INDEPENDENT ADVISORY PANEL FOR UNDERGROUND MINING

ADVICE RE:

DENDROBIUM COAL MINE

LONGWALL 19

SUBSIDENCE MANAGEMENT PLAN

February 2021

EXECUTIVE SUMMARY

Overview

The Executive Director of Energy, Industry and Compliance, NSW Department of Planning, Industry and Environment requested the Independent Advisory Panel for Underground Mining (the Panel) to provide advice in relation to the Subsidence Management Plan (SMP) for Longwall 19 (LW19) in Area 3A at the Dendrobium Coal Mine. Specifically:

> *The Department requests advice from the Panel as to the:*
>
> - *likely impacts on Swamp 15a and whether the proposed longwall panel design would meet the performance measure required under Schedule 3 Condition 5, and performance indicators outline in the SMP – Area 3A Swamp Impact Monitoring, Management and Contingency Plan;*
> - *feasibility and potential environmental benefits of the option of mining west to east with an adaptive management approach to manage impacts on Swamp 15a; and*
> - *appropriateness of the proposed 175 m setback distance from Wongawilli Creek in relation to the performance measure of "minor impacts" as required by Schedule 3 Condition 2 of the consent and proposed performance indicators outlined in the SMP – Area 3A Watercourse Impact Monitoring, Management and Contingency Plan.*
>
> *The Panel should also feel free to provide any other advice it considers would assist the Department in reviewing the Extraction Plan.*

LW19 is the fourth longwall panel to be extracted in Area 3A, the previous three being LW6 to LW8. All these longwalls induce non-conventional subsidence effects which include valley closure. There is a local history of predicted valley closure not correlating with measured valley closure. This has led to the very unusual situation whereby subsidence impacts are predicted on the basis of predicted valley closure (analogous to predicted rainfall) and not on actual valley closure (analogous to actual rainfall).

This advice is focused on adaptive management and the key features of Swamp 15a, Wongawilli Creek, Sandy Creek Waterfall and Sandy Creek. Some aspects of groundwater are also relevant to assisting the Department in reviewing the Extraction Plan.

The SMP for LW19 is based on mining retreating from east to west, in the opposite direction to previous longwalls in Area 3A and, therefore, away from Sandy Creek Waterfall for which stringent performance measures apply. South32 has provided compelling reasons why it is too late to change this mining direction. Among other things, this change in mining direction presents an elevated risk of having to stop mining very soon after the commencement of LW19 if magnitudes and or rates of valley closure that have previously been considered to jeopardise the stability of Sandy Creek Waterfall are induced at the waterfall.

Conclusions

- The options for adaptive management for the Sandy Creek Waterfall, Wongawilli Creek and Swamp 15a are restricted basically to the selection of appropriate setback distances.
- Because of the potential to increment existing valley closure, the proposed 175 m setback from Wongawilli Creek does not provide a high level of confidence that impacts on Wongawilli Creek will be contained to "minor impacts" In determining an appropriate setback, the potential for further reducing impact likelihood by small margins (up to another 3 %) needs to be judged against the required reduction in longwall length to deliver this reduced risk.
- As a matter of due diligence, the Technical Committee formed under the Sandy Creek Waterfall Management Plan should be engaged in determining the setback distance of LW19 from the waterfall and the appropriateness and robustness of the monitoring plan and associated trigger levels and responses.
- LW19 would need to be setback at least 60 m from the edges of Swamp 15a in order to satisfy Condition 5 regarding change in ecosystem functionality of this swamp.

Recommendations

1. The Department should embrace the proposal of South32, dated 15/1/2021, that the Sandy Creek Waterfall Management Plan be re-established and applied to the extraction of LW19.
2. The starting location of LW19 and the proposed monitoring plan and its associated triggers and responses should take into account the latest field survey results and be endorsed by the Technical Committee previously constituted for the Sandy Creek Waterfall.
3. As a minimum requirement for meeting Condition 5 regarding no change in ecosystem functionality of Swamp 15a, LW19 should be set back at least 60 m from all edges of Swamp 15a.
4. To avoid inadvertently approving a mine layout that could result in a breach of the Consent Conditions relating to Swamp 15a, the Department's assessment should include careful consideration of the environmental impacts on that portion of Swamp 15a which lies at the headwaters of SC10B, over the maingate chain pillars of LW19.
5. An additional chemistry site should be added adjacent to the proposed water level site behind the Swamp 15a controlling rockbar.

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1.0 SCOPE OF WORKS

On 3 December 2020, the Executive Director of Energy, Industry and Compliance, NSW Department of Planning, Industry and Environment (Mr Mike Young) requested the Independent Advisory Panel for Underground Mining (the Panel) to provide advice in relation to the Subsidence Management Plan (SMP) for Longwall 19 (LW19) in Area 3B at the Dendrobium Coal Mine. Specifically:

Swamp Impact Management

Condition 5, Schedule 3. The Applicant must ensure that subsidence does not cause erosion of the surface or changes in ecosystem functionality of Swamp 15a and that the structural integrity of its controlling rockbar is maintained or restored, to the satisfaction of the Secretary.

As such, the Department requests the Panel provide advice on the following:

- *likely impacts on Swamp 15a and whether the proposed longwall panel design would meet the performance measure required under Schedule 3 Condition 5, and performance indicators outline in the SMP – Area 3A Swamp Impact Monitoring, Management and Contingency Plan;*

- *feasibility and potential environmental benefits of the option of mining west to east with an adaptive management approach to manage impacts on Swamp 15a; and*

- *appropriateness of the proposed 175 m setback distance from Wongawilli Creek in relation to the performance measure of "minor impacts" as required by Schedule 3 Condition 2 of the consent and proposed performance indicators outlined in the SMP – Area 3A Watercourse Impact Monitoring, Management and Contingency Plan.*

The Panel should also feel free to provide any other advice it considers would assist the Department in reviewing the Extraction Plan.

