

INDEPENDENT EXPERT ADVISORY PANEL FOR MINING

ADVICE RE:

DENDROBIUM COAL MINE LONGWALL 21A SUBSIDENCE MANAGEMENT PLAN

2 July 2024

Report No: IEAPM 202407-1

EXECUTIVE SUMMARY

On 3 April 2024, the Director Resource Assessments, NSW Department of Planning, Housing and Infrastructure (DPHI) requested the Independent Expert Advisory Panel for Mining (IEAPM – “the Panel”) to provide advice in relation to the proposed Subsidence Management Plan (SMP) for secondary coal extraction from Longwall 21A (LW21A) in Area 3C at the Dendrobium Coal Mine.

The scope of the Advice sought from the Panel on the following matters:

- *the cumulative impacts of the extraction of LW21A on water quality and water quantity, including:*
 - *whether these cumulative impacts have been adequately considered;*
 - *whether the development would achieve the performance measure required under Schedule 3 Condition 3 of the development consent, with the extraction of LW21A;*
- *the adequacy of the water and biodiversity monitoring programs;*
- *the water and biodiversity TARPs and whether they:*
 - *enable measurement of compliance with relevant performance measures; and*
 - *have triggers (and associated performance indicators) that adequately reflect the relevant performance measures established under the consent, and that adequately inform the mine’s overall performance with respect to environmental consequences.*

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

The following sections of the report identify the following:

- Chapter 2 – Scope of works
- Chapter 3 – Methodology
- Chapter 4 – Background of mine, mine layout, and physical environment
- Chapter 5 – Current monitoring programs
- Chapter 6 – Subsidence assessment and cumulative impacts
- Chapter 7 – Performance measures and indicators

Based on the material presented to the Panel and the supplementary information supplied by South32-IMC, the Panel has made the following conclusions and recommendations for possible inclusion in any SMP approval for LW21A:

SUMMARY CONCLUSIONS

The Panel has concluded for each of the individual Advice requirements that:

Cumulative impacts of the extraction of LW21A – Water quality and water quantity

Part 1 (adequate consideration of cumulative impacts)

1. The SMP adequately assesses conventional surface subsidence effects and impacts associated with the extraction of LW21A. Connective fracturing to surface is very unlikely to occur over LW21A but, if it did, the consequences would default to the wider adjacent LW22.
2. It is unlikely that Wongawilli Creek will experience adverse physical impacts due to the mining of the proposed LW21A.

3. There will be a reduction in surface flows for tributaries draining Area 3C due to surface fracturing associated with LW21A and the other approved longwall panels in Area 3C.
4. Seepage losses greater than 1 ML/day from Lake Cordeaux (i.e. leakage plus loss of baseflow inflow) are possible. This can only be assessed by improved numerical modelling.
5. Potential long-term changes in (reservoir) water quality, including post-mining, remain a key concern.
6. Near surface fracturing is likely to cause the cracking of swamp substrates and the drainage of perched groundwater potentially affecting those swamps overlying or within 120 m of any of the proposed longwall panels in Area 3C.
7. There will be more than a minor change to the size, hydrology and ecosystem functionality of all swamps overlying LW21A (Swamps 9, 156 and 157).
8. The cumulative impact of the extraction of LWs 21 to 23, including LW21A is that all of the remaining swamps east of Wongawilli Creek in the southern part of Area 3C (including Swamp 154 which is not offset) are possibly or likely to be impacted by more than a minor change to their size, hydrology and ecosystem functionality.
9. LWs 21 to 23 are likely to result in more than minor impacts to a number of fauna species known or predicted to occur over these longwalls, including the Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet and Giant Dragonfly. There is concern from the Panel that these values have not been adequately offset by the SBO.
10. The groundwater assessment is comprehensive and provides a reasonable regional assessment of likely water level and depressurisation cumulative impacts to shallow and deep groundwater systems across Area 3C. However, the Panel is still concerned that long-term recovery of groundwater levels and pressures may not be adequately represented by the current modelling predictions.
11. Potential impacts on aquatic fauna are likely to be negligible.

Part 2 (achieve Schedule 3 Condition 3 Performance Measure)

1. It is unlikely that the "minor impacts" performance measure (flows and levels) at Wongawilli Creek and Sandy Creek will be exceeded due to surface fracturing associated with LW21A.
2. The Panel has no reason to consider that the predicted cumulative flow losses in Wongawilli Creek are greater than negligible in terms of water resources consequences.
3. There will be a reduction in surface flows for tributaries draining Area 3C due to surface fracturing associated with LW21A and the other approved longwall panels in Area 3C however the impact on inflows is unlikely to be measurable.
4. Losses (i.e. leakage plus loss of inflow) greater than 1 ML/day from Lake Cordeaux are possible (1 ML/day being the tolerable loss nominated in 2018 by Dam Safety NSW). The likelihood of 1 ML/day being exceeded due to LW21A and cumulative impacts can only be assessed by improved groundwater numerical modelling.
5. Long-term changes in water quality in all watercourses, including post-mining, remain a concern. If persistent and widespread, observed trends in water quality could lead to greater than negligible consequences on Lake Cordeaux.

Water and biodiversity monitoring programs

1. The proposed surface water monitoring is adequate. Additional reservoir monitoring sites may become advisable if Level 3 triggers or trends are observed at LC1 and LC2.
2. The commitment to monitoring reservoir water quality for two years post-mining should be supplemented by a longer-term monitoring plan for selected sites.

3. The swamp piezometer/soil moisture and groundwater monitoring networks are adequate for monitoring perched, shallow and deep groundwater trends in the vicinity of LW21A except for identifying the recharge and any mining induced trends in the shallow Hawkesbury Sandstone groundwater system.
4. Monitoring of ecosystem functionality, particularly swamp size, does not extend to all swamps with potential to be impacted.
5. Not all biodiversity monitoring is being established in time to provide a minimum of two years of baseline data and, further, swamps previously deemed to be reference/control swamps have become or will become impact swamps, compromising long-term analysis of possible impacts.
6. It is essential that floristic monitoring be conducted to allow comparison with both previous and future mining activities, given that it is well understood that long-term data are needed to distinguish natural and mining-related changes in vegetation.
7. Monitoring of threatened fauna, especially Littlejohn's Tree Frog and Giant Dragonfly, does not appear to be adequate in timing or extent to date.

Water and biodiversity Trigger Action Response Plans (TARPS)

1. The Strategic Biodiversity Offset (SBO) that is in place for all swamps except Swamp 154 negates the need for any management or remedial actions in the relevant TARPs, however ongoing monitoring and reporting is important to assess the severity of impacts, and to collect data for modelling and research purposes.
2. There are inconsistencies in the proposed performance measures in the SMP and those performance measures described in the SIMMCP. The performance measures and performance indicators/triggers in any updated SIMMCP should prevail.
3. The nominated performance measures listed in the updated Area 3C Swamp Impact Monitoring, Management and Contingency Plan) SIMMCP are reasonable for both the ridgeline and valley-fill swamps, with the exception of the absence of performance indicators relevant to ecosystem functionality previously used in Areas 3A and 3B.
4. The nominated surface water performance measures in the updated Area 3C Water Impact, Monitoring, Management, and Contingency Plan (WIMMCP) are reasonable for the primary creeks, their tributaries and the receiving waters of Lake Cordeaux.
5. The nominated aquatic ecology and threatened fauna performance measures in the updated WIMMCP require improved performance indicators.
6. There are no performance measures in the WIMMCP relating to shallow groundwater in the Hawkesbury Sandstone. A performance measure and water level trigger describing declines in the regional water table in this aquifer would be useful in assessing reduced creek flows and baseflow volumes discharging to Lake Cordeaux.
7. In regard to the explicit performance indicators and TARPs in the SIMMCP and WIMMCP:
 - 7.1. the nominated perched groundwater triggers are reasonable to identify potential impacts, however the trigger responses are weak and will not protect swamps from more than minor (mining induced) changes.
 - 7.2. the impacts to swamps will be more than minor so the existing SIMMCP TARPs are effectively just a reporting mechanism for the expected mining-induced impacts.
 - 7.3. the performance indicators and TARPs for Ecosystem Function in the SIMMCP need to be improved by focussing on swamp extent and ecosystem health
 - 7.4. for surface water flow, the proposed WIMMCP TARPs and performance indicator are appropriate for detecting impacts but are not sufficient for quantifying volumetric losses. At present the best available volumetric loss estimates are those derived from the numerical groundwater model.

- 7.5. a new performance indicator related to trends in lake water quality is required to supplement the proposed indicator.

SUMMARY RECOMMENDATIONS

The Panel recommends that DPHI consider the following for inclusion in any SMP approval conditions:

1. The construction of a nested (standpipe) monitoring site at a suitable location (subject to site access) at each of Swamp 7 and Swamp 9 to monitor perched groundwater levels in the weathered rock and the regional water table in the Hawkesbury Sandstone, for the purpose of improved groundwater model calibration, long-term assessment of mining-induced drawdown and recovery, and quantification of baseflow losses to Lake Cordeaux.
2. Adoption of the recommendations contained in Section 4 of the Seepage Validation Report of HGeo (2024) being:
 - *Groundwater levels and strata movements within and around dyke DD9 should be monitored as mining progresses in Area 3C. Observations and trends should be documented at each end of panel review and recommendations made with respect to adaptive management and further investigations if required.*
 - *Numerical and seepage models should be updated regularly to incorporate new observations from the barrier zone investigations. Seepage estimates should be reviewed after each longwall is extracted. Model re-calibration should be carried out if groundwater level observations fall outside expected ranges.*
 - *The mine water balance for Area 3C should be reviewed regularly and trends compared with those expected from numerical modelling. Mine water chemistry, including tritium and carbon-14 can provide an early indication of surface water inflows. Review of the water balance and water chemistry for Area 3C should form part of regular reporting.*
3. Updated numerical groundwater modelling at the completion of the barrier investigation studies and nearby dyke investigations, including more extensive uncertainty analyses, to improve
 - 3.1. predictions of baseflow reductions to and seepage losses from Lake Cordeaux and baseflow reductions in Wongawilli Creek, and
 - 3.2. predictions of drawdown in the shallow and deep aquifers.
4. Longer term, that the post mining predictions of water level and pressure recovery be updated as validation data are obtained from historically mined areas that are permanently sealed.
5. A performance indicator related to trends in lake water quality to assess against the Lake Cordeaux performance measure, that should include metals (at least total Mn, Fe and Zn, and others if advised by WaterNSW).
6. A longer-term water quality monitoring plan for selected reservoir sites beyond the commitment to monitor water quality for two years post-mining.
7. The SIMMCP be updated to better acknowledge the role and influence of approved offsets, and the reasoning behind current swamp monitoring programs.
8. Update the SIMMCP and WIMMCP documents as soon as practical but no later than 6 months prior to the commencement of LW21A.
9. A requirement to update the TARPS in the SIMMCP to include:
 - 9.1. the larger swamps (Swamps 7, 9, and 16), overlying swamps (Swamps 156 and 157) and even the smaller remote swamps (Swamps 144, 145, 153, 154 and 155), so that the ‘more than minor’ impacts are reported in a timely manner and data are available for modelling and research purposes,
 - 9.2. for ‘Ecosystem Function – Minor changes in the size of the swamp’ be modified to make it clear that it is the extent of the whole swamp being considered in this TARP,

9.3. for 'Ecosystem Function – Minor changes in the ecosystem functionality of the swamp' be modified to add 'Area 3C mining induced changes hydrological result in:

- i. changes in the extent of sub-communities, particularly cyperoid heath and teatree thicket, within a swamp
- ii. changes in species composition and total species richness within a swamp as a whole and within sub-communities within the swamp

and in the WIMMCP to include:

- 9.4. a new performance indicator related to trends in lake water quality to assess against the Lake Cordeaux performance measure, which should include metals (at least total Mn, Fe and Zn, and others if advised by WaterNSW).
- 9.5. a performance measure and indicator related to mining induced changes to the water table in the shallow groundwater system any at newly established standpipe locations.
- 9.6. clarification of the intended use of the flow loss performance indicator in the footnote in the WIMMCP, "*Surface water inflows calculation=...*".
10. A requirement to undertake monitoring of Swamp 154 to determine whether greater than negligible impacts to ecosystem functionality occur and, if so, that this swamp is then offset.
11. A requirement to demonstrate that the Madden's Plains offsets provide suitable habitat to offset impacts to the Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet or Giant Dragonfly. If this cannot be demonstrated then South32 be required to prepare a plan outlining how impacts to these species will be remediated or offset, if they occur.

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1.0 INTRODUCTION

The Dendrobium Coal Mine is an operating underground coal mine located approximately 8 kilometres (kms) west of Wollongong. The Dendrobium Coal Mine was determined pursuant to DA60-03-2001 and has been subsequently modified several times.

