	2	-17 % yield change during the extraction of Longwall 14.	HGEO (August 2019)
WC21S1	Catchment Yield	*WC21*	N/A	3	-24 % yield change during the extraction of Longwall 14.	HGEO (August 2019)
WC15S1	Catchment Yield	*WC15*	N/A	1	-10 % yield change during the extraction of Longwall 14.	HGEO (August 2019)
LA4S1	Catchment Yield	*LA4*	N/A	1	-6 % yield change during the extraction of Longwall 14.	HGEO (August 2019)
Swamp 15B	Terrestrial Ecology (Flora)	*Swamp 15B*	N/A	2	A statistically significant difference in TSR and species composition.	Biosis (June 2019)
Swamp 15A (2)	Terrestrial Ecology (Flora)	*Swamp 15A (2)*	N/A	2	A statistically significant difference in species composition.	Biosis (June 2019)
Swamp 1A	Swamp Size	*Swamp 1A*	N/A	1	Two years of decline in total swamp extent greater than the mean (±SE) decline of the control group.	Biosis (June 2019)
Swamp 1A	Ecosystem Function	*Swamp 1A*	N/A	2	Trending decline in the extent of subcommunities for three consecutive monitoring periods greater than the mean (±SE) decline in the control group.	Biosis (June 2019)
Swamp 1B	Swamp Size	*Swamp 1B*	N/A	1	Two years of decline in total swamp extent greater than the mean (±SE) decline of the control group.	Biosis (June 2019)
Swamp 1B	Ecosystem Function	*Swamp 1B*	N/A	2	Trending decline in the extent of subcommunities for two consecutive monitoring periods greater than the mean (±SE) decline in the control group.	Biosis (June 2019)

Site ID	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
Swamp 5	Ecosystem Function	*Swamp 5*	N/A	2	Trending decline in the extent of subcommunity MU43 for three consecutive monitoring periods greater than the mean (±SE) decline in the control group.	Biosis (June 2019)
SC10C	Terrestrial Ecology (Fauna)	*SC10C (Sandy Creek Tributary)*	N/A	1	Significant impacts to local populations of Littlejohn's Tree Frog.	Biosis (June 2019)
DC(1)	Terrestrial Ecology (Fauna)	*Donalds Castle Creek*	N/A	1	Significant impacts to local populations of Littlejohn's Tree Frog.	Biosis (June 2019)
DC13	Terrestrial Ecology (Fauna)	*DC13 (Donalds Castle Creek Tributary)*	N/A	3	Significant impacts to local populations of Littlejohn's Tree Frog.	Biosis (June 2019)
WC21	Terrestrial Ecology (Fauna)	*WC21 (Wongawilli Creek Tributary)*	N/A	3	Significant impacts to local populations of Littlejohn's Tree Frog.	Biosis (June 2019)
Donalds Castle Creek	Aquatic Ecology	*Donalds Castle Creek*	N/A	3	Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period.	Cardno (June 2019)
WC21	Aquatic Ecology	*WC21 (Wongawilli Creek Tributary*	N/A	3	Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period.	Cardno (June 2019)
Browns Road Site 11.	Cultural Heritage	*Sandstone Shelter*	10/05/2019	1	The sandstone shelter at *Browns Road Site 11* has experienced diagonal and vertical cracking with block fall and exfoliation expedited with subsidence.	Niche (June 2019)

Site ID	Impact Type	Feature Affected	Identification Date	Trigger Level	Description	Refer to Impact Report/s Dated
Site 1-DB1.	Cultural Heritage	*Sandstone Shelter*	10/05/2019	1	The sandstone shelter at *Site 1 DB-1* has experienced diagonal and vertical cracking with block fall and exfoliation expedited with subsidence.	Niche (June 2019)