The Panel considers that the potential impact of LW19 on the stability of Sandy Creek Waterfall is another matter that warrants careful consideration. Schedule 3 – Condition 1 of the Development Consent Conditions requires that:

> *The Applicant must ensure that, as a result of the development:*
>
> - *no rock fall occurs at Sandy Creek Waterfall or from its overhang;*
>
> - *the structural integrity of the waterfall, its overhang and its pool are not impacted;*
>
> - *cracking in Sandy Creek within 30 m of the waterfall is of negligible environmental and hydrological consequences, and*
>
> - *negligible diversion of water occurs from the lip of the waterfall to the satisfaction of the Secretary.*

During the course of preparing advice on the above matters, other issues relating to the long - term monitoring and assessment of groundwater impacts from the wider mine development have been noted. These are included in Appendix A for consideration by the Department.

The Chair of the Panel (Em. Professor Jim Galvin) nominated the following members of the Panel to prepare the advice:

- Em. Professor Jim Galvin – Chair – Subsidence and Mining
- Professor Neil McIntyre – Surface Water
- Dr Ann Young – Swamps and Ecology
- Em. Professor Rae Mackay – Groundwater

2.0 METHOD OF OPERATION

On 3 December 2020, COVID19 constraints prevented the Panel from meeting in person and from undertaking a site inspection, with the Panel convening by videoconference. It sourced additional reports from the Department and submitted two sets of questions for the Proponent that were addressed by way of written responses, an additional report and additional documentation.

A wide range of documents was reviewed by the Panel in preparing this review, the principal ones being:

1. Longwall 19 Area 3A - Subsidence Management Plan, March 2020
2. Longwall 19 Area 3A - Subsidence Management Plan, August 2020 - Attachments A to H
3. Agency advice on LW19:
    - Environment Energy and Science, May 2020
    - Dams Safety NSW, Apr 2020
    - Mining. Exploration and Geoscience, May 2020
    - Resources Regulator, May 2020
    - Subsidence Advisory, May 2020
    - WaterNSW, May 2020
    - DPIE Water Group / Natural Resources Access Regulator, October 2020
4. South32 response to Agency Advice, July and November 2020
5. Agency advice on South32 response, September and October 2020
6. Additional background information
    - Development consent conditions
    - SMP LW17 approval conditions
    - End of Panel Report LW15 (Summary Report)
    - Annual Review 2020
7. Responses to Panel questions dated 22/12/2020 directed to South32 through DPIE, received on 15/01/2021; and a Panel query dated 12/01/2021 directed to South32 through DPIE, received on 14/01/2021
8. Additional reports supplied by the Department or Proponent:
    a. 2019 – *Geographic review of mining effects on Upland Swamps at Dendrobium Mine*. Watershed HydroGeo Pty Ltd 2019 (Watershed HydroGeo, 2019).
9. Additional documentation supplied by the Department or Proponent:

b. 2021 – Area 3A Sandy Creek Waterfall Management Plan Version 4. South 32 (South32, 2021).

3.0 ADAPTIVE MANAGEMENT

Adaptive management is a procedure for implementing management while learning about which management actions are most effective at achieving specified objectives.[1] Generally, adaptive management is applied in longwall mining to manage subsidence induced environmental impacts to designated levels through either or both:

- Monitoring the development of subsidence effects and impacts as a longwall panel is being extracted and ceasing to mine when the absolute magnitudes of these and/or the rate of change (velocity or acceleration) of their development approach threshold values.

- On the basis of past experience, designing a longwall panel layout to be set back (or standoff) from features a sufficient distance to avoid exceeding designated tolerable subsidence effects and/or impacts.

Limitations are associated with adaptive management when:

- Predictions of subsidence effects do not correlate well with measured subsidence effects. This applies in the case of valley closure.

- Mining direction is not amenable for practicing adaptive management.

- There is a lack of knowledge of the level of subsidence effects that a feature can sustain without being impacted. This applies to waterfalls.

- Subsidence impacts do not fully develop until a considerable time after mining. This is likely to apply, for example, to swamps.

Aspects of all these limitations are associated with the extraction of LW19, which lies in Area 3A.

LW19 is the fourth longwall panel to be extracted in Area 3A, the previous three being LW6 to LW8. All these longwalls induce non-conventional subsidence effects which include valley closure. There is a local history of predicted valley closure not correlating with measured valley closure. This has led to the very unusual situation whereby subsidence impacts are predicted on the basis of predicted valley closure (analogous to predicted rainfall) and not on actual valley closure (analogous to actual rainfall). Therefore, this approach severely restricts the use of real time monitoring of cumulative subsidence effects for decision making. In the limited number of cases where real time monitoring has been adopted for the purpose of avoiding valley closure-induced impacts, it has been applied when mining towards the feature to be protected

[1] https://www.environment.nsw.gov.au/research/adaptive-management.htm

and almost exclusively on stopping mining either at the onset of valley closure or when there is an increase in the rate of valley closure.

Real time monitoring was employed during the extraction of LW6 to LW8 to determine the finishing lines of these longwalls as they approached Sandy Creek Waterfall from the west. In the case of LW19, mining is planned to retreat in the opposite direction, from east to west and away from Sandy Creek Waterfall and South32 has provided compelling reasons why it is too late to change this mining direction. Hence, this change in mining direction presents an elevated risk of having to stop mining soon after the commencement of LW19 if magnitudes and or rates of valley closure that have previously been considered to jeopardise the stability of Sandy Creek Waterfall are induced as the longwall starts to retreat away from the waterfall.

Against this background, the options for adaptive management for the Sandy Creek Waterfall, Wongawilli Creek and Swamps 15a are basically restricted to the selection of appropriate setback distances. Relevant points of reference in this regard are:

- Surface fracturing without adverse impacts on surface water flows have been observed up to approximately 400 m outside of previously extracted longwalls in the Southern Coalfield (MSEC, 2019) and up to 300 m from completed longwalls in Area 3B (MSEC, 2020).

- Type 3 fracturing, defined as resulting in pool water levels dropping more than expected after considering the rainfall and surface and groundwater flow conditions, has been observed at distances up to 280 m from the previously extracted longwalls at Dendrobium Mine (MSEC, 2019).