South32-IMC is seeking approval for a Subsidence Management Plan (SMP) for secondary coal extraction from Longwall (LW) 21A in Area 3C at the Dendrobium Coal Mine.

As part of the development of the SMP, South32-IMC consulted several agencies to assist with the preparation of the report, including pre-submission consultation with the NSW Department of Planning, Housing and Infrastructure (DPHI). Once the SMP was submitted for approval, DPHI sought advice from those same agencies, which included the following:

- Biodiversity, Conservation and Science Group (BCS) of the Department of Climate Change, Energy, the Environment and Water (DCCEEW);
- Resources Regulator; and
- WaterNSW.

The catalyst for requesting the Panel's advice is concerns raised by WaterNSW (WNSW) and BCS and its predecessors over the last 12 months regarding surface water loss from water sources, swamps and Cordeaux Reservoir and the loss of biodiversity. The primary focus is the cumulative impacts of mining on water quality and quantity, and the associated impacts on biodiversity.

The relevant sections of the Dendrobium Coal Mine consolidated development consent (DA60-03-2001) are the Specific Environmental Conditions in Schedule 3, particularly the performance measures embedded in Conditions 3, 4, 5 and 6:

Watercourse Impact Management

3. The Applicant must ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Secretary.

4. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant must prepare a Watercourse Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:

(a) demonstrate how the subsidence impact limits in conditions 1 - 3 are to be met;

(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and Resources Regulator of the subsidence effects and impacts (individual and cumulative) on Wongawilli Creek, Sandy Creek and Sandy Creek Waterfall;

(c) include a general monitoring and reporting program addressing surface water levels, water flows, water quality, surface slope and gradient, erodibility, aquatic flora and fauna (including Macquarie Perch, any other threatened aquatic species and their habitats) and ecosystem function;

(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on watercourses, which includes a tabular contingency plan (based on the Trigger Action

Response Plan structure) focusing on measures for remediating both predicted and unpredicted impacts;

(e) address third and higher order streams individually but address first and second order streams collectively;

(f) be prepared in consultation with BCS, WaterNSW and Resources Regulator;

(g) incorporate means of updating the plan based on experience gained as mining progresses;

(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on watercourses in the relevant Area; and

(i) be implemented to the satisfaction of the Secretary.

Swamp Impact Management

5. 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.

6. Prior to carrying out any underground mining operations that could cause subsidence in either Area 3A, Area 3B or Area 3C, the Applicant must prepare a Swamp Impact Monitoring, Management and Contingency Plan to the satisfaction of the Secretary. Each such Plan must:

(a) demonstrate how the subsidence impact limits in condition 5 are to be met;

(b) include a monitoring program and reporting mechanisms to enable close and ongoing review by the Department and Resources Regulator of the subsidence effects and impacts (individual and cumulative) of each Area 3A longwall on Swamp 15a;

(c) include a general monitoring and reporting program addressing surface water levels, near surface groundwater levels, water quality, surface slope and gradient, erodibility, flora and ecosystem function;

(d) include a management plan for avoiding, minimising, mitigating and remediating impacts on swamps, which includes a tabular contingency plan (based on the Trigger Action Response Plan structure) focusing on measures for remediating both predicted and unpredicted impacts;

(e) address headwater and valley infill swamps separately and address each swamp individually;

(f) be prepared in consultation with BCS, WaterNSW and Resources Regulator;

(g) incorporate means of updating the plan based on experience gained as mining progresses;

(h) be approved prior to the carrying out of any underground mining operations that could cause subsidence impacts on swamps in the relevant Area; and

(i) be implemented to the satisfaction of the Secretary.

DPHI's previous SMP approval conditions for Area 3C (DPE 2022) and Panel's advice for LW21 (IEPMC 2019) and LWs22 & 23 (IAPUM 2022) also have relevance and are referenced in this advice.

2.0 SCOPE OF WORKS

The NSW Department of Planning, Housing and Infrastructure (DPHI) established the Independent Expert Advisory Panel for Mining (the Panel). The Panel's purpose is to give DPHI and the Independent Planning Commission access to expert advice when assessing mining proposals under the *Environmental Planning and Assessment Act 1979*.

On 3 April 2024, the Director Resource Assessments, DPHI requested the Panel to provide advice in relation to the proposed Subsidence Management Plan (SMP) for secondary coal extraction from Longwall 21A (LW21A) in Area 3C at the Dendrobium Coal Mine (refer Appendix A).

DPHI's Request for Advice sought advice from the Panel on the following matters:

- *the cumulative impacts of the extraction of LW21A on water quality and water quantity, including:*
 - *whether these cumulative impacts have been adequately considered;*
 - *whether the development would achieve the performance measure required under Schedule 3 Condition 3 of the development consent, with the extraction of LW21A;*
- *the adequacy of the water and biodiversity monitoring programs;*
- *the water and biodiversity TARPs and whether they:*
 - *enable measurement of compliance with relevant performance measures; and*
 - *have triggers (and associated performance indicators) that adequately reflect the relevant performance measures established under the consent, and that adequately inform the mine's overall performance with respect to environmental consequences.*

DPHI also advised that *the Panel should feel free to provide any other advice it considers would assist the Department in reviewing the SMP.*

The Panel considered DPHI's request for it to deal with cumulative impacts on water quality and quantity due to extraction of LW21A. In doing so, it focussed its analysis on the cumulative impacts of LW21A, the adjacent extracted LW21, and the adjacent approved LWs22 and 23 in Area 3C ("the Study Area").

The Chair of the Panel (Em. Professor Jim Galvin) nominated the following members of the IEAPM to prepare the advice. Mr John Ross chaired this individual Panel and coordinated the advice report:

- Em. Professor Jim Galvin – Subsidence and Mining
- Mr John Ross – Groundwater
- Ms Lucy Reading – Surface Water and Groundwater
- Professor Neil McIntyre – Surface Water
- Dr Ann Young – Swamps
- Mr Nathan Garvey – Biodiversity and Ecology

More background on the Panel can be viewed at Appendix B.

3.0 METHOD OF OPERATION

3.1. ACTIVITIES AND TIMELINE

The Panel convened by videoconference during the preparation of its advice and was administratively supported by the Panel Secretariat staff provided by DPHI – Major Projects Advisory.

The Panel convened on 5 April 2024 and received the supply of initial documentation. A virtual briefing was held on 11 April 2024 and additional information was then supplied to the Panel throughout May 2024. The additional information was focussed on groundwater monitoring sites, swamp and seepage impacts around Area 3C.

The timeline relating to the IEAPM’s assessment of the Dendrobium LW21A SMP is summarised in Table 1.

Table 1: Timeline relating to IEAPM’s assessment of Dendrobium LW21A SMP.

Date	Milestone
3/4/2024	DPHI request for advice from IEAPM
5/4/2024	IEAPM Panel convened and supply of initial documentation from South32-IMC and the agencies
11/4/2024	Briefing from DPHI staff
26/4/2024	Panel teleconference to discuss issues and report structure
1/5/2024 and 8/5/2024	Supply of additional information by South32-IMC after RFIs submitted on 22 April 2024
22/5/2024	Panel teleconference to discuss draft report and to resolve any advice queries
7/6/2024	Panel teleconference to discuss draft report and to resolve any advice queries
2/7/2024	Finalisation of IEAPM advice

3.2. REFERENCE DOCUMENTATION

Numerous key documents were provided through DPHI to support the Panel in preparing this Advice. These documents are listed in Table 2. A range of documents that the Panel has had regard to in compiling this advice are also recorded under References.

Table 2: Reference Documentation

Stage	Document Reference	Document Name
Initial Documentation	Provided by DPHI	LW21A SMP including: • Appendix 1 – Longwall Plans • Appendix 2 – SIMMCP Rev I • Appendix 3 – WIMMCP Rev J • Appendix 4 – Landscape TARP • Attachment A – Aquatic Flora and Fauna Assessment • Attachment B – Groundwater Assessment • Attachment C – MSEC report • Attachment D – Risk Assessment • Attachment E – Surface Water Assessment • Attachment F – Terrestrial Ecology Assessment • Attachment G - Geology • Attachment H – Aboriginal Cultural Heritage Assessment • Sandy Creek Water Management Plan • WaterNSW Asset Protection Plan Agency Advice: • BCS pre-lodgement advice • WaterNSW pre-lodgement advice Proponent Response • South32-IMC response to agency pre-lodgement advice LW21 End of Panel Report • Report and 10 attachments • BCS advice • WaterNSW advice Four Monthly Impact Monitoring Report (31 January 2024)
Supplementary Information	Provided by DPHI	• BCS referral response LW21A • WaterNSW referral response LW21A • Consolidated Consent for DA 60-03-2001 • Dendrobium Area 3B Swamp Rehabilitation Research Program • Dendrobium Area 3B Swamp Rehabilitation Research Program – Status Report January 2024
	Provided by South32-IMC	• Dendrobium Area 3C Seepage Validation Report • Dendrobium Area 3C Monitoring Network Review • Dendrobium Mine - Assessment of iron-staining in Wongawilli Creek: Update as of September 2023 • Longwall 19A Impact Reports • Longwall 21 Impact Reports

Stage	Document Reference	Document Name
		• Latest groundwater monitoring network map and hydrographs for S1969, S2211, S2212, S2514, and S2545 • Dyke and Lake Cordeaux investigation bore logs • South32-IMC submission to DPE regarding Dendrobium Area 3C Monitoring Network Review • Dendrobium Mine - Update on Geographic Review of mining effects on Upland Swamps: Update to January 2024 • Tabulated response to the Panels final request for information
	The Panel also sourced additional information from DPHI's and South32 - IMC websites	• LW21 SMP – Notice of Approval • LWs21 and 22 SMP – Notice of Approval • LWs21 and 22 SMP – Reasons for Approval • Dendrobium Mine Biodiversity Offset Strategy (October 2023)

4.0 BACKGROUND

The sequence, timing, and direction of longwall mining surrounding LW21A and the environmental setting and current monitoring programs and trends in the vicinity of this longwall panel have a significant bearing on the Panel's advice presented later in this document. This section provides summary background material in relation to these aspects.

4.1. MINE LAYOUT

Longwall mining has been undertaken at Dendrobium Mine in Areas 1, 2, 3A, 3B and 3C, shown in Figure 1. LW21A is located in the southern portion of Area 3C adjacent to LW21 and extends eastwards towards Lake Cordeaux. LW21A is proposed to be 256 metres (m) wide, 1590 m long and an extraction height of up to 3.9 m. The depth of cover above LW21A varies between 300 m and 370 m.

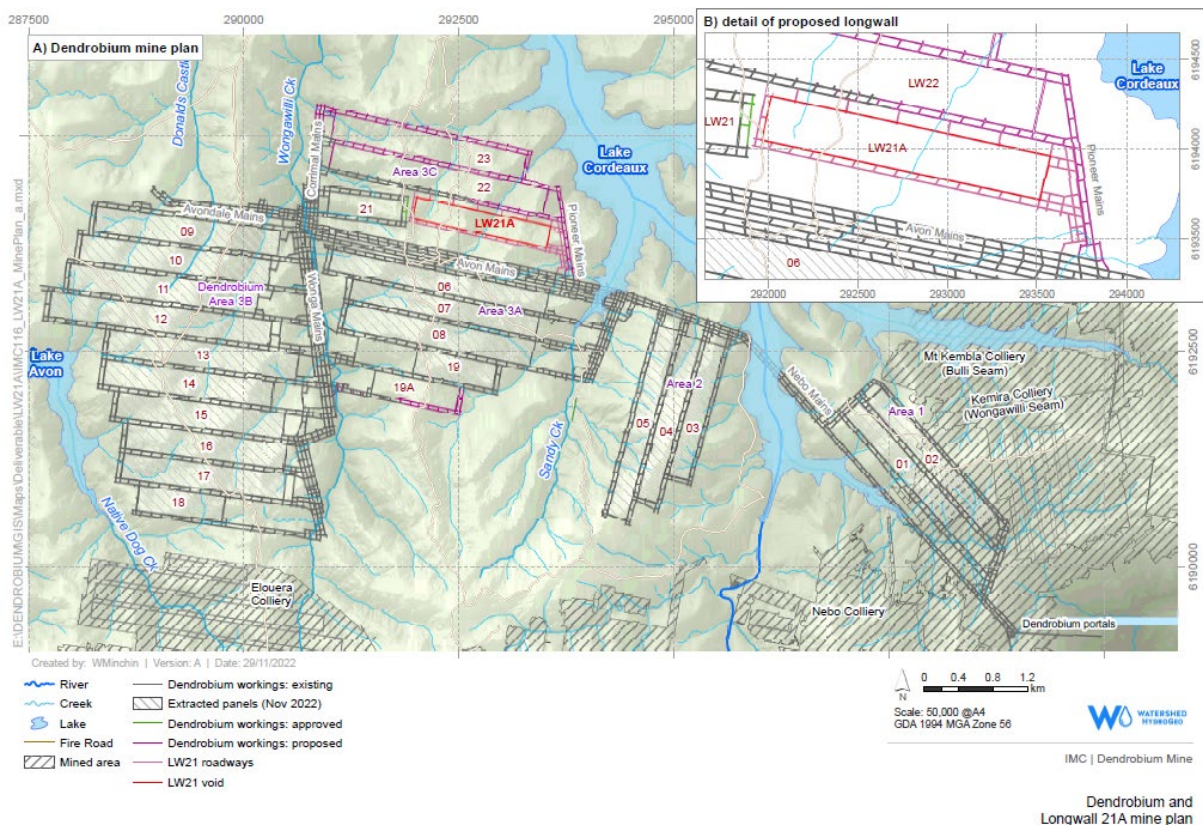


Figure 1: Locations of Areas 1, 2, 3A, 3B and 3C and associated longwall panels within these areas (Figure 1-2 from Watershed HydroGeo, 2023).