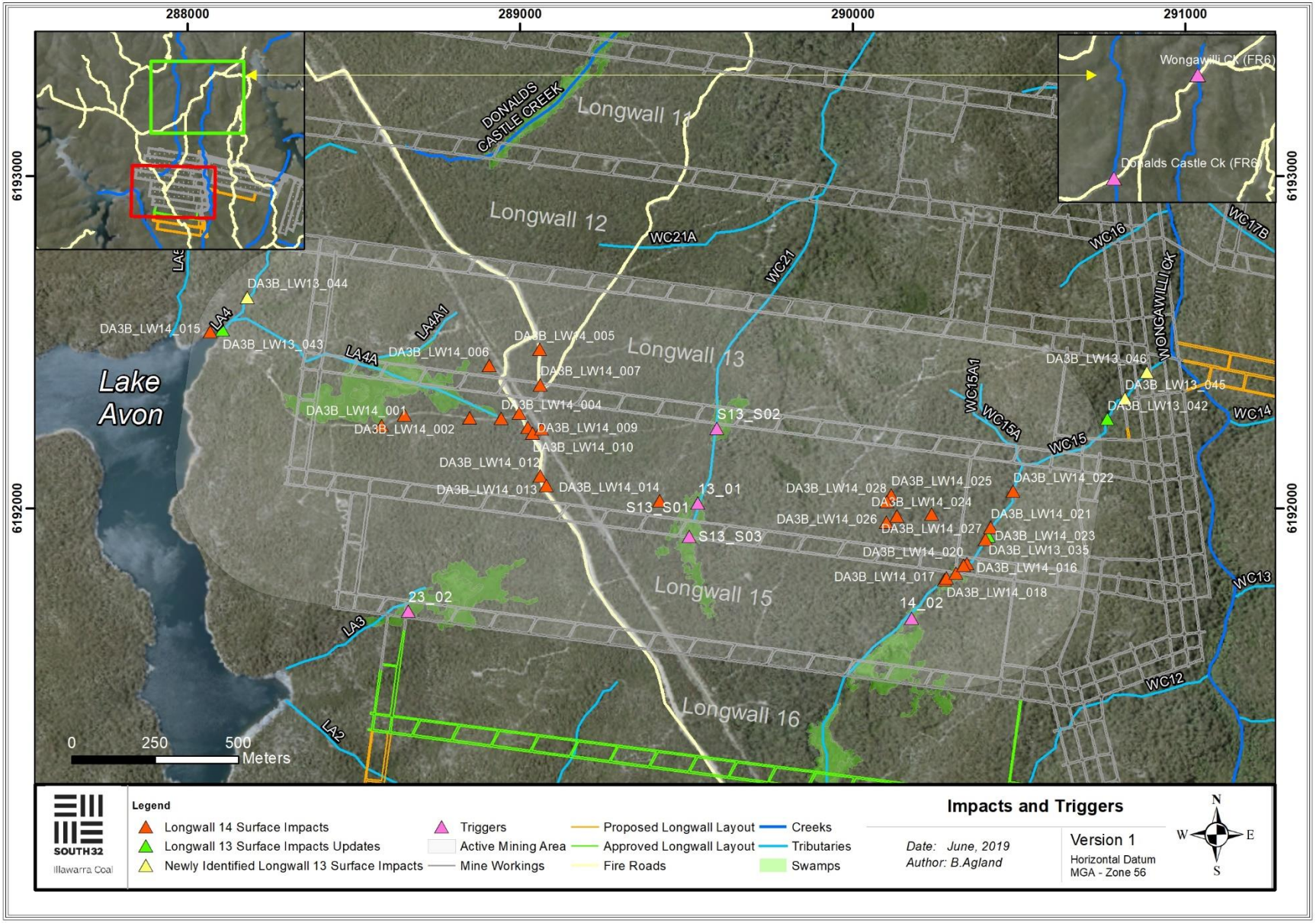


Figure 17: Overview of surface impacts observed during the extraction of Longwall 14.

6 LONGWALL 14 MONITORING PROGRAM

Table 20: Summary of monitoring sites associated with the extraction of Longwall 14. Recommended monitoring sites associated with the extraction of Longwall 15 are also included.

Aspect	Monitoring Sites Associated with Longwall 14	Monitoring Frequency	Recommended Future Monitoring for longwall 15
Watercourses	**Observational, photo point and water monitoring**		
	• Donald's Castle Creek • LA3 • LA4, LA4A, LA4B • Swamp 23 • Swamps 4, 5, 8, 10, 11,13 and 14 • WC15 • WC21, WC16 and WC18 • Wongawilli Creek	Monthly 2 years pre and post mining, weekly when longwall is within 400m of monitoring site. SLMMP Sites: pre and post mining, monthly when longwall is within 400m of monitoring site.	• Donald's Castle Creek – Continue as required. • Lake Avon • LA2 • LA3 – Continue as required • LA4, LA4A, LA4B - Continue as required • Swamp 23 – Continue as required • Swamps 4, 5,10,11,13 and 14 – Continue as required • WC12 • WC15, WC16 and WC21 – Continue as required • Wongawilli Creek – Continue as required • WC6, WC7, WC8, WC9, ND1; and Swamps 35a and 35b - *pre-mining monitoring*
	Water Quality		
	Wongawilli Creek • WWU1 (Wongawilli Creek headwaters) • WWU4 (Wongawilli Creek upstream) • WC_Pool 49 (Wongawilli Creek adjacent to Longwall 15) • WC_Pool 46 [*Previously named WWM1*] (Wongawilli Creek adjacent to Longwall 12) • WWM2 (Wongawilli Creek adjacent to Longwall 11) • WC_Pool 43b [*Previously named WWM3*] (Wongawilli Creek downstream of Longwall 9) • Wongawilli Ck (FR6) [*Previously named WWL2*] (Wongawilli Creek downstream) • WC21_Pool 5 [*Previously named WC21S1*] (Wongawilli Creek tributary downstream of mining) • WC21_Pool 30 (Wongawilli Creek tributaries over mining) • WC21_Pool 53 (Wongawilli Creek tributaries over mining) • WC12_Pool 1 (Wongawilli Creek tributaries downstream of mining) • WC15_Pool 9 [*Previously named WC15S1*] (Wongawilli Creek tributary downstream of mining)	Monthly monitoring during and post mining for two years until required.	Continue water quality sample sites as required by the SMP.