- Rapid drawdown to levels lower than pre-mining levels and increased rate of recession (drainage) in the water tables in sediments of Upland Swamps have not been observed in swamps further than 60 m from a longwall panel (Watershed HydroGeo, 2019).

- Debate and uncertainty exist about subsidence impacts on swamp ecology in the medium to long-term

4.0 SUBSIDENCE ASSESSMENT

4.1. ASPECTS RELATING TO THE PREDICTION OF SUBSIDENCE EFFECTS AND IMPACTS

The empirically based Incremental Profile Method (IPM) utilised by Mine Subsidence Engineering Consultants (MSEC, 2020) for predicting conventional subsidence effects is well established and has been utilised extensively at Dendrobium Mine. It is supported by calibration to extensive site-specific performance data and supplemented with numerical modelling. Predictions are at least as good as any alternative method and limitations are transparently identified. The predictions of non-conventional subsidence effects, principally valley closure and upsidence, are derived from empirical models also developed by MSEC that are based on extensive field performance data sourced from the Southern Coalfield.

Because of the site-specific nature of subsidence, the prediction of subsidence effects is not a precise science and a degree of uncertainty is associated with the outcomes of any prediction technique. Experience at Dendrobium Mine and Metropolitan Mine has demonstrated that variability associated with the IPM and the prediction of valley closure using the MSEC model, with few exceptions, can be managed through approval conditions that require the Proponent to monitor predicted versus measured subsidence, regularly update subsidence predictions, employ adaptive management, and undertake mitigation and remediation.

The height of connective fracturing is an important consideration when assessing subsidence impacts and consequences for surface features arising from subsidence effects, and one around which there has been much debate in recent years. There now appears to be general consensus that the height of connective fracturing will extend to the surface over LW19. This is reflected in Figure 12 in the Department's assessment of the Dendrobium Extension Project (DPIE, 2020), the revised Sandy Creek Waterfall Management Plan (South32, 2021) and the more recent reviews by Hebblewhite (2020a) and (2020b) of the height of depressurisation over Area 3B, undertaken in accordance with Schedule 3, Condition 19(c) of the Area 3B SMP Approval which concluded that:

- *……. it is reasonable to conclude that the height of depressurisation is close to, or equal to the total depth of overburden above the working coal seam, i.e. extending to the surface in each instance.*

- *In spite of the reduced longwall panel width in Area 3A (LW6 and LW7), the height of depressurisation has still effectively extended to the surface, albeit with a reduced strata fracture density above the mined panels. It is likely that a more significant panel width reduction and or mining height reduction would be necessary to cause a significant reduction in height of depressurisation in this particular mining region.*

4.2. WONGAWILLI CREEK

The thalweg (i.e. base or centreline) of Wongawilli Creek is located 175 m south-west of the finishing end of LW19, at its closest point to the proposed longwall. The maximum predicted total subsidence effects for Wongawilli Creek, due to the mining in Areas 3A, 3B and 3C, are less than 20 mm vertical subsidence, 150 mm upsidence and 210 mm closure. The maximum predicted incremental movements along the creek, due to the mining of the proposed LW19 only, are less than 20 mm vertical subsidence, 50 mm upsidence and 70 mm valley closure.

It is predicted that fracturing could occur along the section of Wongawilli Creek that is located within a distance of approximately 400 m from the proposed longwall. It is reported in MSEC (2019) and MSEC (2020) that the extraction of LW6 to LW14 has resulted in one Type 3 impact (DA3B_LW9_017) (i.e. fracturing associated with surface water flow diversions) along Wongawilli Creek. The rate of Type 3 impacts has been assessed as low, affecting less than 10 % of rockbars and other stream controlling features located within the Study Area.

The Panel notes that the Subsidence Assessment has also identified riffle zones along Wongawilli Creek and assigned predicted valley closure values to these. The fracture identified (DA3B_LW9_017) occurred across a riffle (LWs 14-19 Application 2016, Attachment O Fig 2-58).

Due to the poor correlation between predicted and measured valley closure effects and impacts, adaptive management based on real time monitoring of subsidence effects is not a strong control for determining how close LW19 can approach Wongawilli Creek without inducing fracturing of the creek. Rather, a stronger control is to increase the stand-off distance on the basis of the rock bar model in order to reduce the likelihood of mining induced fracturing. This pre-mining control is available irrespective of whether LW19 is extracted from east to west or west to east.

It is proposed in the SMP to setback LW19 from Wongawilli Creek by 175 m. Considerations relating to whether or not this distance provides an appropriate level of confidence that the performance measure of "minor impacts" will be met are:

- IEPMC (2019) concluded that "a Type 3 impact should constitute an exceedance of a performance measure of minor environmental consequence" on the basis of the correlation between the established definition of Type 3 and the relevant performance indicators. It also concluded that there is no basis for assuming that a low rate of predicted Type 3 impacts (e.g. < 10%) meets the condition of "minor impacts". IEPMC (2019) also noted the importance of considering potential fracturing of bedrock under pools, riffles and other controls on pool levels.

- The total length of Wongawilli Creek within 400 m of previously extracted longwalls is 2 km (MSEC, 2020). Approximately 1750 m of that 2 km is predicted to have an increased likelihood of Type 3 impacts due to LW19 (i.e. a predicted increase in valley closure that increases the likelihood, from MSEC (2020), Figure C.03).

- The previous Type 3 impact fracture observed in Wongawilli Creek was 200 m from LW6 (MSEC, 2020). However, this fracture was only detected as an impact when LW9 approached to approximately 380 m from the Creek (South32, 2014).

- The surface features map in Appendix 2 of Area 3A Watercourse Impact Monitoring, Management and Contingency Plan (South32, 2020b) shows near-continuous pools with intermittent riffles and one major rockbar opposite LW8. The predicted total valley closure of approximately 180 mm at this rockbar corresponds to a predicted 5 % rate of Type 3 impacts at this location, with 4% of that being accounted for by previous longwalls. The predicted rate of Type 3 impacts to the bedrock under the pools at the point of maximum valley closure is 7 %, with around 4 % of that accounted for by previous longwalls, if the rockbar model is assumed applicable to pools. There is also potential for Type 3 impacts at the numerous riffles.