The location of LW21A in relation to important natural features is provided in Figure 2. LW21A is wholly within the Lake Cordeaux catchment and extends from the ridgeline in the west to within 600 m of Lake Cordeaux in the east.

LW21A is the fourth longwall panel planned for Area 3C and will be the third to be extracted after the first longwall (LW21) was completed in August 2023. Extraction within LW19A in Area 3A is nearing completion at the time of preparing this advice and it is expected that LW22 will follow in June 2024, with LW21A scheduled to commence mid-2025 (Watershed HydroGeo 2023). LW21A will be extracted from west to east.

The current status of proposed longwalls to the north in Area 3C (LW24 and LW25) is not known.

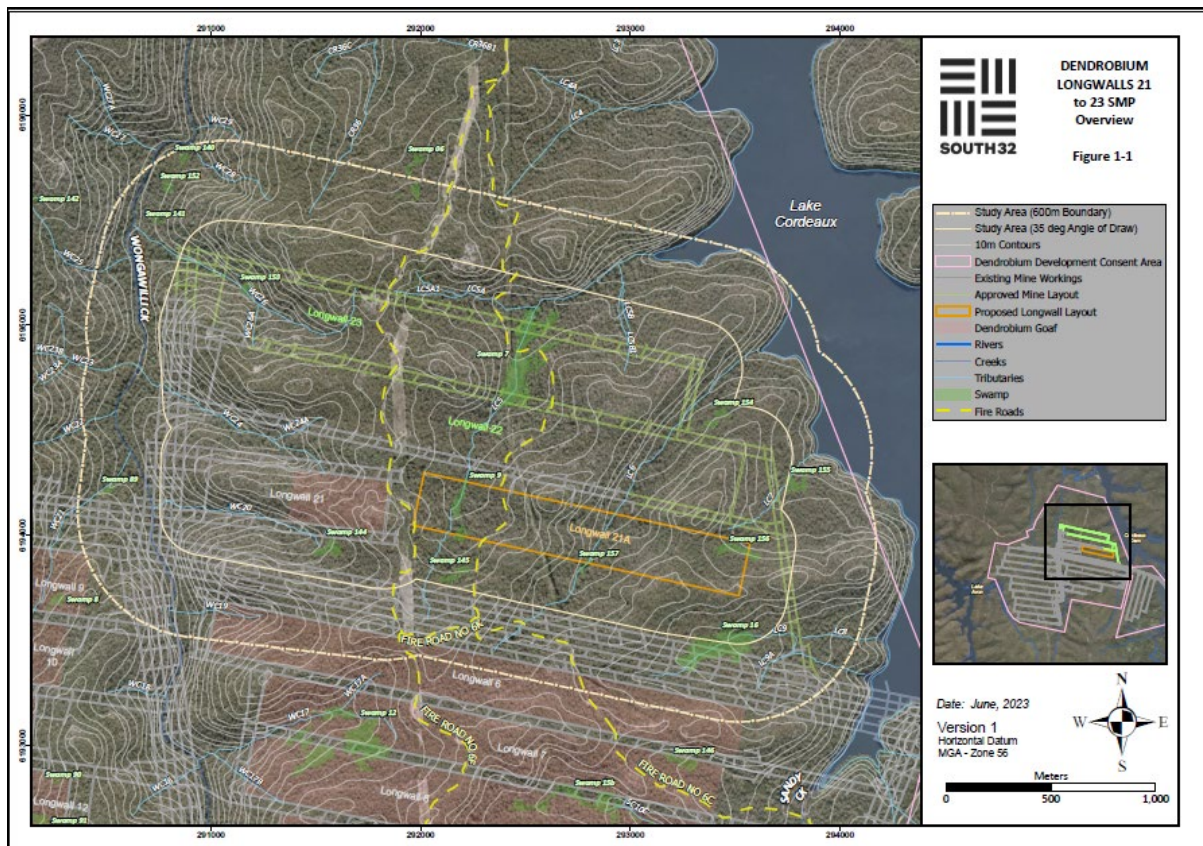


Figure 2: Location and setting of LW21A (Figure 1-1 from South32, 2023a).

4.2. SUBSURFACE AND SURFACE SUBSIDENCE

Figure 2 shows the location of LW21A and how it is effectively an extension of LW21 and adjacent to LW22. The SMP for LW21 was assessed in 2019 by the Independent Expert Panel for Mining in the Catchment (IEPMC) (IEPMC 2019) and the SMP for LW22 and LW23 was assessed by the Independent Advisory Panel for Underground Mining (IAPUM) in 2022 (IAPUM 2022). Three of the authors of this current IEAPM Advice Report were members of one or both of the preceding assessment teams. Consequently, many of the matters relating to subsidence and relevant to assessing the SMP for LW21A have already been studied in detail and reported upon in previous assessments. Hence, this current advice primarily has a focus on significant incremental or new environmental impacts and consequences due to conventional and non-conventional subsidence effects arising from the extraction of LW21A.¹

LW21 has been extracted and LW22 is the next longwall panel to be extracted. Since the area of influence of LW21A extends into those of LW21 and LW22, it is important to also consider if and how the extraction of LW21A may alter the conditions on which the previous assessments of LW21, LW22

¹ Refer to Glossary for definitions of *conventional subsidence*, *non-conventional subsidence*, *subsidence effects*, *subsidence impacts*, and *environmental consequences*.

and LW 23 were based. Cumulative impacts across the Study Area are discussed in Section 6 of this Advice.

The environmental impacts and consequences associated with extracting LW21A primarily relate to the creation of a sink for groundwater inflow and to ground deformation and subsidence that can impact subsurface features (such as aquifers) and natural features and systems and built structures on the surface.

4.3. PHYSICAL ENVIRONMENT IN THE VICINITY OF LW21A

4.3.1. Geology

The geology overlying LW21A and the target Wongawilli Seam in the Permian Illawarra Coal Measures (ICM), and underlying the ridgeline separating the Wongawilli Creek and Sandy Creek catchments, comprises:

- sandy soil and near surface colluvium (typically 1 to 3 m thick),
- Triassic Hawkesbury Sandstone (HBSS) (ranges from 50 to 120 m thick), and
- Triassic Narrabeen Group sandstones and claystones, (typically around 200 m thick).

Hawkesbury Sandstone is exposed in the base of Wongawilli Creek and Sandy Creek, however the Cordeaux River gorge is incised and the uppermost Narrabeen Group formations (primarily the Bulgo Sandstone (BGSS)) are exposed in the flooded gorge of Lake Cordeaux. The Bald Hill Claystone (BHCS) is exposed at Sandy Creek waterfall.

Structurally there are intrusions, faults, dykes and lineaments mapped around the Dendrobium Mine area. There are two main east-west dykes (DD9 and DD7A) in the vicinity of LW21A and the longwall block has been designed and orientated to occur parallel to and between these dykes so as to minimise contact and to avoid poor quality coal. A third dyke (DAD14) has a north-south strike and is located east of LW21A in the barrier pillar. No high permeability or groundwater inflow zones have been detected associated with any of these dykes (South32, 2024a) to date but there are ongoing investigations.

None of these structural features are known to extend into the overlying Triassic strata or impact the very shallow colluvium.

4.3.2. Hydrology

LW21A is located between Wongawilli Creek and Lake Cordeaux as shown in Figure 3. LW21A sits entirely within the Lake Cordeaux catchment and is overlain by the sub-catchments of creeks LC5, LC6, LC7 and LC9. LW21A will directly mine under tributaries LC5 and LC6. Large areas of the LC5 and LC6 catchments are upstream of LW21A. Flows from these upstream areas will flow over the goaf area and therefore may be diverted due to subsidence impacts. Although LW21A will not undermine LC7 and LC9, areas of the LC7 and LC9 catchments either directly overlie the goaf or are within 400 m of it. A small area of WC20, a tributary of Wongawilli Creek, is within 400 m of LW21A.

Figure 1 of South32 (2024d) shows that the area of the Lake Cordeaux catchment directly undermined and proposed to be undermined by Dendrobium Areas 1, 2 and 3 up to the end of LW23 is 5.1 km². LW21A accounts for 0.41 km² of that area. Figure 1 of South32 (2024d) implies that this area will not increase due to mining in Area 3C beyond LW23. The 5.1 km² area excludes areas upstream of longwall footprints and other areas outside of the longwall footprint but within the potentially impacted area. It also excludes historical mining (Nebo, Kembla and Kemira mines all have footprints in the Lake

Cordeaux catchment, as shown in Figure 1 of this advice). The total catchment area of Lake Cordeaux at its dam is 91 km².

Further overview of the hydrology of the Study Area is provided in HGeo (2023c).

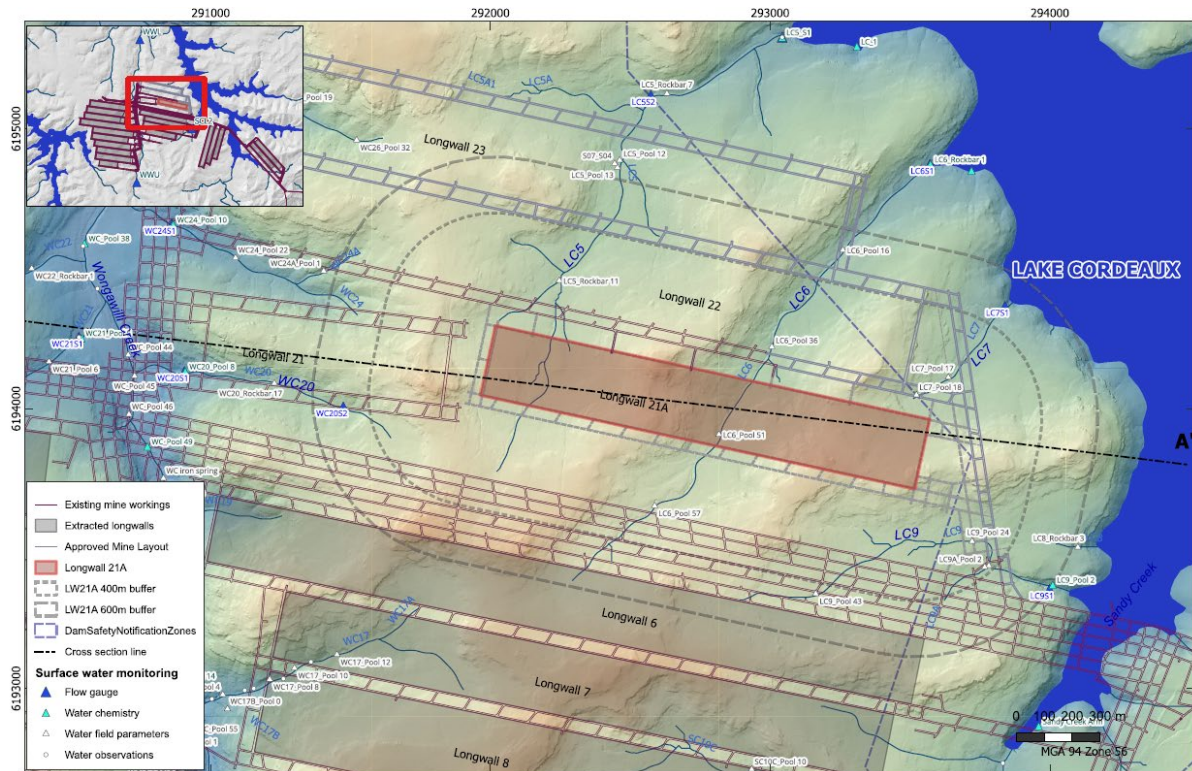


Figure 3: Location of Longwall 21A relative to surface watercourses (Figure 1 from HGeo 2023c)

4.3.3. Hydrogeology

Perched groundwater occurs in sandy colluvium deposited in the swamp areas located primarily along the drainage lines that drain to Lake Cordeaux. Overlying LW21A there are relatively few swamps and deposits of colluvium. Localised perched groundwater to around 10 m depth also occurs in the underlying weathered Hawkesbury Sandstone at selected sites, although there is very limited monitoring in place to confirm its spatial extent.