	Lake Avon • LA4_S1, LA4_S2, LA5_S1, LA5_S2, LA_1, LA1, LA2_Pool 5, LA3_Pool 4 **Donalds Castle Creek:** • Donalds Castle Ck (FR6) [*Previously named DCU3*] (Donalds Castle Creek lower) • DCL3 (Donalds Castle Creek @ Cordeaux River) • DC_Pool 22 [*Previously named DCS2*] (Donalds Castle Creek downstream of mining) • DC13_Pool 2b [*Previously named DC13S1*] (Donalds Castle Creek tributary downstream of mining)		
Swamps	**Observational, Photo Point and Water Monitoring**		
	• Swamps 4, 5, 8, 10, 11, 13, 14 and 23	Pre and post mining for two years, monthly when longwall is within 400m of monitoring site.	• Swamps 3, 4, 5, 10, 11 13, 14 and 23 - continue as required by the SMP
	Shallow Groundwater Level		
	• Swamp 05: 05_01, 05_02, 05_03, 05_03i, 05_03ii, 05_03iii, 05_04, 05_05, 05_06 • Swamp 08: 08_01, 08_02, 08_03, 08_04, 08_05, 08_06 • Swamp 10: 10_01 • Swamp 11: S11-H1, S11-H2, S11-H3 • Swamp 13: 13_01 • Swamp 14: 14_01, 14_02 • Swamp 23: 23_01, 23_02 **Reference Sites:** • Swamp 2: 02_S01 • Swamp 7: 07_S05, 07_S06 • Swamp 15A: S15a_S01, S15a_Piezo, S15a_S04, S15a_S06 • Swamp 22: 22_01, 22_02 • Swamp 25: S25_S01 • Swamp 33: S33_S01, S33_S03 • Swamp 84: S84_S02 • Swamp 85: S85_S01, S85_S02 • Swamp 86: S86_S01, S86_S02 • Swamp 87: S87_S01, S87_S02 • Swamp 88: S88_S01, S88_S02	For open hole sites: • Monthly monitoring pre, during and post mining for two years to be removed annually • Reference sites 6 monthly For instrumented sites: • Automatic groundwater level monitoring, during and post mining (4 hour interval or similar) • Monitoring post mining for five years to be reviewed annually	• Swamp 05: 05_01, 05_02, 05_03, 05_03i, 05_03ii, 05_03iii, 05_04, 05_05, 05_06 • Swamp 10: 10_01 • Swamp 11: S11-H1, S11-H2, S11-H3 • Swamp 13: 13_01 • Swamp 14: 14_01, 14_02 • Swamp 23: 23_01, 23_02 Reference Sites: • Swamp 2: 02_S01 • Swamp 7: 07_S05, 07_S06 • Swamp 15A: S15a_S01, S15a_Piezo, S15a_S04, S15a_S06 • Swamp 22: 22_01, 22_02 • Swamp 25: S25_S01 • Swamp 33: S33_S01, S33_S03 • Swamp 84: S84_S02 • Swamp 85: S85_S01, S85_S02 • Swamp 86: S86_S01, S86_S02 • Swamp 87: S87_S01, S87_S02 • Swamp 88: S88_S01, S88_S02
	Soil Moisture		
	• Swamp 05: S05_S01, S05_S02, S05_S03, S05_S03i, S05_S03ii, S05_S03iii, S05_S04, S05_S05, S05_S08 • Swamp 08: S08_S01, S08_S02, S08_S03, S08_S04, S08_S05, S08_S06 • Swamp 11: S11_S01, S11_S02, S11_S05	• 6 monthly baseline and reference site monitoring • Weekly monitoring when longwall is within 400m of swamp • 6 monthly monitoring for 2 years post mining	• Swamp 05: S05_S01, S05_S02, S05_S03, S05_S03i, S05_S03ii, S05_S03iii, S05_S04, S05_S05, S05_S08 • Swamp 11: S11_S01, S11_S02, S11_S05 • Swamp 13: S13_S01, S13_S02, S13_S03