- There are concerns that non-minor impacts have already occurred at Wongawilli Creek (IEPMC (2019), WaterNSW (2020)). This follows reports of Level 2 and Level 3 impacts and flow loss due to mining (e.g. South32 (2018) and (2020a)). These may be considered reasonable concerns, depending on interpretations of "minor impacts" and associated trigger levels.

- The potential cumulative impacts of individual impacts to the hydrology and ecology of the Special Areas is not well understood and has been raised as a general concern in previous reports (see IEPMC (2019)). Potentially, the greatest hydrological and ecological cumulative impacts arise from regional groundwater drawdown and loss of baseflow, which are unlikely to be effectively addressed even by a 400 m setback of LW19 from Wongawilli Creek.

It is concluded that, while the best available model (the rockbar model) predicts that it is unlikely that there will be greater than minor fracturing of Wongawilli Creek and associated impacts due to the proposed LW19, the limitations of this model are considerable in this context, and other relevant evidence is that a previous fracture has occurred within 400 m from the nearest longwall. A high level of caution regarding Type 3 impacts is warranted due to the reasonable concerns that non-minor impacts may have already occurred. For this reason, the Panel does not consider that the proposed setback of 175 m is appropriately cautious. Due to the impacts of existing longwalls, the scope for reducing the maximum likelihood of Type 3 impacts is approximately 3% (from 7 % to 4 %). In determining an appropriate setback, the loss of longwall length against the limited potential reduction in likelihood of Type 3 impacts needs to be judged.

4.3. SANDY CREEK

Sandy Creek is located 750 m east of the commencing end of LW19, at its closest point to the proposed longwall. The Subsidence Assessment states that at this distance, the creek is not predicted to experience measurable conventional or valley related effects due to the mining of LW19 and that it is unlikely, therefore, that Sandy Creek would experience adverse impacts due to the mining of the proposed longwall. The Panel concurs.

4.4. SANDY CREEK WATERFALL

The impact of longwall mining at Sandy Creek Waterfall was studied in detail during the extraction of LW6 to LW8 and used to inform the finishing locations for these longwall panels. The study involved an extensive instrumentation and monitoring program overseen by an external peer reviewer and a Technical Committee and supported by a robust Management Plan, as described by Walsh, Hebblewhite, et al. (2014) and Walsh, Mills, et al. (2014). The longwall panels were extracted from west to east, thus providing the opportunity to adopt adaptive management in controlling how close the longwall panels approached the waterfall.

A challenge faced by the project was deciding how much valley closure the waterfall could tolerate without exceeding the performance measures specific in the Approval Conditions. Walsh, Mills, et al. (2014) report that during the lead up to the first precautionary stoppages in LW6, it became clear that the conventional three-dimensional survey lines previously installed and surveyed at the site were not going to be sensitive enough to detect the very low level deformations that stress cells were indicating. In response to this realisation, a network of eight high resolution one-dimensional survey monitoring points was established across Sandy Creek

Waterfall and the incised valley immediately downstream. Figure 1 shows the location of these lines and the movements that were observed.[2] Table 1 summarises incremental and cumulative valley closures for survey line H1.

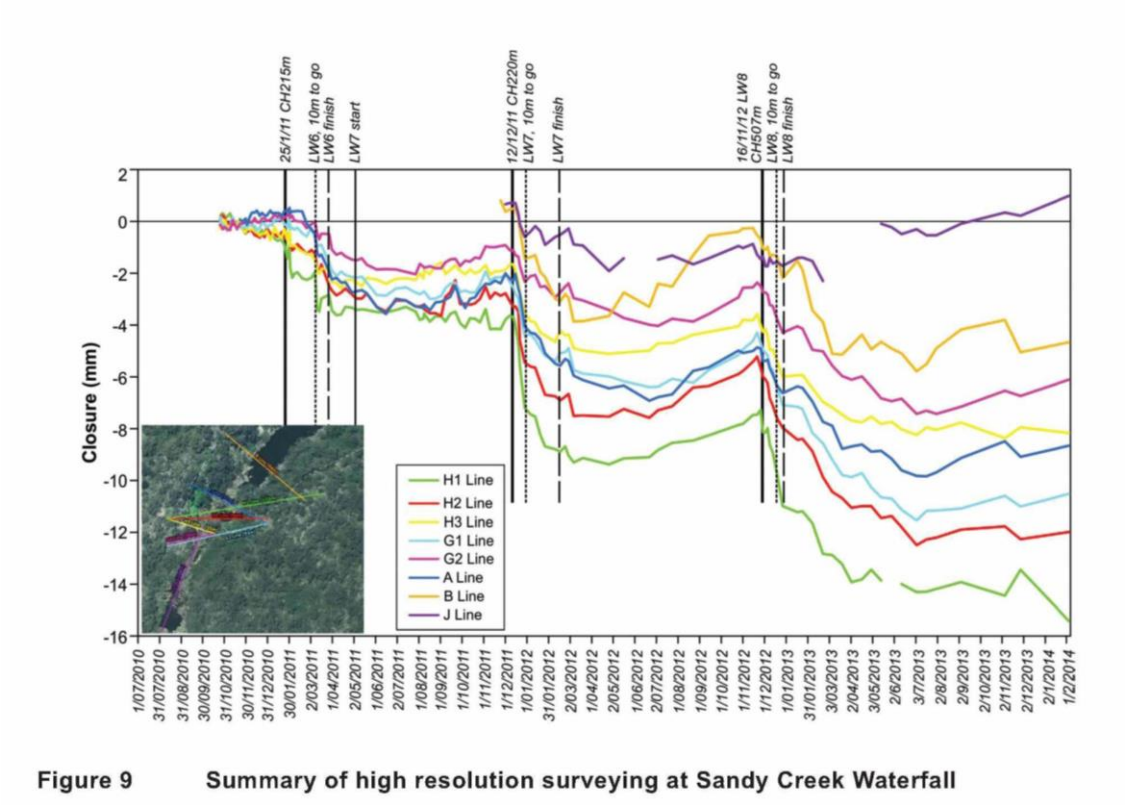

Figure 1: High resolution closure line survey data from monitoring of Sandy Creek waterfall associated with extraction of LW7 and LW8 in Area 3A (Figure 9 in Walsh, Mills, et al. (2014))

Table 1: Measured (LW6 to LW8) and predicted (LW19) incremental closure at Sandy Creek Waterfall (adapted from Table 5.6 of the Subsidence Assessment for LW19).