The regional water table occurs within the porous and fractured rock of the saturated Hawkesbury Sandstone. Rainfall recharges the regional water table across the catchment and groundwater flows from more elevated ridgeline areas to discharge as baseflow in Wongawilli Creek, Sandy Creek and (locally) into Lake Cordeaux. Across the western portion of the Sandy Creek catchment, the regional water table ranges between 20 and 50 metres below ground level (mbgl) (HGeo 2023a) but would be shallower near incised drainage lines. High water levels in the swamp piezometers within Swamp 7 (downgradient location along LC5 overlying proposed LW23) suggest that discharge from the regional water table is maintaining water levels in this valley fill swamp (Dendrobium Swamp 7 hydrographs in Appendix D of HGeo 2023b).

Groundwater in the deeper aquifer systems is naturally confined and is recharged by leakage from overlying Hawkesbury Sandstone aquifers, and to a limited extent from Lake Cordeaux. Natural groundwater flow is northwest into the Sydney Basin with non-natural discharge occurring into current mine workings and voids in old mine workings.

Naturally there is a vertical hydraulic gradient from the shallow aquifers in the Hawkesbury Sandstone to the deep aquifers in the Narrabeen Group and Illawarra Coal Measures. It is only the aquifers in the Hawkesbury Sandstone that are more elevated than the Lake Cordeaux full supply level (FSL is 303.7 mAHD) that provide baseflow to local streams and the reservoir.

4.3.4. Swamps and Biodiversity

Rainfall, run-on and perched groundwater sustain upland swamps, and water levels cycle between at surface (saturated) and dry (unsaturated) depending on the climatic conditions. In an undisturbed natural setting, saturation and soil moisture always rebound after a dry period but there is a large variability in climatic responses due to each swamp's local geomorphology and hydrology.

Three upland swamps will be directly undermined by the proposed LW21A. The overlying swamps are Swamp 9 on stream LC5 and the upper end of Swamp 156 at the eastern end of the longwall. Swamp 157 lies on the southern boundary of LW21A in the upper valley of stream LC6. Swamp locations are shown in Figures 2 and 6. Summary details for all swamps are provided in Table 3.

Table 3: Upland swamps located within the Longwall 21A SMP study area.

SWAMP	TOTAL AREA (ha)	VEGETATION COMMUNITIES	GROUNDWATER SITES	SOIL MOISTURE SITES
<i>Swamps located above Longwall 21A</i>				
9	0.79	Sedgeland-Heath Complex	09_01 since 7/2020 09_02 since 9/2022	S09_01 since 10/2021 S09_02 since 3/2022
156	0.71	Tea tree thicket	156_01 since 2/2024	S156_01 since 1/2024
157	0.12	Tea tree thicket	157_01 since 2/2024	S157_01 since 2/2024
<i>Swamps located adjacent to Longwall 21A</i>				
145	0.41	Banksia thicket	145_01 since 4/2020	S145_01 since 10/2021
<i>Swamps within the 600 m study area for Longwall 21A</i>				
7	4.87	Banksia thicket, Tea tree thicket, Sedgeland-Heath Complex	07_05 and 07_06 since 07/2015 07_07 since 1/2022	S07_05 and S07_06 since 12/2021 S07_07 since 9/2022
16	3.75	Banksia thicket, Tea tree thicket, Sedgeland-Heath Complex	16_01 and 16_03 since 2/2024	S16_01 since 1/2024 S16_03 since 2/2024
144	0.54	Banksia thicket	144_01 since 8/2020	S144_01 since 8/2020
154	0.40	Banksia thicket	154_01 since 11/2022	S154_01 since 9/2022
155	0.50	Banksia thicket	155_01 since 2/2024	S155_01 since 1/2024

Source: South32 (2023d) SIMMCP Appendix 2 Table 5-3 and Appendix C; Watershed HGeo (2024) Appendix A and Swamp Site spreadsheet supplied May 2024

It is worth noting that Swamp 9 lies upstream of Swamp 7 which is to be undermined by LW23. Swamp 7 is the only large complex swamp of the three swamps used in the study of water balance in upland swamps above Dendrobium Mine, conducted by UNSW Water Research Laboratory (Harrison et al. 2023).

The swamps have shallow sandy soils which are at risk of erosion if the vegetation cover is disturbed or removed by fires. Baseline surveys for gully erosion were completed in December 2005, using airborne laser scanning. A verification survey is to be completed prior to longwall extraction.

Shallow groundwater and soil moisture sites have recently been established at all three swamps (Watershed HGeo 2024). Prior to the commencement of mining LW21A, Swamp 9 will have more than two years of baseline data while the other two swamps will have around 18 months of data. Reference Swamps 85, 86 and 25 in Area 3B are reasonably close and comparable in size and have long term groundwater monitoring sites. Swamps 6 (Area 3C), 22, 23 (Area 3B), and 132 have also been nominated as reference sites in the SIMMCP (South32 2023d).

Limited surveys for threatened species have been undertaken to date (Niche 2023), with nocturnal frog searches undertaken in September less likely to detect species such as the Giant Burrowing Frog (*Heleioporus australiacus*), Littlejohn's Tree Frog (*Litoria littlejohni*) and Red-crowned Toadlet (*Pseudophryne australis*) and limited to no surveys undertaken for the Giant Dragonfly (*Petalura gigantea*).

Littlejohn's Tree Frog is known to occur along LC5 and LC6 with abundant populations occurring along both waterways including within sections of LC6 overlying LW21A. Littlejohn's Tree Frog is also known to occur along WC20 to the west of LW21A and over LW21. The Giant Burrowing Frog occurs along LC5, including in Swamp 7, and LC6 and was observed during surveys undertaken by Niche (2023). Records of the Red-crowned Toadlet and Giant Dragonfly are much more sparse, likely due to limited survey undertaken. The Giant Dragonfly has been observed in Swamp 7 within the 600 m boundary from LW21A. The Red-crowned Toadlet has not been identified in the 600 m boundary for LW21A to date, but suitable habitat is likely to be present. There are numerous records of this species north of LC5A and LW23 (Niche 2023, Figure 5).

4.4. LW21 END OF PANEL REPORT

Extraction of LW21 commenced in April 2023 and was completed in August 2023. Condition 9 of the Consolidated Consent requires that an End of Panel (EoP) report be produced within four months of the completion of each longwall panel and that the report describes in detail associated subsidence effects, impacts and consequences, and compares these with predictions. The Panel's review of the LW21 EoP report (South32 2023b) and numerous technical appendices is provided in this Section.

Progressively drier conditions occurred during the passage of LW21 in 2023. During the extraction of LW21, there were numerous impact reports submitted as a result of the exceedance of the current Trigger Action Response Plan (TARP) triggers including:

- 36 soil cracking, rock fracturing, and rock fall events, and
- 14 groundwater and soil moisture events.

36 of these events related to LW21 (32 subsidence impacts and 4 swamp/groundwater impacts) (Figure 9 in South32 2023b) and these are discussed in the sections below.

Historically South32-IMC considered that swamp impacts were contained close to longwall panels as there were no reported impacts to water levels within swamps at distances greater than 60 m (Watershed HydroGeo, 2019). Following the completion of Longwalls 17, 18, 19 and 21, the analysis has been

updated, and monitoring data now suggests a small number of impacts occurring at distances up to 120 m (Watershed HydroGeo 2024).

4.4.1.Subsidence

Measured conventional subsidence effects associated with the extraction of LW21 were all within the typical order of accuracy of predictions and there were no subsidence related exceedances of performance measures. **Figure 4** shows that vertical displacement was generally overpredicted except for the starting and finishing ends of LW21, which is not unusual in longwall mining due to the nature of how caving and subsidence develop around a static abutment at the start of a longwall panel and a dynamic abutment at the longwall face line.

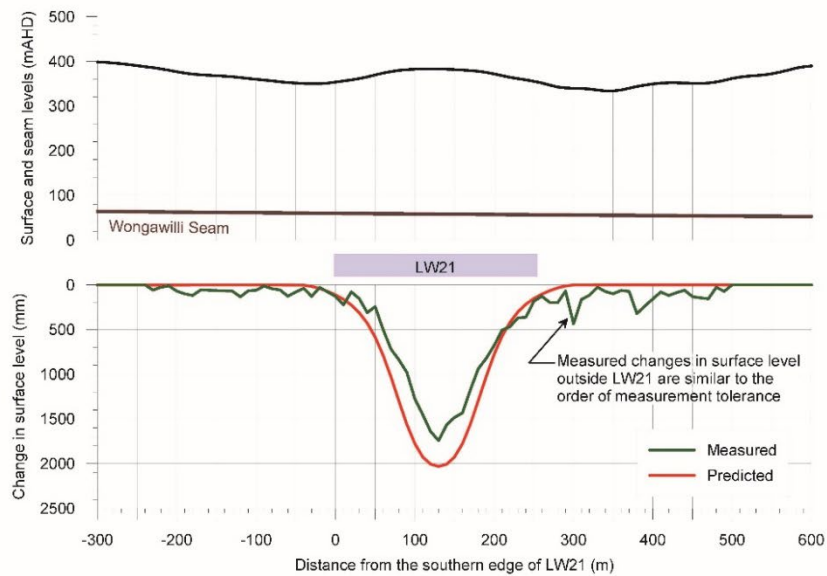


Fig. 2.5 Measured changes in surface level and predicted vertical subsidence for the Cross-section across LW21 near the mid-length of the longwall

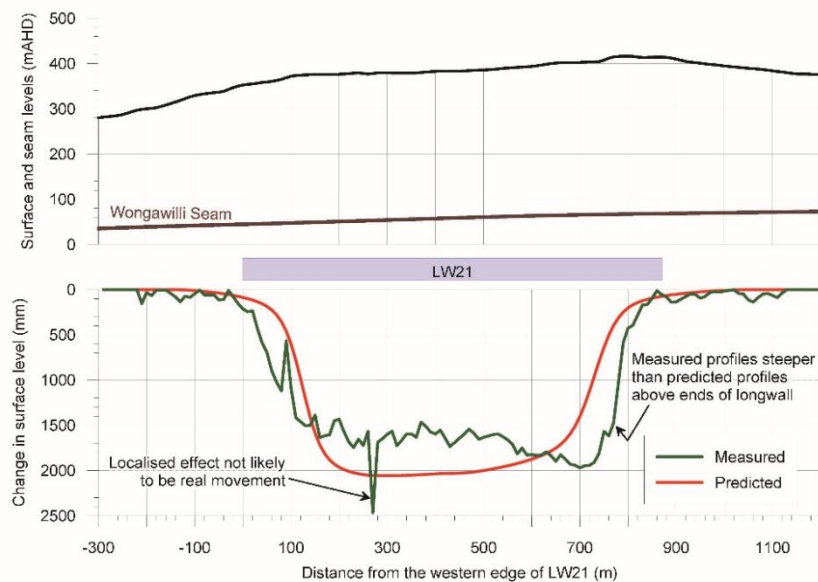


Figure 4: Predicted and measured vertical surface displacement along a transverse line near the mid-length of LW21 and along the centreline of LW21 (MSEC, 2023b)

MSEC (2023b) reports that:

It can be inferred from the slopes of the profiles across LW21 that the measured changes in grade are similar to the predicted tilts along the cross-sections and long-section. It is not possible to derive the curvature nor the horizontal movements from the LiDAR surveys.

Analysis undertaken by the Panel based on **Figure 4** indicates that measured maximum tilt on the flanks of the transverse line was of the order of 18 mm/m compared to predicted of the order of 25 mm/m. The measured tilt along the centreline at the finishing end (western end) of LW21 was of the order of 10 mm/m compared to predicted of around 18 mm/m (noting that the horizontal scale on the longitudinal section is compressed by a factor of about 0.6 to that of transverse section). Measured maximum tilt on the starting flank (eastern end) of the centreline was higher than predicted, but still only of the order of 18 mm/m and, therefore, not greater than that predicted for the transverse section. Hence, on a percentage basis, the Panel does not agree that the measured tilts are similar to predictions; they differ by 50 to 80%. However, in terms of the resulting subsidence impacts and consequences, the differences are not material in the LW21 setting and, in fact, for the most part are more favourable from an environmental perspective.

Performance measures related to the impacts and consequences of non-conventional subsidence apply to Wongawilli Creek and Sandy Creek Waterfall. The primary subsidence effect of concern for both natural features is valley closure.