	• Swamp 13: S13_S01, S13_S02, S13_S03 • Swamp 14: 14_01, 14_02 • Swamp 23: 23_01, 23_02 **Reference Sites:** • Swamp 2: S02_S01 • Swamp 7: S07_S05, S07_S06 • Swamp 15A: S15a_S01, S15a_Piezo, S15a_S04, S15a_S06 • Swamp 22: 22_01, 22_02 • Swamp 24: S24_S01 • Swamp 25: S25_S01 • Swamp 33: S033_S01, S033_S03 • Swamp 84: S84_S02 • Swamp 85: S85_S01, S85_S02 • Swamp 86: S86_S01, S86_S02 • Swamp 87: S87_S01, S87_S02 • Swamp 88: S88_S01, S88_S02		• Swamp 14: 14_01, 14_02 • Swamp 23: 23_01, 23_02 **Reference Sites:** • Swamp 2: S02_S01 • Swamp 7: S07_S05, S07_S06 • Swamp 15A: S15a_S01, S15a_Piezo, S15a_S04, S15a_S06 • Swamp 22: 22_01, 22_02 • Swamp 24: S24_S01 • Swamp 25: S25_S01 • Swamp 33: S033_S01, S033_S03 • Swamp 84: S84_S02 • Swamp 85: S85_S01, S85_S02 • Swamp 86: S86_S01, S86_S02 • Swamp 87: S87_S01, S87_S02 • Swamp 88: S88_S01, S88_S02
Landscape	**Targeted Sites**		
	Cliffs • DA3-CF19 • DA3-CF20 • DA3-CF21 • DA3-CF22 • DA3-CF23 **Fire Trails** Fire Road 6A (across LWs 10-18) - Continue as required by the SMP Fire Road 6N	• Baseline monitoring campaign prior to monitoring • Monthly monitoring during any subsidence period • Monitoring to continue 6 monthly for 2 years following the completion of mining	**Cliffs** No targeted cliff lines associated with Longwall 15 **Fire Trails** Fire Road 6A (across LWs 10-18) - Continue as required by the SMP Fire Road 6N Fire Road 6P
	Inspection of Active Mining Area – Landscape Features, Vegetation, Watercourses		
	All mapped cliff, steep slopes, watercourse, swamp and fire trail sites in subsidence area. General observation of active mining areas.	• Weekly monitoring when longwall extraction is within 400m of feature.	Continue monitoring of all mapped cliffs, steep slopes, watercourse, swamp and fire trail sites in subsidence area. Continue general observation of active mining areas.

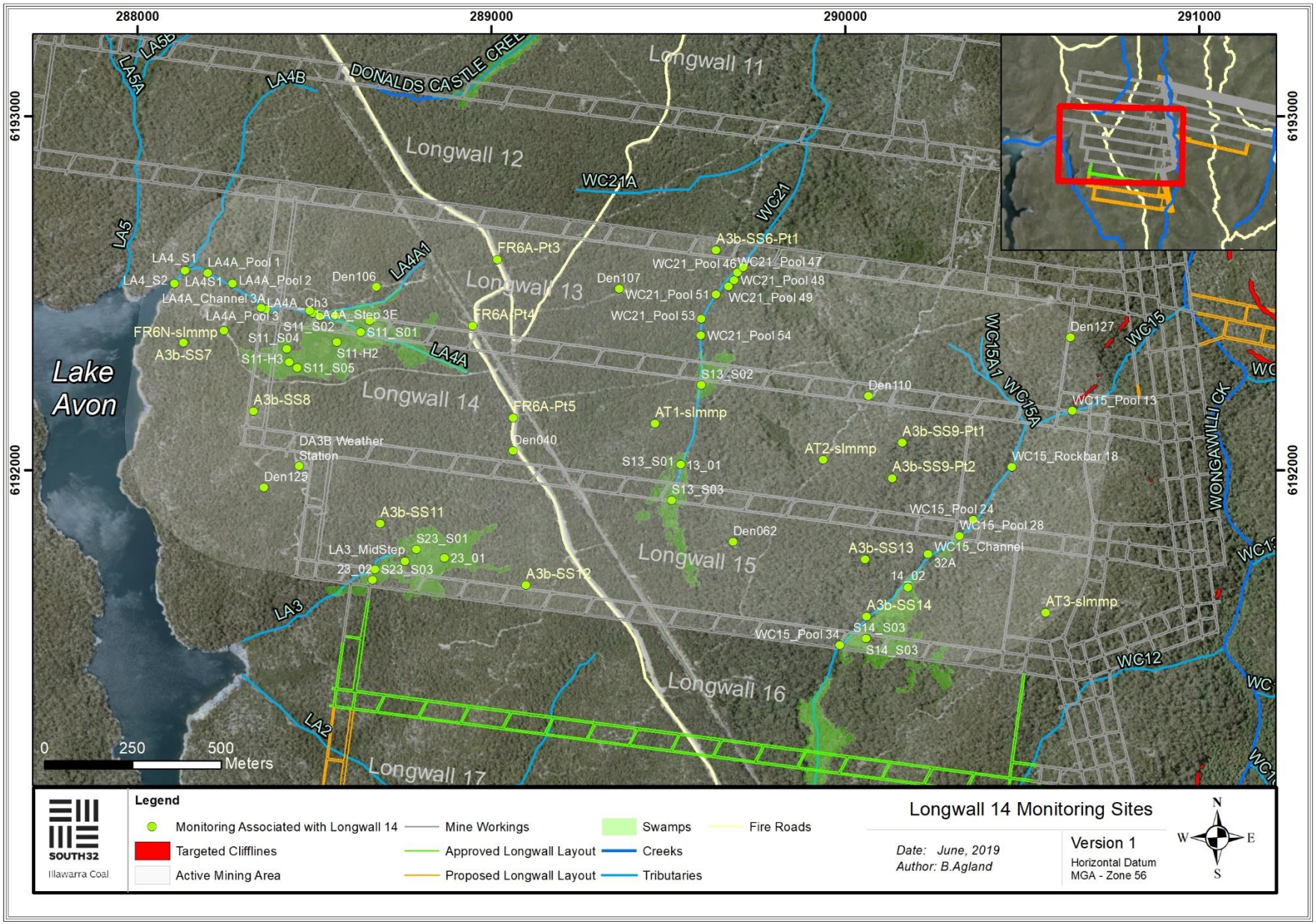


Figure 18: Overview of monitoring sites relevant to Longwall 14.