Source	Longwall	Distance from Centreline of Sandy Creek Waterfall (m)	Measured Incremental Closure (mm)
SCW HRS H1-Line	LW6	390	4
	LW7	430	5
	LW8	500	5
Subsidence Assessment, Attachment C	LW19	900	<2
Response to Panel's Queries	LW19	900	<5

[2] The stated precision of the new high resolution closure lines was ±1.0mm at two standard deviations (95% confidence interval). In practice the observed survey data proved to be substantially more precise, with results indicating long term precisions in the order of ±0.4mm at two standard deviations.

LW19 SMP Attachment C advises that:

> *Sandy Creek Waterfall is located 900 m north-east of the commencing end of LW19. The total closure measured at the waterfall, due to the previous mining of LW6 to LW8 in Area 3A, was 14 mm. The predicted incremental closure for Sandy Creek Waterfall, due to the mining of the proposed LW19, is less than 2 mm, which is in the order of survey tolerance and environmental effects.*
>
> *It is considered unlikely, therefore, that Sandy Creek Waterfall would experience adverse impacts due to mining of LW19.*
>
> *It is recommended that the closure across the waterfall is measured monthly during the first 1000 m of mining of LW19. A Trigger Action Response Plan (TARP) should also be established based on these measured movements.*

The approach proposed in the SMP to managing mining induced subsidence effects on Sandy Creek Waterfall prompted a number of questions from the Panel to South32 (IAPUM, 2020). In responding to these, South32 has advised that:

- The H2 Line was surveyed on 8 January 2021 and an additional closure since the previous survey on 18 September 2014 of approximately 4 mm was measured.

- The predicted closure due to the extraction of LW19 has been revised and increased to less than 5 mm.

- *It is extremely difficult to quantity the additional closure capacity of the waterfall as it is dependent on many factors that themselves are difficult to fully quantify….Even if these factors could be quantified, it would still be difficult to quantify the extent to which these factors influence the stability of the waterfall in its natural state or when subjected to mine subsidence effects*.

- For the purpose of managing LW19, South32 has reactivated the Sandy Creek Water Management Plan (developed for the extraction of LW6 to LW8). This includes updating it from the 14/9/2012 version and re-establishing the Sandy Creek Waterfall Technical Group.

- Weekly surveys (rather than monthly as originally proposed) will be carried out for the first 600 m of mining.

- Some of the monitoring instrumentation previously installed at Sandy Creek Waterfall is no longer functional.

- The Technical Committee will review monitoring data during the mining of LW19 and will advise the Steering Committee of the interpretation of the monitoring results with respect to the status of the waterfall. The Steering Committee will review and assess information provided by the Technical Committee, assess the acceptability of the ongoing level of risk to the waterfall and implement management actions as required.

Against this background, the Panel advises that it does not have the appropriate knowledge to be able to assess the reasonableness of the LW19 panel layout for ensuring the ongoing protection of Sandy Creek Waterfall. This is compounded by LW19 retreating from east to west, away from the waterfall rather than towards it. Although an incremental increase in predicted closure of less than 5 mm may appear a trivial value in absolute terms, it is significant when compared with the amount of closure associated with the cessation of extraction of LW6, LW7 and LW8 (see Table 1). These issues aside, the Panel considers that as a matter of due diligence, the Technical Committee formed under the Sandy Creek Waterfall Management Plan should be engaged in determining the setback distance of LW19 from the waterfall and the appropriateness and robustness of the monitoring plan and associated trigger levels and responses.

The Panel recommends that:

1. The Department embrace the proposal of South32, dated 15/1/2021, that the Sandy Creek Waterfall Management Plan be re-established and applied to the extraction of LW19.
2. The starting location of LW19 and the proposed monitoring plan and its associated triggers and responses should take into account the latest field survey results and be endorsed by the Technical Committee previously constituted for the Sandy Creek Waterfall.

4.5. SWAMP 15A

The mining consent states:

> *Condition 5, Schedule 3. The Applicant must ensure that subsidence does not cause erosion of the surface or changes in ecosystem functionality of Swamp 15a.*

In considering the potential for impacts on the swamp, the likelihood of meeting this condition and the monitoring for changes have been addressed.

4.5.1. Ecosystem Functionality

The footprint of Swamp 15a is shown in Figure 2. A significant point of note is that a portion of Swamp 15a is located over the upper reaches of SC10B and abuts and partially overlies the footprint of LW19.[3] It has the potential to seriously impact the permissible length or width of LW19 given the Consent Conditions relating to Swamp 15a.

[3] This is shown to be the case on Figure 2 of Watershed HydroGeo (2019). Further, the Panel was advised on 14/1/21 via email from DPIE that South32 had confirmed that this swamp segment is part of Swamp 15a.