Measured total valley closure across all four closure lines installed across Wongawilli Creek was still well below predicted values at the completion of LW21. It is reported that no fracturing was observed along Wongawilli Creek due to the mining of LW21. The extent of iron staining fluctuated but is reported to have been less extensive than when it was first reported prior to extracting LW21. Fracturing of a number of tributaries was reported but there are no subsidence performance measures related to these tributaries.

Sandy Creek Waterfall was monitored across five closure lines, with incremental valley closure predicted to be ± 2 mm. Incremental valley opening was measured across four of the closure lines during the extraction of LW21 and ranged from -1.1 mm to -2.4 mm. Incremental valley closure of 0.1 mm was measured across the fifth closure line. These values are all within the range of seasonal movements and survey tolerance. The Panel agrees with the End-of-Panel assessment that the measured ground movements are consistent with predictions provided in the Extraction Plan Application for LW21.

Against this background, the EoP Report for LW21 does not raise concerns that impact on the predictions of subsidence effects in the SMP for LW21A.

4.4.2. Hydrology

There were no water quality triggers in Area 3C during the reporting period of LW21 (25/4/2023 to 6/9/2023). In Area 3B, there is a persistent trigger for water quality at LA4_S1 “*Dissolved Fe, Mn, Al, Zn and Si remain elevated above baseline after flow returned in 2020*” (Table 6 of HGeo 2023b). In Sandy Creek Rockbar 5 and SC10C Pool 1, despite there being no triggers, various metal concentrations remain above baseline. An iron-rich seepage discharge near to Pool 50, first noted in August 2021, re-emerged in October 2023 causing staining in the downstream Wongawilli Creek. Analysis in HGeo (2023b) implies that this was associated with a combination of groundwater repressurisation due to wet weather and possibly subsidence fracturing associated with Longwall 6.

Following Panel advice associated with the LW18 Subsidence Management Plan, South32-IMC has undertaken additional trend analysis of water quality, which is reported in Section 4.3 and Appendix A2 of HGeo (2023b). Results in Section 4.3 of HGeo (2023b) show that all three analysed sites have

upward trends that did not exist in the baseline period. As an example, Appendix A2 of HGeo (2023b) shows that the total manganese concentration measured at Sandy Creek Rockbar 5 is approximately 0.3 mg/L higher during the LW21 reporting period than it was during the baseline period after allowing for the rainfall and flow condition. HGeo (2023b) conclude that:

The observed changes, while statistically significant, were not sufficient to trigger TARPs for EC, pH nor DO during the review period. Further analysis would be required to assess environmental consequences such as the effects on aquatic ecosystems and water supply.

The potential future significance of the seepage events and water quality trends are addressed later in this advice in context of LW21A.

Stream flows were not assessed for the LW21 reporting period due to baseline data from a WaterNSW gauging station (213200 O'Hares Creek at Wedderburn) being unavailable at the time of reporting. There were no pool level or fracturing triggers on Wongawilli Creek or Sandy Creek during the reporting period. Declining pool levels were associated with low rainfall in the reporting period.

4.4.3. Hydrogeology

The perched groundwater monitoring locations within the swamps in the immediate vicinity of LW21 and LW21A all showed declining water level trends aligned with the drying conditions. This decline in perched groundwater levels resulted in Level 3 TARP triggers for three of the four performance measure swamp sites including Swamps 9, 144 and 145 (09_01, 09_02, 144_01 and 145_01) (South32 2023e, South32 2023f, South32 2023g). The EoP report (South32 2023b) concluded that:

based on the distance from the longwall and comparison with reference sites, the triggers are unlikely to be related to mining and instead reflect the dry conditions in 2023, contrasting with the wetter conditions experienced during the baseline monitoring period for most of the swamp sites.

However, the Panel maintains that monitoring location 144_01 (located 113 m south of LW21) in Swamp 144 adjacent to LW21 did show a (probable) mining induced impact in mid-2023 when the post mining rate of water level recession in the swamp piezometer exceeded the rate recorded before mining (IEAPM 2023) even though a similar decline occurred over a longer period in 2023 at the more distant Swamp 9 (location 09_01). HGeo (2023b) argues that “It is unlikely that all of the observed declines in groundwater level during Longwall 21 are mining effects” on the basis that:

- all swamp piezometers except for 144_01 are located more than 300 m from the goaf footprint,
- swamp piezometers located well-beyond mining influence (>400 m) such as 154_01 and 153_01 show a similar decline in groundwater level below baseline levels,
- swamp piezometers in Area 3C have a limited baseline that largely coincides with the very high rainfall period between 2020 and 2023. Reference sites have much longer baseline periods that include several dry periods including the severe drought between 2017 and 2019, and
- at all sites, observed recession rates are similar to baseline and do not show the anomalously high recessions that are characteristic of mining impacts.

The Panel agrees that many of the observed declines are natural responses to low rainfall, however based on the quick recession rate and non-recovery of water levels observed at site 144_01, the Panel is still of the opinion that the drying impact observed at Swamp 144 is most likely mining induced. This conclusion is supported in the most recent assessment of geographic impacts to upland swamps (Watershed HydroGeo 2024).

The groundwater trends in the deeper groundwater systems (both the shallow Hawkesbury Sandstone and the deeper Narrabeen Group/Illawarra Coal Measure strata) are discussed in HGeo 2023a. The hydrographs for the closest (operational) monitoring sites to LW21 (S1892, S2514) and S2545 overlying LW21 showed:

- no mining induced drawdown in the very shallow (<10 mbgl) Hawkesbury Sandstone water levels (based on the one vibrating wire piezometer (VWP) sensor at S1892),
- mining induced drawdown in the regional water table in the Hawkesbury Sandstone at both S1892 and S2514 of up to 10 m with no drawdown at S2545 (in fact a slight rise due to strata compression) until the VWP cables sheared in May 2023, and
- regional depressurisation of the Narrabeen Group strata below the Bald Hill Claystone at S1892 and S2514 as well as at S2545 before its destruction.

The Panel agrees that these impacts and trends are consistent with those observed near previous longwall panels. The latest modelling runs for location S1892, presented in Figure 6.3 of Watershed HGeo (2023) up until the end of 2022, suggest good correlation with observed depressurisation in the deep groundwater system but poor correlation with the regional water table in the Hawkesbury Sandstone (observed water levels are consistently higher than modelled elevations).

A comparison of modelled and observed groundwater levels at S1969 (east of LW21A near Lake Cordeaux) since the completion of LW21 (supplied as part of the RFI request) show a fair match between Hawkesbury Sandstone water levels (observed levels are higher than modelled suggesting recharge is underestimated); a good match with the Bulgo Sandstone piezometric levels; and a poor match with piezometric levels in the Illawarra Coal Measures (observed levels are much lower than modelled). The divergence in the piezometric levels in the deep strata could be related to the presence of dykes to the south and west of this VWP location that are not explicitly included in the numerical model. This hydrograph is reproduced in Figure 5.

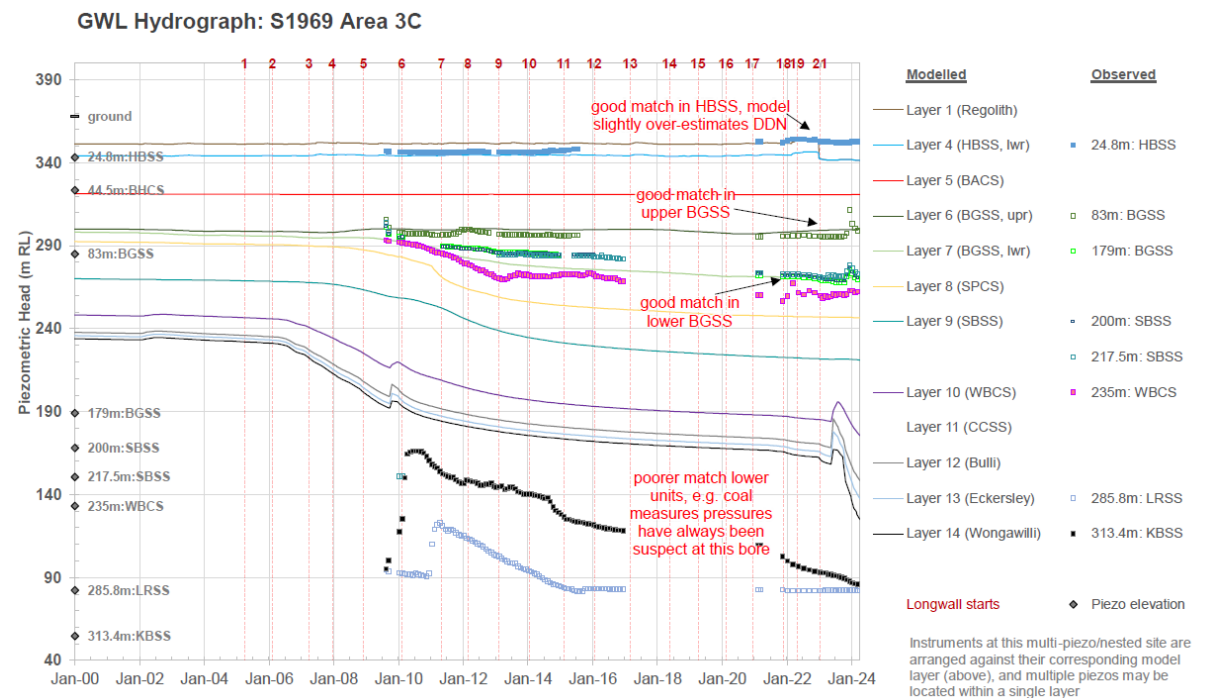


Figure 5: Modelled and observed groundwater levels at S1969.

It appears that the model requires some refinement in Area 3C for recharge and aquitard parameters, and potentially the inclusion of different parameters to replicate the multiple dykes in the deep model layers.

There was no perched or shallow groundwater quality monitoring at any sites close to the footprint of LW21 during the extraction period.

The mean total mine inflow during the LW21 extraction was 8.05 ML/d which was a 28% decrease compared to the previous LW19 extraction period. Only 0.77 ML/d was modelled to be derived from Area 3C. Area 3B is contributing most of this inflow, however the recent peak in inflows was mostly derived from Area 2 (HGeo 2023a). This is supported by the tritium results that show higher tritium in mine water from Area 2 goaf and a lower contribution of modern water from Area 3B. There is currently no tritium data for mine water from Area 3C.

These mine inflow results are not unexpected given the return to drier conditions and the preceding very wet period from early 2020 until late 2022.

4.4.4. Swamps and Biodiversity

Shallow groundwater hydrographs and soil moisture levels declined to below baseline at swamp sites within the area of influence of LW21, resulting in Level 3 TARP triggers for both measures at Swamps 9, 144 and 145. These exceedances are discussed above.

There were 30 impacts of rock fracturing, rockfall, soil cracking and iron stain flow through bushland. There was iron staining on stream WC_20 at the basal step of Swamp 144 as well as a number of rock fracturing events below the swamp. No monitoring of aquatic habitat in 1st and 2nd order streams was reported, but impacts of cracking were deemed minor because of the ephemeral nature of these streams and the comment that such streams '*provide aquatic habitat of limited value*'. A number of rock fracturing events in the base of waterways were a Level 2 trigger as per the Dendrobium Watercourse TARP. WC20 is known to support the Littlejohn's Tree Frog.

5.0 CURRENT MONITORING PROGRAMS

This section describes the current water and biodiversity monitoring programs, the available data sets, and the adequacy of these monitoring programs to identify mining induced impacts related to the extraction of LW21A.

5.1. SURFACE WATER

The surface water monitoring network associated with LW21A is shown in Figures 3.1, 3.2 and 3.3 of the Watercourse Impact Monitoring Management and Contingency Plan (WIMMCP) (South 32 2023c). The monitoring includes observational sites (visual, water levels and basic water quality parameters), chemistry sites (suite of water quality parameters) and flow sites. Supplementing the shown sites, water chemistry monitoring will be added at LC5S2 in response to a recommendation of WaterNSW (South32 2024d). The WIMMCP for LWs 22 and 23 introduced monitoring of water quality in Lake Cordeaux at LC1, and the WIMMCP for LW21A introduces one more lake site, LC2. LC1 is approximately 150 m along the shore from the confluence of LC5 with Lake Cordeaux, and LC2 is approximately 150 m from LC6. LC1 has baseline data since mid-2021, LC2 since start of 2023.

The Panel regards the proposed surface water monitoring as adequate. Additional reservoir monitoring sites may become advisable if Level 3 TARP triggers or trends are observed at LC1 and LC2.