7 REFERENCES

Biosis 2003. Dendrobium Coal Mine Flora and Fauna Environmental Management Program (Subsidence) - Area 1, Longwalls 1 and 2. Biosis Pty Ltd, Sydney.

Biosis 2007b. Dendrobium Area 3 Species Impact Statement. Biosis Pty Ltd, Sydney.

Biosis 2017b. Dendrobium Area 3A and 3B TARP response. Littlejohn's Tree Frog tadpole surveys. DC13, WC21, DC(1), SC10C and WC17. Report for Illawarra Coal. Author: J Lidsey, Biosis Pty Ltd, Wollongong. Project no. 23829.

Biosis, 2019. Dendrobium Terrestrial Ecology Monitoring Program Annual Report for 2018. Prepared for Illawarra Coal.

Cardno, 2019. Longwall 14 End of Panel Report Aquatic Flora and Fauna Review. Prepared for Illawarra Coal

Cardno Ecology Lab (2012). Dendrobium Area 3B SMP – Aquatic Flora and Fauna Assessment. Report Prepared for BHPBIC. Report No. EL1112029A

Chessman, B.C Growns, J.E and Kotlash, A.R. (1997). Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: Application to the Hunter River system, New South Wales. Marine and Freshwater Research, 48, pp. 159-172.

Ecoengineers (2011). Dendrobium Area 3B Subsidence Management Plan. Surface and Shallow Groundwater Assessment. Report prepared for BHPBIC.

HGEO. 2019. Dendrobium Mine – End of Panel Groundwater Assessment for Longwall 14 (Area 3B). D19326. Report by HGEO Pty Ltd for South32 Illawarra Coal.

MSEC, 2019. End of Panel Subsidence Monitoring Review Report for Dendrobium Longwall 14. MSEC1039, May 2019 Prepared for Illawarra Coal.

Niche 2012. Dendrobium Area 3B Terrestrial Ecological Assessment. Report prepared for BHPBIC. September 2012

Niche, 2019. Dendrobium Colliery Longwall 14 End of Panel Report - Aboriginal Heritage Assessment (#4872). Prepared for Illawarra Coal.

South32. 2012. Dendrobium Mine Groundwater Management Plan. South32 Illawarra Coal, Management Plan Rev 1.5.

South32, 2015a. Dendrobium Area 3 Swamp Monitoring Impacts, Triggers and Response. 12 October 2015.

South32, 2015b. Dendrobium Area 3 Watercourse Monitoring Impacts, Triggers and Response. 12 October 2015.

South32, 2019. Dendrobium Area 3B – Longwall 14 End of Panel Landscape Report. April 2019.

8 APPENDIX A – IMPACTS, TRIGGERS AND RESPONSE

Table 21: Dendrobium Area 3B Landscape TARPs.

Monitoring	Trigger	Action
LANDSCAPE FEATURES		
AREA 2 **Cliffs** • A2-CL1 (above LW4) **Steep Slopes** • A2-SL1 and A2-SL2 (above LWs 4 & 5) **Watercourses** • A2-WC10 and A2-WC11 (above LW3) • A2-WC13 & A2-WC16 (above LWs 4 & 5) **Swamp** • A2-SW1 (above LWs 4 & 5) **4WD Track** • A2-FT1 (above LWs 4 & 5) **Crinanite Surface Extent** • A2-CN1 & A2-CN2 (above LWs 3 & 4) **AREA 3A**	***Level 1*** * • Rock fall from a cliff which is left mostly intact (<10% length), resulting in insignificant ground disturbance • Surface movement or rock displacement with negligible soil surface exposed • Crack at the surface, which should not result in any significant erosion or further ground movement • Crack in a fire trail which should not result in erosion or impede access • Crack or fracture up to 100mm width • Crack or fracture up to 10m length • Erosion in a localised area which would be expected to naturally stabilise without CMA and within the period of monitoring	• Continue monitoring program • Report impacts to key stakeholders • Summarise impacts and Report in the End of Panel Report and AEMR
	Level 2 *	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Provide safety signage and barricades as appropriate • Implement approved repairs to ensure safety and serviceability on fire trails • Implement agreed CMAs as approved *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*