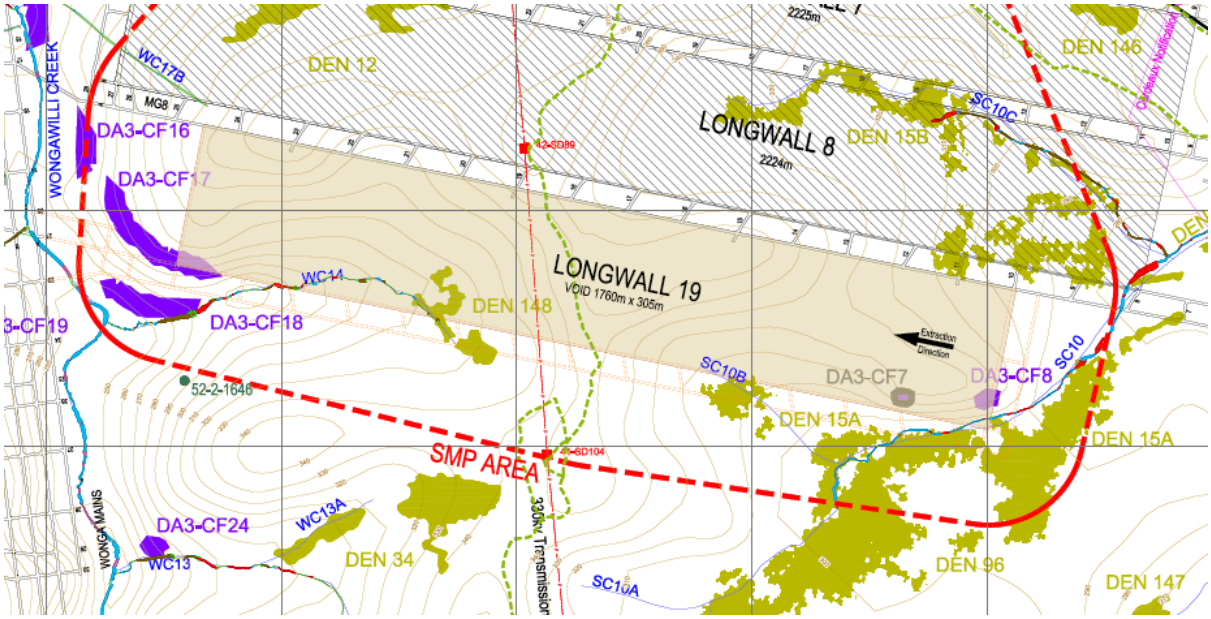

Figure 2. Extract from Drawing DEN-01-7783 from the SMP showing the location of Swamp 15a relative to LW19

The Consent Condition for Swamp 15a appears to be absolute in stipulating no change to ecosystem functionality and, as such, is different to the consent conditions for the swamps in Area 3B, which permits '*minor environmental consequences [including] negligible erosion of the swamp surface….minor changes in the ecosystem functionality of the swamp'* or '*no significant environmental consequences beyond predictions*' (Area 3B SMP Approval, Schedule 3, clause 9 Performance Measures).

With the present Consent Condition for Swamp 15a, the southern edge of LW19 needs to be offset at least 60 m from the edges of Swamp 15a. This requires either a narrowing or a reduction in the length of the longwall to substantially reduce the likelihood of a change in ecosystem functionality. Monitoring of performance would still be needed. To date, vegetation changes – swamp size; species richness, distribution, composition and diversity; vegetation sub-communities – have been used as surrogates for ecosystem functionality for approvals of mining to date in Dendrobium. The Proponent proposes to continue with this approach (South 32, 2020 - SIMMCP Table 6.1).

Section 3.9.1 of the SIMMCP states:

- *At the Agency Consultation Workshop 27 May 2013 there was discussion about the definition of 'ecosystem functionality' in relation to subsidence impact performance measures for swamps. The term 'ecosystem functionality' is included in Table 1 of Condition 13 of the SMP Approval. The term is not included in the definitions of the Approval.*

- *At the workshop it was stated that the BCD (Biodiversity Conservation Division of DPIE, now EES) disagrees with the definition of ecosystem function included in the Plans as they consider it is too simplistic and does not cover shallow groundwater levels. DPIE advised the intent of the performance measure relating to ecosystem*

functionality for swamps was more general in intent; basically, the swamp will remain a swamp.

- *The outcome of the workshop was that IMC is to propose a definition in the next version of the SIMMCP which was approved in the 3C SIMMCP. Therefore, ecosystem functionality of swamps is to be measured via the following attributes: the sizes of the groundwater dependent communities contributing to the swamps. Specifically, any changes in the proportion of Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex within the monitored swamps.*

The problem with adopting changes in proportion of species as a measure of impact is the timescale over which such changes occur. The damage to a swamp has typically occurred before sufficient evidence can be collected to show the impact. Identifying with confidence an exceedance based on observed vegetation changes cannot generally be expected within less than decadal time spans.

While changes in vegetation communities in Swamp 15a relative to within control swamps can and should be monitored, the Panel considers that the performance indicator "proportion of Banksia Thicket, Tea-tree Thicket and Sedgeland-heath Complex within the monitored swamps" does not overcome the problems of the time-lag between subsidence impacts to the swamp and consequences to the swamp flora and thus does not provide an adequate early indicator of likely changes in ecosystem functionality.

IEPMC (2019) concluded (Section 4.4.1) that:

> *By definition, swamps are groundwater-dependent ecosystems. Therefore, a change in piezometric levels should be the primary gauge of impacts on the ecosystem. If maintenance of ecosystem functionality is to be mandated for any swamp, then piezometric variation must be used not only in TARPs but also in performance measures.*

The Panel concurs and considers that for '*a swamp to remain a swamp*', the groundwater conditions must be maintained. This view is consistent with the observation made in the SMP (Section 4.5) that "*Where there are changes to swamp hydrology that are large and persistent there is likely to be a vegetation response*". Undermining has led to rapid and persistent changes in groundwater at many swamps in the Southern Coalfield.

The Panel notes that in general usage, meanings of the term 'ecosystem functionality' reflect the biological, chemical and physical processes that occur within an ecosystem made up of plants, animals and microbes that sustain terrestrial life. The Panel does not discount the holistic nature of ecosystem functionality and the importance of potential changes not only to vegetation, sediments and groundwater but to obligate fauna, downstream habitats and microclimate. Nevertheless, it considers that measurement of groundwater variations within a BACI framework would be an efficient, timely and objective method of assessing whether ecosystem functionality at Swamp 15a is (or will be) impacted.

4.5.2. Likelihood of changes to ecosystem functionality

With the current longwall layout, the Panel considers it predictable with a high level of certainty that the proposed LW19 will result in changes in ecosystem functionality in parts of

Swamp 15a within 60 m of the longwall. This is based on the significant changes to swamp groundwater levels observed within that distance at other swamps in the Dendrobium mining area (Watershed HydroGeo, 2019). The Panel notes that 7 or 9 % of the swamp would be within 60 m of the proposed longwall (both figures are noted in SMP Section 5.3.3).