The Panel notes the efforts being undertaken to quantify and improve the accuracy of the flow gauging, and that further gauges are planned (South 32 2023c, Appendix D). The increasing number of flow gauges comes with increasing challenges of conducting the maintenance and calibration required to achieve good accuracy. The Panel recommends that the number of flow gauges on minor tributaries should be limited to that which can be well maintained and regularly re-calibrated even if this means fewer flow TARP sites.

5.2. GROUNDWATER

Groundwater is (or was) monitored at numerous locations across Area 3C as described in the Impact, Monitoring, Management and Contingency Plans (WIMMCP (South32 2023c) and SIMMCP (South32 2023d)) and is currently being expanded. Updated maps were received from South32-IMC in early May 2024 and the current swamp and groundwater monitoring locations are shown in Figure 6 and Figure 7 respectively.

The swamp monitoring locations are paired shallow piezometer and soil moisture locations. The shallow groundwater locations are all VWP sensors, although some standpipes are planned to confirm water table elevations. The deep groundwater locations are all VWP sensors. The existing locations (as of April 2024) that overlie or are immediately adjacent to LW21A are underlined in the list below:

- Fourteen (active) shallow colluvial locations within 10 swamps and within the largest swamps there are three locations in each of Swamp 6 and Swamp 7, plus
 - Two locations in Swamp 9
 - One location in Swamp 156
 - One location in Swamp 157
- Shallow groundwater in the Hawkesbury Sandstone is monitored at:
 - S1871 – operational (VWP sensors at 10 and 31.3m)
 - S1892 – operational (VWP sensors at 8 and 49m)
 - S1969 – operational (VWP sensors at 10, 24.8, and 44.5m)
 - S2212 – operational (VWP sensor at 64m)
 - S2508 – operational (VWP sensors at 50, 72, and 94m)
 - S2508A – operational (VWP sensors at 35.4, 62.9 and 93.8m)
 - S2514 – operational (VWP sensors at 45, 55 and 65m)

- S2518 – operational (VWP sensors at 45, 66.5, and 88m)
- S2545 – destroyed (VWP sensors at 13, 50.6 and 88.1m) overlying LW21
- S2655 - (new) inclined dyke VWP operational – (3 sensors at 17.5, 40 and 65m)
- S2656 - (new) inclined dyke VWP operational – (3 sensors at 28, 48 and 68m)
- S2658 - (new) operational – (VWP sensor at 30m))
- S2658A – (new) operational (VWP in sand - 30m deep)
- S2659A – (new) operational (VWP in sand - 30m deep)
- Deep groundwater is monitored at:
 - S1390 - decommissioned
 - S1779 - decommissioned
 - S1844 - operational (sensors at 329 and 356.8m)
 - S1845 - decommissioned
 - S1871 - operational (9 sensors from 88 to 312.9m)
 - S1892 - operational (6 sensors from 113 to 336.1m)
 - S1969 - operational (8 sensors from 83 to 313.4m)
 - S2018 - decommissioned
 - S2059 - operational (8 sensors from 113 to 340.7m)
 - S2207 - decommissioned
 - S2208 - decommissioned?
 - S2211 - operational (2 sensors at 317 and 350m)
 - S2212 - operational (9 sensors from 92.4 to 370.2m)
 - S2288 - decommissioned?
 - S2508 - operational (7 sensors from 115 to 362.2m)
 - S2508A - operational (2 sensors at 115.3 and 128.8m)
 - S2514 - operational (5 sensors from 84.8 to 232m)
 - S2518 - operational (6 sensors from 128.4 to 343.9m)
 - S2518A - operational (4 sensors from 343.9 to 368.5m)
 - S2545 - destroyed (5 sensors from 110.6 to 255.9m) overlying LW21
 - S2545A - replacement VWP – 273.51m deep
 - S2655 - (new) inclined dyke VWP operational – (5 sensors from 95 to 259m)
 - S2656 - (new) inclined dyke VWP operational – (5 sensors from 87 to 248m)
 - S2656A - (new) dyke VWP in sand operational – (3 sensors from 144 to 154m)
 - S2658 - (new) operational – (4 sensors from 68 to 212m)
 - S2658B - (new) GW pump operational – 200m deep
 - S2659 - (new) operational – 225.4m deep
 - S2659B - (new) GW pump operational – 225m deep

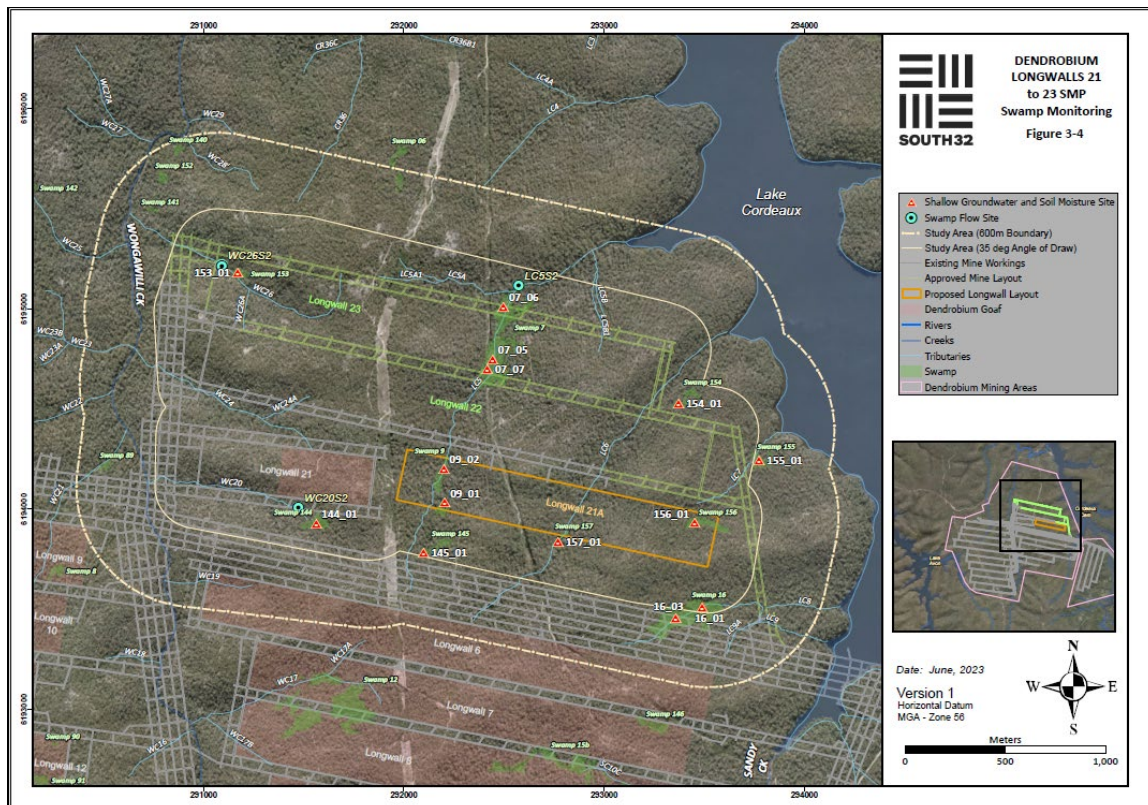


Figure 6: Swamp monitoring sites (paired shallow groundwater and soil moisture sites)

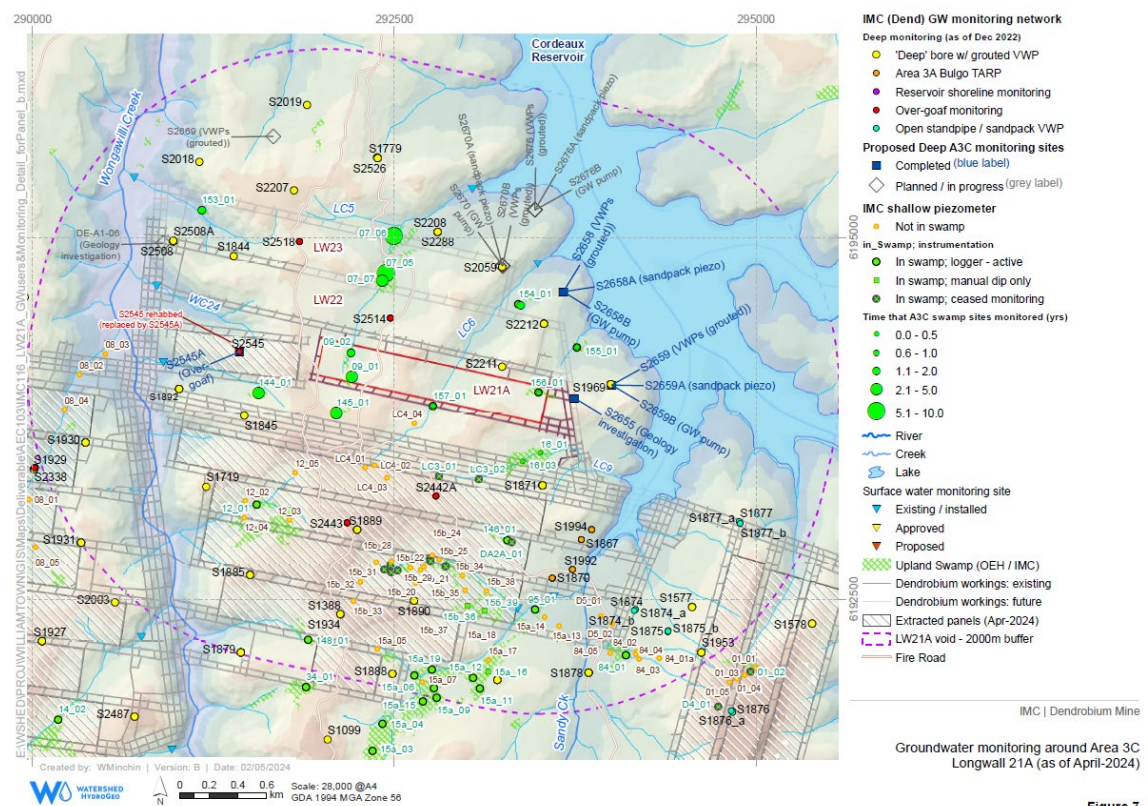


Figure 7: Groundwater monitoring sites (vibrating wire (VWP) and standpipe monitoring sites)

The Panel notes that the groundwater monitoring network is currently being expanded, mostly to monitor deeper groundwater depressurisation trends between the Area 3C longwalls and Lake Cordeaux. The outcome of these new barrier investigations and the final status of each site is not known so results are not included in the discussion below.

The perched groundwater and soil moisture monitoring network in the upland swamps provides adequate spatial coverage to assess any mining induced impacts associated with the extraction of LW21A. However, the depth coverage is lacking as there are no nested standpipes adjacent to any of these swamps to confirm whether there is connectivity between perched groundwater in the colluvium/weathered rock and the regional groundwater in the Hawkesbury Sandstone. The Panel recommends a nested monitoring site at the edges of each of Swamps 7 and 9 to monitor perched groundwater levels in the weathered rock and the regional water table in the sandstone to better assess potential mining induced impacts. These should be paired with (or close to) existing swamp monitoring locations.

There are seven (7) operational VWP locations across Area 3C with sensors monitoring shallow groundwater in the Hawkesbury Sandstone. There are no known standpipe locations although up to six (6) locations are proposed (Figure 3.5 in HGeo 2023a). This provides reasonable spatial coverage although there are only four (4) locations within 500 m and none overlying LW21A.

There are 11 operational VWP locations with multiple sensors across the Area 3C that monitor deep groundwater in the Narrabeen Group strata and the Illawarra Coal Measures. There are five (5) locations within 500 m of LW21A that provide adequate coverage of deep groundwater depressurisation trends.

An adequacy review of the groundwater monitoring network was completed in March 2024 by Australasian Groundwater & Environmental Consultants (AGE 2024). The author concluded:

the spatial coverage of groundwater monitoring within the footprint of mining Area 3C is considered adequate to track the vertical propagation of dewatering impacts into each overlying unit

And

Further consideration should therefore be given to identifying suitable groundwater level control sites in the lower Hawkesbury Sandstone (HBSS) and upper Bulgo Sandstone (BGSS) i.e. both outcropping units with the potential to be impacted by mining operations.

South 32's response to DPHI (South32 2024b) argued that there were existing multi-sensor VWPs in the western area of Area 3 that satisfied this recommendation, and that no new control sites were required.

The Panel concludes that the swamp and groundwater monitoring networks are adequate for monitoring shallow and deep groundwater trends in the vicinity of LW21A except for identifying the recharge and mining induced trends in the shallow Hawkesbury Sandstone groundwater system near swamps. The Panel recommends that the groundwater monitoring network would benefit from:

- a nested (standpipe) monitoring site at a suitable location (subject to site access) at each of Swamp 7 and Swamp 9 to monitor perched groundwater levels in the weathered rock and the regional water table in the Hawkesbury Sandstone,

for the purpose of improved groundwater model calibration, and long-term assessment of mining-induced drawdown and recovery trends.