Monitoring	Trigger	Action
Cliffs All mapped cliff sites in subsidence area (Refer to Dendrobium Area 3A SMP Figures 19.3 for location of sites) **Steep Slopes** All mapped steep slopes in subsidence area *Refer to Dendrobium Area 3A SMP Figures 19.3 for location of sites* **Watercourses/ Swamps** All mapped watercourse and swamps in subsidence area *Refer to Dendrobium Area 3A SMP Figure 19.3* **Fire Trails** All mapped fire trails in subsidence area *Refer to Dendrobium Area 3A SMP Figure 19.3* **AREA 3B** **Cliffs** All mapped cliff sites in subsidence area *Refer to Dendrobium Area 3B SMP Figures 18.1 for location of sites*	• Rock fall or overhang collapse at a cliff site, where characteristics of the cliff have changed, and there has been significant ground disturbance • Surface movement or rock displacement that has exposed significant areas of soil • A crack at the surface, which could result in significant erosion or movement at the surface • A crack at the surface with potential risk to safety and/or fauna entrapment • A crack in the fire trail, which could result in significant erosion or impede vehicle access • Crack or fracture between 100 and 300mm width • Crack or fracture between 10 and 50m length • Significant erosion at any location, which is not likely to naturally stabilise within the period of monitoring, or is located in a sensitive area e.g. swamps, creek, lake shore, and may result in increased sediment transport to Cordeaux Dam, or has been previously identified as Level 1, but is not likely to naturally stabilise within the monitoring period	
	Level 3 * • Major cliff collapse where the characteristics of the cliff change significantly and there is significant ground disturbance that is unlikely to naturally stabilise within the monitoring period • Crack or fracture over 300mm width • Crack or fracture over 50m length • Mass movement of a slope causing large areas of exposed soil with potential for further movement	• *Actions as stated for Level 2* • Immediately notify DoPI, DPIM, SCA, resource managers and relevant technical specialists and seek advice on any CMA required • Site visits with stakeholders if required • Review monitoring program and modify if necessary within 1 month • Implement increased monitoring if required within 2 weeks • Develop site CMA in consultation with key stakeholders within 1 month, (pending stakeholder availability) and seek approvals • Completion of works following approvals • Issue CMA report within 1 month of works completion • Conduct initial follow up monitoring & reporting within 2 months of CMA completion • Review the relevant TARP and Management Plan in consultation with key stakeholders *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*

Monitoring	Trigger	Action
Sandy Creek Waterfall	***Exceeding Prediction*** • Rock fall at Sandy Creek Waterfall or from its overhang • Structural integrity of the waterfall, its overhang and its pool are impacted • More than negligible cracking within 30 m of the waterfall • More than negligible diversion of water from the lip of the waterfall	• Actions as stated for Level 3 • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation

Table 22: Dendrobium Area 3B Swamp TARP.

Performance Measures	***Potential Impacts***	***Performance Triggers***	***Management Strategies***	***Offsets***	***Other Actions***
Negligible erosion of the surface of the swamp	Gully erosion or similar	<u>*Level 1:*</u> The increase in length of erosion within a swamp (compared to its pre-mining length) is **2%** of the swamp length or area; and/or Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring. <u>*Level 2*</u>: The increase in length of erosion within a swamp (compared to its pre-mining length) is **3%** of the swamp length or area; and/or Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention; and/or Gully knickpoint forms or an existing gully knickpoint becomes active. <u>*Level 3:*</u> The increase in length of erosion within a swamp (compared to its pre-mining length) is **4%** of the swamp length or area; and/or Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention. <u>*Exceeding Prediction*</u> Mining results in the total length of erosion within a swamp (compared to its pre-mining length) to increase **>5%** of the length or area of the swamp compared to any increase in total erosion length in a reference swamp (ie increase in length or area of erosion in an impact swamp less any increase in length or area in erosion in a reference swamp is **>5%**).	a) upfront mine planning b) erosion monitoring (ie ALS, observation) c) coir logs d) knickpoint control e) water spreading f) weeding g) fire management h) reporting i) investigation and review j) update future predictions	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective. This period can be extended to **5 years**, with the agreement of the Secretary.	
Minor changes in the size of the swamps **Minor changes** in the ecosystem functionality of the swamps **No significant change** to the composition or	Swamp vegetation changes: - Swamp size - Species richness, distribution, composition and diversity - Vegetation sub-communities	**Swamp Size** <u>*Level 1:*</u> A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the standard error (SE) of the Control Group <u>*Level 2:*</u> A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group.	a) upfront mine planning b) vegetation monitoring c) water spreading d) seeding/planting e) weeding f) fauna monitoring g) fire management h) grouting of controlling of controlling rockbars and	Offset required **immediately**, if no remediation considered practicable. Offset required **5 years** following remediation, if it is ineffective.	Monitoring period for swamp size is related to capture of LiDAR (ALS) data at the end of each longwall ~ 1 year Triggers for groundwater decline result in increased intensity and frequency of

distribution of species within the swamps		*Level 3:* A trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Exceeding Prediction:* Mining results in a trending decline in the extent of an upland swamp (combined area of groundwater dependent communities) for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Ecosystem Functionality** *Level 1:* A trending decline in the extent of any individual groundwater dependent community within a swamp for two consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 2:* A trending decline in the extent of any groundwater dependent community within a swamp for three consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Level 3:* A trending decline in the extent of any groundwater dependent community within a swamp for four consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. *Exceeding Prediction:* Mining results in a trending decline in the extent of a groundwater dependent community within a swamp for five consecutive monitoring periods, greater than observed in the Control Group, and exceeding the SE of the Control Group. **Species Composition and Distribution** *Level 1:* A **2%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **two** consecutive years; and/or *Level 2:* A **5%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **three** consecutive years. *Level 3:* An **8%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **four** consecutive years.	bedrock base and/or use of other remediation techniques i) reporting j) investigation and review k) update future predictions	This period can be extended to **10 years**, with the agreement of the Secretary.	vegetation monitoring