This layout would certainly fail to meet the performance measure required under Condition 5. Regarding the proposed groundwater performance indicators in Table 1.2 of the SIMMCP, the Level 1 indicator would almost certainly be surpassed if any of the monitoring points were within the 60 m threshold, while the Level 2 and 3 indicators are unlikely to be surpassed as they require increasing proportions of the monitoring points to be affected. The other indicators related to ecosystem functionality may not be surpassed on a useful time-scale for reasons covered previously.

Any changes in water quality due to impacts on Swamp 15a are unlikely to be detected by the proposed chemistry sites (Figure 3-2, South32 (2020a)). An additional chemistry site should be added adjacent to the proposed water level site behind the Swamp 15a controlling rockbar.

4.5.3. Adequacy of relying on the 60 m threshold

The Panel considers that the (Watershed HydroGeo, 2019) report (which concluded that no changes to swamp hydrology have been observed greater than 60 m horizontal distance from a longwall panel in the Dendrobium mining area) is the most relevant available evidence regarding potential hydrological impacts to Swamp 15a. This does not necessarily mean that all the impacted sites at Swamp 15a will be within 60 m of the longwall: the potential for impacts beyond 60 m is clear from the previously observed impacts in drainage lines in Areas 3A and 3B (see for example, MSEC (2020), Section 5.4.4).

The impacts on Swamps within 60 m of a longwall happen quickly and the magnitude of the hydrological change is significant in the analysis presented by Watershed Hydrogeo. Avoiding mining within 60 m of a Swamp therefore avoids this type of rapid impact but may not avoid more progressive or subtle impacts where vertical permeability changes are smaller and subsurface cracking frequency is much less than within 60 m. Slower and more subtle impacts for the Swamp areas beyond 60 m of longwalls would need to be measured over longer time frames and be measured both in terms of a change to the median groundwater or soil moisture conditions relative to reference swamps. Nevertheless, the evidence regarding the 60 m threshold allows the existence of swamp groundwater level impacts within 60 m to be predicted with high confidence.

The Panel concludes that, at the very least, LW19 would need to be setback a distance of 60 m from the edges of Swamp 15a in order to satisfy Condition 5 regarding ecosystem functionality of the swamp. Monitoring of shallow groundwater should be re-established and continued across Swamp 15a to assess long term compliance with the Condition.

The Panel recommends that:

- As a minimum requirement to meet Condition 5 regarding ecosystem functionality of Swamp 15a, LW19 should be set back at least 60 m from all edges of Swamp 15a.

- Monitoring of shallow groundwater should be re-established and continued across Swamp 15a in the medium to long term in order to be able to assess long term compliance with the Condition 5.

4.5.4. Erosion

Condition 5, Schedule 3. The Applicant must ensure that subsidence does not cause erosion of the surface .. of Swamp 15a …

The expected reduction in soil moisture due to the proposed LW19 could increase the possibility that Condition 5 will not be achieved in relation to "erosion of the surface" and potentially reduce resilience of swamps to fire and subsequent gullying (IEPMC (2019), Section 4.2.2). Nevertheless, it is noted that erosion of the surface of the swamps as a result of mining has not yet been observed in Area 3B (South32 (2020a), Section 4.4), and erosion is unlikely to occur or be observed until well after mining has stopped. The Panel does not see a useful measure of erosion that can be used to assess compliance within a short time frame and thus suggests that monitoring of erosion and soil moisture as proposed in the SMP be carried out to ensure long-term compliance.

4.5.5. Structural integrity of the controlling rockbar

Condition 5, Schedule 3. The Applicant must ensure that .. the structural integrity of its [Swamp 15a] controlling rockbar is maintained or restored, to the satisfaction of the Secretary.

Rockbar SC10-RB15A, approximately 160 m east of the eastern end of LW15, controls the surface flow out of Swamp 15a. The likelihood of Type 3 impacts at SC10-RB15A due to the mining of the proposed LW19 is estimated to be of the order of 13 % (MSEC (2020), Section 5.10.4). The subsidence assessment (MSEC (2020), Section 5.4.5) concluded "*Based on the previous experience of mining beneath a similar sized waterfall at Elouera Colliery and near to cliffs elsewhere in the Southern Coalfield, the likelihood of an instability at the waterfall SC10-WF15 is considered to be very low. It is possible, however, that isolated rockfalls could occur at or near the waterfall due to mining, due to natural processes, or both*".

Noting the difficulty of making accurate predictions, the Panel agrees with these assessments. The Panel also considers that cracking or a rockfall from rockbar SC10-RB15A could constitute a loss of 'structural integrity' and is concerned that the recommended remediation strategy of grouting may not be practicable or suitable to restore that integrity.

The Panel thus concludes that there is low to moderate likelihood of Condition 5 not being met in regard to the Swamp 15a controlling rockbar SC10-RB15A.

4.6. OTHER

The Panel concurs that impacts on Cordeaux and Avon Reservoirs and associated dam walls are likely to be very small and unlikely to be measurable.

5.0 CONCLUSIONS

Adaptive Management

- The change in mining direction presents an elevated risk of having to stop mining very soon after the commencement of LW19 if magnitudes and or rates of valley closure that have previously been considered to jeopardise the stability of Sandy Creek Waterfall are induced as the longwall starts to retreat away from the waterfall.
- Adaptive management options for the Sandy Creek Waterfall, Wongawilli Creek and Swamp 15a are basically restricted to the selection of appropriate setback distances.

Wongawilli Creek

- Because of the potential to increment existing valley closure, the proposed 175 m setback from Wongawilli Creek does not provide a high level of confidence that impacts on Wongawilli Creek will be contained to "minor impacts" In determining an appropriate setback, the potential for further reducing impact likelihood by small margins (up to another 3 %) needs to be judged against the required reduction in longwall length to deliver this reduced risk.