5.3. UPLAND SWAMPS AND BIODIVERSITY

The development consent requires monitoring and reporting of aquatic flora and fauna and ecosystem function in relation to streams including 1st and 2nd order streams (Schedule 3 condition 4c of the Consolidated Consent) and also of the attributes of upland swamps including flora and ecosystem function (Schedule 3 condition 6c of the Consolidated Consent). The biodiversity considerations within the immediate LW21A area are largely related to the presence of two upland swamps (Swamp 9 on tributary LC5 and Swamp 156 in the upper catchment of LC7) and to the channels of tributaries, notably the pools and long section of channel along LC5 and LC6 (see locations on Figure 6 above).

The Panel notes that the Strategic Biodiversity Offset (SBO) was approved in December 2016. The latest SBO (South32 2023h) captures all swamps except Swamp 154 and therefore negates the need for any management or remedial actions in the relevant Area 3C SIMMCP (South32 2023d) and associated TARPs. However ongoing monitoring and reporting is important to assess the severity of impacts, and to collect data for modelling and research purposes. It is on this scientific basis that the Panel provides the following discussion on the adequacy of the swamp and biodiversity monitoring programs. The Panel's monitoring recommendations are for South32-IMC's consideration rather than for DPHI in considering appropriate SMP approval conditions.

5.3.1. Upland swamps

The SIMMCP (South32 2023d) outlines the monitoring proposed to determine impacts to upland swamps. Monitoring proposed includes a mix of:

- observational and photopoint monitoring,
- near surface groundwater and soil moisture monitoring, and
- swamp size and subcommunity mapping.

A summary of the monitoring proposed for each upland swamp is outlined in Table 4.

Table 4: Summary of upland swamp impact monitoring proposed in the SIMMCP

SWAMP	PHOTOPOINT MONITORING	GROUNDWATER MONITORING SITES	SOIL MOISTURE MONITORING SITES	SWAMP SIZE AND SUBCOMMUNITY MAPPING
<i>Swamps located above Longwall 21A</i>				
9	Yes	09-01 since 7/2020 09-02 since 9/2022	S09_01 since 10/2021 S09_02 since 3/2022	Yes – with replication following mining
156	Yes	156_01 since 2/2024	S156_01 since 1/2024	Yes – but will not be replicated
157	Yes	157_01 since 2/2024	S157_01 since 2/2024	Yes – but will not be replicated
<i>Swamps located adjacent to Longwall 21A</i>				
145	Yes	145_01 since 4/2020	S145_01 since 10/2021	Yes – with replication following mining

<i>Swamps within the 600 m study area for Longwall 21A</i>				
7	Yes	07_05 and 07_06 since 07/2015 07_07 since 1/2022	S07_05 and S07_06 since 12/2021 S07_07 since 9/2022	Yes – with replication following mining
16	Yes	16_01 and 16_03 since 2/2024	S16_01 since 1/2024 S16_03 since 2/2024	Yes – with replication following mining
144	Yes	144_01 since 8/2020	S144_01 since 8/2020	Yes – with replication following mining
154	Yes	154_01 since 11/2022	S154_01 since 9/2022	Yes – but will not be replicated
155	Yes	155_01 since 2/2024	S155_01 since 1/2024	Yes – with replication following mining

Swamp 154 within the catchment of LC7 is not covered by the Strategic Biodiversity Offset (SBO) (South32, 2023h). This swamp lies more than 500 m from LW21A but relatively close to LWs 22 and 23. Monitoring of ecosystem functionality at this site is therefore important; swamp size and subcommunity mapping should be continued. This will provide essential baseline data to determine in the future whether this swamp may be affected by more than minor impacts. However, monitoring of ecosystem functionality, particularly swamp size, does not extend to all swamps with potential to be impacted. Although Swamps 156 and 157 are covered by the SBO, it is recommended that an assessment of ecosystem functionality is undertaken following mining to assess the severity of impacts, and to collect data for modelling and research purposes.

The monitoring program involves a Before-After Control-Impact (BACI) design with data collected at impact and control sites for two years prior to mining and the impact sites compared to control or reference sites. The SIMMCP outlines the control or reference sites to be used in the monitoring program, summarised in Table .

Table 5: Summary of upland swamp control monitoring proposed in the SMP and SIMMCP

SWAMP	PHOTOPOINT MONITORING	GROUNDWATER MONITORING SITES	SOIL MOISTURE MONITORING SITES	SWAMP SIZE AND SUBCOMMUNITY MAPPING
6	Not established	Not established	Not established	Yes
22	Yes	22_01 and 22_02 since 8/2015	S22_01 since 7/2018	Yes
25	Yes	25_01 since 7/2009	S25_01 since 4/2023	Not established
33	Yes	33_01 since 7/2009 and 33_03 since 8/2015	S33_01 and S33_03 since 6/2023	Yes
84	Yes	84_01 since 7/2015	S84_01 since 7/2023	Not established

85	Yes	85_01 and 85_02 since 06/2015 and 85_03 since 5/2017	S85_01 and S85_02 since 7/2023 and S85_03 since 7/2017	Not established
86	Yes	86_01 and 86_02 since 6/2015 and 86_03 since 6/2017	S86_01 and S86_02 since 9/2023 and 86_03 since 7/2017	Not established
87	Yes	87_01 and 87_02 since 7/2015	S87_01 since 3/2023 and S87_02 since 5/2016	Not established
88	Yes	88_01 since 7/2015 and 88_02 since 8/2015	S88_01 since 3/2023 and S88_02 since 11/2022	Not established
131	Yes	Not established	Not established	Not established
132	Not established	Not established	Not established	Yes

The Panel is concerned that not all monitoring is being established in time to provide a minimum of two years of baseline data and that swamps previously deemed reference/control swamps have become or will become impact swamps.

The SIMMCP states that where the mining plan evolves and has potential to impact on a previous reference swamp, the data will be updated to reflect former reference data as pre-mining data and will no longer be included in the analysis as a control swamp. An example is Swamp 7 which was a reference site for Area 3B but will be impacted by mining in Area 3C. The Panel is concerned about the ability to determine long-term changes and potential for recovery given the lag between impacts to groundwater and changes in vegetation, as swamps change from reference to impact status.

The Panel's Advice re LWs22 and 23 (IAPUM 2022) made the following comment in relation to the performance indicator for ecosystem functionality:

As noted in the IAPUM Advice re Dendrobium LW19 (February 2021), the revised performance indicator of 'proportion of Banksia Thicket, Tea-tree Thicket and Sedgeland-Heath Complex does not overcome the problems of 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'. ... In its Advice for Dendrobium Longwalls 20 and 21 (December 2019), the IEPMC also had expressed reservations about vegetation change (including in proportions of sub-communities) as an indicator of ecosystem functionality and about the analysis of shallow groundwater impacts in previous mining.

It commented that 'As impacts on Swamp 7 have been offset by the Maddens Plains Strategic Biodiversity Offset, performance measures for Swamp 7 per se are now largely irrelevant'.

The Panel considers that the monitoring program (SIMMCP Appendix A: Table 1.1 Monitoring program) in Area 3C and the performance indicators (SIMMCP Appendix A: Table 1.2 TARPs) as defined in South32 (2023d) require attention. Specifically, the Panel notes:

- No monitoring of composition and distribution of vegetation species in Area 3C.
- For assessing the performance measure for ecosystem function, the performance indicator is limited to hydrological changes.

- Some measure of species composition or Total Species Richness (TSR) relating to changes in groundwater levels or soil moisture.

Further comment on the adequacy of the swamp ecosystem TARPs is provided in Section 7.1.

While monitoring of the sub-communities within the swamps and of the groundwater levels within the swamps are important indicators of possible ecosystem functionality, floristic data are also required to assess the severity of impacts, and to collect data for modelling and research purposes. Changes in the species composition and floristic data was explicit in an earlier SIMMCP for Area 3B (see Table 5-2 of the Dendrobium Area 3B SIMMCP as reproduced in Table 6):

Table 6: Explicit performance measure requirements in SIMMCP for Area 3B

DENDROBIUM AREA 3B

SWAMP IMPACT, MONITORING, MANAGEMENT AND CONTINGENCY PLAN

Table 5-2 Performance Measures, Potential Impacts, Mitigation and Contingent Measures for Swamps

Swamp	Performance Measure	Potential Impacts	How Monitored	Management Strategies	Exceeding Prediction	Offsets
Swamps 1a, 1b, 5, 8, 11, 14 and 23	Negligible erosion of the surface of the swamp	Gully erosion or similar	• Observation of swamps for new erosion or changes to existing erosion • Identification and measurements of erosion via airborne laser scanning (ALS) and on ground survey	a) upfront mine planning b) erosion monitoring (i.e. 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	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 (i.e. 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%).	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 distribution of species within the swamps	Swamp vegetation changes: • Swamp size • Species richness, distribution, composition and diversity • Vegetation sub-communities	• Repeat mapping of swamp boundaries • Repeat mapping of groundwater dependent community boundaries • Statistical analyses of species richness and diversity	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 rockbars and bedrock base and/or use of other remediation techniques i) reporting j) investigation and	• 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 standard error of the Control Group. • 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 standard error of the Control Group. • Mining results in a >10% (or otherwise statistically significant) decline in species richness or diversity during a period of stability or	Offset required immediately, if no remediation considered practicable. Offset required 5 years following remediation, if it is ineffective. This period can be extended to 10 years, with the agreement of the Secretary.

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Source: South 32 Dendrobium 3B Swamp Impact Monitoring Management and Contingency Plan - June 2015

The Panel sees no reason to apply a lesser monitoring requirement to swamps in Area 3C. Furthermore, it considers it essential that floristic monitoring be conducted to allow comparison with both previous and future mining activities, given that it is well understood that long-term data are needed to distinguish natural and mining-related changes in vegetation.

The Panel therefore recommends the following for South32-IMC's consideration:

- Detailed mapping of the boundaries of the swamps and vegetation sub-communities be undertaken for all impact and control swamps and that this mapping be replicated following mining for all swamps. This replication should certainly be undertaken for Swamps 156 and 157.
- South32-IMC ensure baseline data are collected from control/reference swamps in areas that will not be undermined for a period of at least two years prior to mining of LW21A.

- Monitoring of Swamp 154 should continue to include monitoring of total swamp size and size of groundwater dependent communities.
- South32-IMC may wish to consider re-starting monitoring of ‘Terrestrial flora – composition and distribution of species’ throughout Area 3C for all swamps within 120 m from longwalls approved and/or extracted to date.

5.3.2. Threatened species

The Panel is aware of the Strategic Biodiversity Offset (SBO) (South 2023h) sited at Maddens Plains and that the Reasons for Approval for LWs22 and 23 confirmed “*that the SBO satisfies impacts to the vegetation communities of the upland swamps, as well as other environmental attributes such as 1st and 2nd order stream and threatened fauna species (including the Littlejohn’s Tree Frog and Red-crowned Toadlet)*”. It is the Panel’s understanding that, to date, the Madden’s Plain offsets provide limited to no known habitat for the Littlejohn’s Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet or Giant Dragonfly.

The LW21A SIMMCP (South32 2023d) notes that mining in Area 3C ‘would likely cause a significant impact’ not only on the Littlejohn’s Tree Frog and Red-crowned Toadlet but also on the Giant Burrowing Frog, Stuttering Frog and Giant Dragonfly. The Stuttering Frog was not found in the Study Area and has not been recorded to date in the broader Dendrobium Mine Area despite a number of surveys. Populations of Littlejohn’s Tree Frog and Giant Burrowing Frog have been found in Area 3C and standardised transects have been or will be established in potential breeding habitat, along with pool level monitoring. The Red-crowned toadlet also has been recorded but is considered less at risk than the Littlejohn’s tree frog; however impacts detected for Littlejohn’s Tree Frogs are ‘likely relevant’ for the toadlet (Niche 2023).

In its 2022 Advice for LWs22 and 23 (IAPUM 2022), the Panel noted that:

- based on the recorded occurrences within the Study Area, the Littlejohn’s Tree Frog and potentially also the Red-crowned Toadlet should arguably be considered not as species dependent on upland swamps but as species dependent on the pools within streams, i.e. within the aquatic ecosystem, and
- should the Littlejohn’s Tree Frog and/or the red-crowned toadlet be classified as species dependent on the pools within streams, the proponent needs to show how they would meet Condition 17b of Schedule 4 of the Consolidated Consent that requires South32-IMC to ‘mitigate and/or offset any adverse impacts on groundwater dependent ecosystems, aquatic ecosystem or riparian vegetation’.