		Exceeding Prediction: Mining results in a **>10%** (or otherwise statistically significant) decline in species richness or diversity during a period of stability or increase in species richness/diversity in reference swamps for **five** consecutive years.			
Maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamps	Subsidence impacts (ie cracking) on bedrock base or controlling rockbar	*Level 1:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **10%** compared to baseline for the pool (in addition to any decrease in reference pools). *Level 2:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **20%** compared to baseline for the pool (in addition to any decrease in reference pools). *Level 3:* Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water of **20%** compared to baseline for the pool for **>20%** of the time over a period of **1** year (in addition to any decrease in reference pools). *Exceeding Prediction* Structural integrity of the bedrock base of any significant permanent pool or controlling rockbar cannot be restored, ie pool water level within the swamp after CMAs continues to be **>20%** lower than baseline for **>20%** of the time over a period of **1** year.	a) upfront mine planning b) subsidence monitoring c) surface water monitoring d) groundwater monitoring e) grouting of controlling of controlling rockbars and bedrock base and/or use of other remediation techniques f) CMAs g) reporting h) investigation and review i) update future predictions	Offset required **immediately**, if no remediation considered practicable. Offset required **2 years** following remediation, if it is ineffective. This period can be extended to **5 years**, with the agreement of the Secretary.	
Minor changes in the ecosystem functionality of the swamps	Falls in surface or near-surface groundwater levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*Level 1:* Groundwater level lower than baseline level at any monitoring site within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at any monitoring site (measured as average mm/day during the recession curve). *Level 2:* Groundwater level lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at a **50%** of monitoring sites (within 400m of mining) within the swamp.	a) upfront mine planning b) groundwater monitoring c) implementation of swamp research program d) weeding e) fire management f) reporting g) update future predictions		Triggers for groundwater decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars

		Level 3: Groundwater level lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **>80%** of monitoring sites (within 400 m of mining) within the swamp.			
Minor changes in the ecosystem functionality of the swamps	Falls in soil moisture levels in swamps *NB. Not linked specifically to a PM and would not be considered a breach if predictions were exceeded.*	*Level 1:* Soil moisture level lower than baseline level at **any** monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps). *Level 2:* Soil moisture level lower than baseline level at **50%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps). *Level 3:* Soil moisture level lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps).	a) upfront mine planning b) soil moisture monitoring c) water spreading d) weeding e) fire management f) reporting g) update future predictions		Triggers of soil moisture decline result in increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars

Table 23: Dendrobium Area 3B Watercourse TARP.

Monitoring	Trigger	Action
OBSERVATIONAL, PHOTO POINT AND WATER MONITORING		
Native Dog, Wongawilli and Donalds Castle Creeks, WC21, WC15, LA4, DC13, LA5, ND1, WC6, WC7, WC8, WC9, WC12, WC16 and WC18 General observation of streams in active mining areas when longwall is within 400m	***Level 1 **** • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Observable increase in iron staining within the mining area	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
•Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences • Waterfall WC-WF54 – negligible environmental consequences	***Level 2 **** • Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in observable loss of surface water or erosion • Crack or fracture between 10 and 50m length • Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • Observable increase in iron staining within the mining area continues to outside the mining area i.e. 400m from the longwall	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback) •
	Level 3 * • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention • Gas release results in vegetation dieback, mortality or loss of aquatic habitat • Observable increase in iron staining within the mining area continues more than 600m from the longwall •	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success

Monitoring	Trigger	Action
		• Review relevant TARP and Management Plan in consultation with key stakeholders
	Exceeding Prediction • Structural integrity of the bedrock base of any significant pool or controlling rockbar cannot be restored i.e. pool water level within the pool after CMAs continues to be lower than baseline period • Gas release results in vegetation dieback that does not revegetate • Gas release results in mortality of threatened species or ongoing loss of aquatic habitat • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at Wongawilli Creek downstream monitoring site WONGAWILLI CK (FR6) • Iron staining and associated increases in dissolved iron resulting from the mining is observed in water at the Donalds Castle Creek downstream monitoring site Donalds Castle Ck (FR6) • Rock fall at WC-WF54 or its overhang • Impacts on the structural integrity of WC-WF54, its overhang or its pool	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
•WATER QUALITY		
Wongawilli Creek Wongawilli Ck (FR6) Baseline means: • pH 5.98 • EC 98.8 uS/cm • DO 89.5% •Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences	***Level 1*** * • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)

Monitoring	Trigger	Action
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two conecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.45 – EC 154.1 uS/cm – DO 50.5%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Donalds Castle Creek Donalds Castle Ck (FR6) Baseline means: • pH 5.41 • EC 116.0 uS/cm • DO 85.6%	***Level 1 **** • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
•Relevant Performance Measure(s): • Donalds Castle Creek - minor environmental consequences	***Level 2 **** • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback) •