Sandy Creek

- The Panel concurs that Sandy Creek is not predicted to experience measurable conventional or valley related effects due to the mining of LW19 and that it is unlikely, therefore, that Sandy Creek would experience adverse impacts due to the mining of the proposed longwall.

Sandy Creek Waterfall

- Although an incremental increase in predicted closure of less than 5 mm may appear a trivial value in absolute terms, it is significant when regard is had to the amount of closure associated with the cessation of extraction of LW6, LW7 and LW8.
- As a matter of due diligence, the Technical Committee formed under the Sandy Creek Waterfall Management Plan should be engaged in determining the setback distance of LW19 from the waterfall and the appropriateness and robustness of the monitoring plan and associated trigger levels and responses.

Swamp 15a

- With the current longwall layout, the Panel considers it predictable with a high level of certainty that the proposed LW19 will result in changes in ecosystem functionality in parts of Swamp 15a within 60 m of the longwall.
- The proposed layout would certainly fail to meet the performance measure required under Condition 5. Regarding the proposed groundwater performance indicators in Table 1.2 of the SIMMCP, the Level 1 indicator would almost certainly be surpassed if any of the monitoring points were within the 60 m threshold, while the Level 2 and 3 indicators are unlikely to be surpassed as they require increasing proportions of the monitoring points to be affected.

- The Panel concludes that, at the very least, LW19 would need to be setback a distance of 60 m from the edges of Swamp 15a in order to satisfy Condition 5 regarding ecosystem functionality of the swamp.
- Monitoring of shallow groundwater should be re-established and continued across Swamp 15a to assess long term compliance with the Condition.
- The Panel does not see a useful measure of erosion that can be used to assess compliance within a short time frame and thus suggests that monitoring of erosion and soil moisture as proposed in the SMP be carried out to ensure long-term compliance.

6.0 RECOMMENDATIONS

1. The Department should embrace the proposal of South32, dated 15/1/2021, that the Sandy Creek Waterfall Management Plan be re-established and applied to the extraction of LW19.
2. The starting location of LW19 and the proposed monitoring plan and its associated triggers and responses should take into account the latest field survey results and be endorsed by the Technical Committee previously constituted for the Sandy Creek Waterfall.
3. As a minimum requirement for meeting Condition 5 regarding no change in ecosystem functionality of Swamp 15a, LW19 should be set back at least 60 m from all edges of Swamp 15a.
4. To avoid inadvertently approving a mine layout that could result in a breach of the Consent Conditions relating to Swamp 15a, the Department's assessment should include careful consideration of the environmental impacts on that portion of Swamp 15a which lies at the headwaters of SC10B, over the maingate chain pillars of LW19.
5. An additional chemistry site should be added adjacent to the proposed water level site behind the Swamp 15a controlling rockbar.

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Appendix A – Whole of Mine Matters

LONG TERM MONITORING

The long-term groundwater monitoring program prepared by SLR Consulting (Appendix B of South32 (2020b)) proposes sets of vibrating wire and standpipe piezometers that should be retained for use in the long-term monitoring program of the groundwater system. The objectives of the monitoring are largely explained in terms of monitoring groundwater levels to observe head changes in the vicinity of major surface features, to be used to improve the calibration of the groundwater model for predictions and to continue monitoring through to the end of groundwater recovery.

There are four areas where further development of the monitoring program is justified:

1. Linking the groundwater monitoring more strongly to the surface hydrological monitoring of Swamps and water courses in order to assist with better understanding the near surface hydrological processes of swamps that are being protected during mining but may suffer from long term changes.

2. Using the groundwater monitoring to gain greater insight into long term behaviour of the effluent and influent flow distributions along the major creeks, such that better assessment of the trajectory of net surface water losses relevant to water supply due to mining is developed.

3. Improving the spatial distribution of depth to the groundwater table and its relationship to topography, valley geometry and mining impacts that at the moment appear to be poorly described by the available modelling.

4. Further integration of understanding of groundwater flow and groundwater chemistry above longwalls and in the near surface.

It is unclear which groundwater model was used to show the predicted groundwater heads related to each of the monitoring points but it is clear that the model outputs plotted have a range of errors in them that render the comparisons largely meaningless.

VWPs have a finite lifespan, not only due to ground movements but also due to degradation of the electronics and wiring. Evaluation of the available groundwater pressure and mine inflow data in the reports shows that there can be long delays before replacement equipment is installed. There should be a condition on all installations of rapid replacement to ensure data continuity and that data infilling methods are not employed except for short periods for the purposes of modelling and analysis. Such a condition on replacement of monitoring equipment may alter the design of monitoring installations that will be needed over the long term.

GROUNDWATER MODELLING

The groundwater model used for the assessment of the hydrogeological impact of LW19 retains the limitations of identified in the evaluation of Dendrobium Extension Project. Namely:

1. All post mining groundwater rebound data are based on an incorrect conceptual model that is not connected adequately to the expected mine closure plan for the mining

complex and cannot therefore be relied on for determination of the long term conditions across the catchment.

2. The modelled near surface groundwater conditions appear to produce depths to water that are too small when compared to the available shallow groundwater observations away from the streams and that this affects the estimates of the groundwater recharge above the longwalls. While the result is almost certainly conservative for mine inflows it is likely to produce model results for the near surface hydrology that are not reliable.

3. Vertical hydraulic conductivities are based on lower bound estimates from core scale data and could be biasing the assessment deep percolation of water through the different geological formations.

4. Sensitivity testing is based on large scale changes to regional hydraulic properties, but there is a need to adopt a more targeted approach to sensitivity testing that looks at a wider range of possible conditions so that a clearer assessment of the uncertainties in the model can be made.

5. The presentation of much of the modelling output is at a spatial and temporal scale that is not appropriate for a reader to investigate specific features of the model results.

While the modelling results are likely to be adequate for estimating upper bound mine inflows arising from the extraction of LW19, greater uncertainty exists with the determination of short- and long-term groundwater head changes beneath swamps and creeks is apparent. As recommended in the review of the Dendrobium Extension Project, a continued improvement of the groundwater model that takes proper account of the issues identified above is essential.