Monitoring	Trigger	Action
	– EC 185.8 uS/cm – DO 40.1%	
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to stakeholder feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two conecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 3.60 – EC 185.8 uS/cm – DO 40.1%	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
Lake Avon Lake Avon tributary (LA4_S1) Baseline means: • pH 5.38 • EC 90.8 uS/cm • DO 89.9%	***Level 1*** * • One exceedance of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR

Monitoring	Trigger	Action
(24 months of baseline data available - to be updated with additional baseline data) •Relevant Performance Measure(s): • Lake Avon - negligible reduction in the quality of surface water inflows to Lake Avon	***Level 2*** * • Two exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback) •
	Level 3 * • Three exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5%	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Collect laboratory samples and analyse for: – pH, EC, major cations, major anions, Total Fe, Mn & Al – Filterable suite of metals • Develop site CMA (subject to stakeholder feedback). This may include: – Limestone emplacement to raise pH where it is appropriate to do so – Grouting of fractures in rockbar and bedrock base of any significant pool where flow diversion results in pool water level lower than baseline period • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Mining results in two conecutive exceedances of the ±3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean of the Lake Avon inflows during the monitoring period: – pH 4.90 – EC 129.8 uS/cm – DO 69.5% –	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent

Monitoring	Trigger	Action
•POOL WATER LEVEL		
Mapped pools in the mining area: • Wongawilli Creek • Donalds Castle Creek • • •Relevant Performance Measure(s): • Wongawilli Creek - minor environmental consequences • Donalds Castle Creek - minor environmental consequences •	***Level 1*** * • Fracturing not resulting in diversion of flow	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Fracturing resulting in diversion of flow	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
	Exceeding Prediction • Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent
•Waterfall WC-WF54 •Relevant Performance Measure(s): • Waterfall WC-WF54 – negligible environmental consequences	***Exceeding Prediction*** • Fracturing in Wongawilli Creek within 30m of the waterfall which results in observable flow diversion • Fracturing in Wongawilli Creek which results in observable flow diversion from the lip of the waterfall	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent

Monitoring	Trigger	Action
MODELLED PERIODS OF RECESSIONAL, BASEFLOW AND SMALL STORM UNIT HYDROGRAPH PERIODS		
Subcatchments of Wongawilli and Donalds Castle Creeks and Lake Avon tributaries **	***Level 1 **** • Change 6-12% less than average annual precipitation ***	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Change 12-18% less than average annual precipitation ***	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Change >18% less than average annual precipitation ***	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success • Review relevant TARP and Management Plan in consultation with key stakeholders
Inflows to Lake Avon and Cordeaux River ** •Relevant Performance Measure(s): • Lake Avon - negligible reduction in the quantity of surface water inflows to Lake Avon • Cordeaux River - negligible reduction in the quantity of surface water flows from Wongawilli Creek to Cordeaux River	***Exceeding Prediction*** • Measured surface water flow reduction in Wongawilli Creek at its confluence with Cordeaux River that is greater than predicted by the groundwater model (to the satisfaction of the Director General - Condition 13 of the SMP) that cannot be attributed to natural variation • Surface water flow reduction into Lake Avon is greater than predicted by the groundwater model (to the satisfaction of the Director General - Condition 13 of the SMP) that cannot be attributed to natural variation	• *Actions as stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide residual environmental offset for any mining impact where CMAs are unsuccessful as required by Condition 14 Schedule 3 of the Development Consent

Monitoring	Trigger	Action
AQUATIC ECOLOGY		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 8 sites • Donalds Castle Creek catchment – 1 site	***Level 1 **** • Reduction in aquatic habitat for 1 year •	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 * • Reduction in aquatic habitat for 2 years following the active subsidence period	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success
TERRESTRIAL FAUNA – THREATENED FROG SPECIES		
Pool water level, interconnectivity between pools and loss of connectivity, noticeable alteration of habitat • Wongawilli Creek catchment – 2 sites • Donalds Castle Creek catchment – 2 sites • Lake Avon tributary – 1 site	***Level 1 **** • Reduction in habitat for 1 year •	• Continue monitoring program • Submit an Impact Report to OEH, DoPE, T&I, Water NSW and other relevant resource managers • Report in the End of Panel Report • Summarise actions and monitoring in AEMR
	Level 2 *	• *Actions as stated for Level 1* • Review monitoring frequency

Monitoring	Trigger	Action
• Native Dog tributary – 1 site	• Reduction in habitat for 2 years following the active subsidence period	• Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved (subject to stakeholder feedback)
	Level 3 * • Reduction in habitat for > 2 years or complete loss of habitat following the active subsidence period	• *Actions as stated for Level 2* • Site visit with OEH, DoPE, T&I, Water NSW and other resource manager/s (if requested) • Implement additional monitoring or increase frequency if required • Review relevant TARP and Management Plan in consultation with key stakeholders • Develop site CMA (subject to stakeholder feedback). This may include: grouting of rockbar and bedrock base of any significant pool where it is appropriate to do so in consultation with OEH, DoPE, T&I, Water NSW and other stakeholders • Completion of works following approvals and at a time agreed between BHPBIC, DoPE, T&I and Water NSW (i.e. may be after mining induced movements and impacts are complete), including monitoring and reporting on success