South32 (2024c) in the Swamp Rehabilitation Research Program (SRRP) Status Report deals with, *inter alia*, research into Littlejohn’s tree frog restoration within Dendrobium lease area and occupancy within the Maddens Plains offset site, as well as Giant Dragonfly research. Ongoing routine monitoring of threatened species, as required under SMP approvals, has a significant role in understanding the impacts on threatened species and thus on the role of offsets and the possibility of any rehabilitation program successes. The Panel is concerned that baseline data do not appear to be currently available for this purpose in Area 3C. While it has particular concern for the Littlejohn’s tree frog and Giant dragonfly data, it recommends that the monitoring system (baseline data, location and frequency) for Red-crowned toadlet and Giant burrowing frog be clarified.

5.3.2.1. Littlejohns Tree Frog (*Litoria littlejohni*)

The background studies on Littlejohn’s Tree Frog were commissioned in 2017 and produced valuable ecological data about habitat loss through drying of pools and absence of frogs in iron-stained areas

(South32 2023i). Increased iron staining, floc and suspended iron levels have characterised other small streams above Dendrobium including WC17 and SC10C as well as Wongawilli Creek (HGeo 2023d). The extraction of LW21 caused rock fractures sufficient to trigger TARP levels (two Level 2 and one Level 1) and iron staining (two Level 1 occurrences) on WC20 and WC24 ‘presently flowing on valley slope within proximity to Wongawilli Creek’ (South32 2023b).

It should be noted that habitats suitable for Littlejohn’s Tree Frog are also viable sites for Giant Burrowing Frog for which ‘significant impact’ has been determined and that changes in hydrology due to bedrock cracking of streams is likely to have a significant impact on Red-crowned Toadlet also (Niche 2023 Table 15). Both these species have been recorded within the 600 m study boundary for LW21A (Niche 2023 Figure 5).

However, to date there is very little practical outcome of the restoration program proposed for the Littlejohn’s Tree Frog. Possible sites for constructed ponds have been identified and in summer/autumn 2024 surveys ‘will begin to get baseline data’ on abundance and effective population size. The studies are to be completed by mid-2026. No Littlejohn’s Tree Frogs were located in the Maddens Plains offset area. There is therefore as yet no clear evidence that a viable population of Littlejohn’s Tree Frog can be re-established either within the Dendrobium leases or at the Maddens Plains site.

To date only very limited data are available for any part of Area 3C (Niche 2023). The species was detected in Swamp 7 in September 2022 (Niche 2023). It is known to occur along LC5 downstream of Swamp 9 and along LC6 downstream of Swamp 157. Swamp 7 is located on LC5 above approved LWs 22 and 23. LC5 upper catchment and Swamp 9 will be impacted by LW 21A, and Swamp 157 above LC6 will also be impacted directly by LW21A. Niche 2023 (Appendix 1) records ‘multiple’ BioNet records of Littlejohn’s Tree Frog above proposed LW21A; these records were noted in the SMP for LWs 22 and 23 and provided the basis for the Panel’s recommendations concerning this species.

The SIMMCP (South32 2023d) Figure 3-5 shows five (5) frog monitoring tributaries – WC20, 24, 26 and LC5, 6. As noted above, no data are available for these except in Swamps 7 and 9 i.e. none are presented for the pools along the creeks. Monitoring for Littlejohn’s Tree Frog along LC7 should be added and baseline monitoring commenced as soon as possible, noting that winter is the preferred season for monitoring.

5.3.2.2. Giant Dragonfly (*Petalura gigantea*)

For the Giant Dragonfly, the Swamp Rehabilitation Research Program (SRRP) (South32 2023i) notes that surveys have commenced in 2024 at five impact swamps and four control swamps. The location of these swamps is not specified and it may be that none are in Area 3C. The aim is to determine ‘*local and regional impacts of mining with habitat loss and degradation being identified as the main threats to the species*’. Monitoring to date has shown that mining impacts have dropped the groundwater level below the depth of larval burrows (>70 cm) and reduced the number of permanent pools (which are the sites where female dragonfly were most commonly recorded). In this SRRP study, no proposals for any necessary restoration work have been included. Yet loss of habitat may constitute an ‘adverse impact’ on a groundwater dependent ecosystem. In Area 3C, ‘significant impact is determined’, mainly due to impacts in the larger swamps DEN 07 and 09 (Niche 2023 Table 15). Targeted surveys for the species were recommended for DA3C but the data presented in the Niche Terrestrial Ecology Assessment are only from public sources (BioNet and the NSW Wildlife Atlas for Threatened Species). Similarly for LWs 22 and 23, targeted assessment of threatened species did not include Giant dragonfly (Niche 2021).

The Panel is concerned that no monitoring of Giant Dragonfly has been commenced before 2024, given that the species was identified as at risk in the 2019 Species Impact Study done by Niche and referred to in all subsequent Terrestrial Ecology Assessments. It notes that this study was a condition of the LW18 Approval in 2018 (South32 2023i).

Currently the only monitoring site in Area 3C is Swamp 7. If they are not already included in the swamps monitored for Giant Dragonfly as part of the SRRP (South32 2023i), Swamps 9 and 16 should be added to this program.

5.3.3. Aquatic fauna and flora

The Panel is concerned that no monitoring related to the stream ecosystem directly above LW21A (other than for frog species and related pool levels) is proposed. It notes also that the most recent assessment of aquatic flora and fauna is quoted as dating from 2021 (South32 2023c). It recommends that consideration be given to monitoring of appropriate fauna e.g. macroinvertebrates, rather than continuing the assumption that the perennial nature of the streams will not be greatly enhanced by bedrock cracking or other subsidence-related effects.

The Panel therefore recommends the following for South32-IMC's consideration regarding their monitoring programs:

- monitoring for Littlejohn's tree frog along LC7 should be added and baseline monitoring commenced as soon as possible.
- if they are not already included in the swamps monitored for Giant dragonfly as part of the SRRP (South32 2023i), Swamps 9 and 16 should be added to this program.
- the monitoring system (baseline data, location and frequency) for Red-crowned Toadlet and Giant Burrowing Frog should be clarified.
- monitoring of appropriate fauna e.g. macroinvertebrates, rather than continuing the assumption that the perennial nature of the streams will not be greatly enhanced by bedrock cracking or other subsidence-related effects.

6.0 SUBSIDENCE ASSESSMENT AND CUMULATIVE IMPACTS

This section provides the Panel’s assessment of the subsidence impacts of the proposed layout of LW21A on overlying swamps, ecosystems, water resources and Lake Cordeaux, and the likelihood of satisfying Schedule 3 Condition 3, and the adequacy of the TARPS in the Watercourse and Swamp Management Plans conditioned in Schedule 3 Conditions 4 and 6.

This is the third Panel advice for longwalls in Dendrobium Area 3C. Cumulative impacts arising from other panels in this area were not assessed in the respective SMPs and supporting technical reports. This advice does include an improved cumulative impact assessment for Area 3C and mining in adjacent areas but does not cater for any future longwalls that maybe located to the north beyond LW23.

6.1. SUBSIDENCE

The prediction of surface subsidence and its impacts on natural and built surface features has been undertaken by Mine Subsidence Engineering Consultants (MSEC) and comprises Attachment C of the SMP (MSEC, 2023a). The assessment of the environmental consequences of some of these surface subsidence impacts is addressed in other specialist reports that comprised part of the LW21A SMP. The assessment of subsurface impacts and consequences is also spread across a number of other specialist reports. This section of the Panel’s Advice is focused on the effects and impacts of mining-induced ground deformation.

6.1.1. Subsurface subsidence

The primary concern in relation to subsurface subsidence relates to the height of connective fracture. This has been a contentious issue at Dendrobium Mine for many years, during which time two empirically based models (Ditton and Tammetta) have been applied to calculate the height of connective fracturing. These produce significantly different outcomes. It is generally accepted that there is one section of the mine (Area 2) which has connective cracking networks to the surface and responds quickly to rainfall, and that initially there is groundwater depressurisation all the way from the seam to surface in Areas 3A and 3B, as predicted by the Tammetta model. However, there is evidence of subsequent recovery in upper perched horizons, which produces outcomes that are more consistent with the Ditton model. Field studies have been undertaken to evaluate the veracity of both and summary outcomes to date are noted in the *Swamp Rehabilitation Research Program Status Report – January 2024* (South32 2024c).

The LW21A SMP notes² that pre-mining and post-mining studies are undertaken in Area 3 at Dendrobium Mine to investigate and monitor the connected fracture network above the goaf and the upwards migration of the phreatic surface. However, it does not discuss outcomes. The Panel has assessed the potential for connective fracturing to surface above LW21A using both the Tammetta and the Ditton models, noting that the panel width for LW21A has been restricted to 256 m (as compared to 305 m for LW22 and many other longwall panels at Dendrobium Mine). The Tammetta model predicts connective fracturing to surface over the shallower western end of the panel. The Ditton model predicts that the height of free drainage will approach no closer to the surface than about 100 m. If connective fracturing were to occur over LW21A, then it is almost assured to occur to a greater extent over LW22 (because it is wider) and, therefore, the consequences would default to LW22.

² p9, LW21A SMP

The Panel concludes that:

- connective fracturing to surface is very unlikely to occur over LW21A but, if it did, the consequences would default to the wider adjacent LW22.

The Panel recommends that:

- future SMPs should include a comprehensive summary of the outcomes to that time of investigations into connective fracturing and depressurisation at Dendrobium Mine.

6.1.2.Surface subsidence

6.1.2.1. Conventional Subsidence

The methodology to predict conventional subsidence effects on the surface is well detailed in MSEC (2023a), as it has also been in previous SMPs for Areas 3B and 3C. The Panel's previous conclusions remain in place, effectively being that the methodology for predicting conventional subsidence effects transparently identifies the order of accuracy of the methodology, is adequately calibrated and is fit-for-purpose.

The assessment of the subsidence impacts to natural and built features due to conventional subsidence effects does not identify any particularly sensitive features that have not already been assessed in the SMPs for LW21 and for LWs22 and 23. Nor does it identify that these sensitive features may experience significantly elevated impacts due to incremental subsidence effects. However, the geographical extent of conventional subsidence impacts for drainage line, watercourses, swamps and ecology will obviously be greater. These are assessed in later sections of this Panel advice.

The Panel concludes that:

- The SMP adequately assesses conventional surface subsidence effects and impacts associated with the extraction of LW21A.

6.1.2.2. Non-conventional Subsidence

The methodology to predict non-conventional subsidence effects on the surface is not as well detailed in the SMP as in assessments for other longwall panels at Dendrobium Mine. However, it has been reviewed in detail on some of these past occasions and the Panel considers that these reviews suffice for current purposes. In particular, this is because the two features that are particularly sensitive to non-conventional subsidence effects, being Sandy Creek Waterfall and Wongawilli Creek, were assessed in detail when considering the SMPs for LW21 and for LW22 and LW23 and are unlikely to experience more than minor incremental effects due to the extraction of LW21A.

Nevertheless, careful consideration still needs to be given to potential impacts of incremental valley closure on Sandy Creek Waterfall and Wongawilli Creek. In both cases, the SMP makes the point that incremental closures are likely to be within the order of survey accuracy and seasonal ground movements. The Panel sought more detailed analysis from South32 in regard to Sandy Creek Waterfall. While the Panel accepts that any incremental movements for both structures may be within the order of survey accuracy and seasonal ground movements, they can still constitute an increase in valley closure.

In the case of Sandy Creek Waterfall which has an unknown but very likely, low tolerance to closure and which has already experienced some 18 to 20 mm of mining-induced closure, vulnerability to incremental closure effects cannot be dismissed. The subsidence assessment (MSEC, 2023a) recommends that closure across the waterfall is measured monthly during the last 600 m of mining

LW21A and that the existing TARP for this structure be updated to incorporate LW21A. The Panel agrees with this approach, and also recommends that:

- the monitoring interval for Sandy Creek Waterfall should be expressed in terms of meters of longwall retreat, rather than in time, and have regard to the location of recovery cut-throughs in the event that the longwall has to stop short of its currently planned finishing point.

6.2. WONGAWILLI CREEK AND SANDY CREEK

The principal Performance Measure (Schedule 3 condition 2 of the Consolidated Consent) that addresses impacts to Wongawilli Creek and Sandy Creek is

“The Applicant must ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than “minor impacts” (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary”

LW21A at its closest point is 1.17 km away from Wongawilli Creek, and with a predicted incremental effect on valley closure at Wongawilli Creek of less than 5 mm. Due to this distance and low predicted valley closure, Wongawilli Creek has not been assessed for bed fracturing and pool drainage impacts as part of the LW21a SMP. LW21A at its closest point is 0.98 km away from Sandy Creek, which also has a predicted valley closure less than 5 mm and also has not been assessed for bed fracturing and pool drainage impacts. The Panel agrees with the subsidence assessment that, due to these large set-back distances and low predicted valley closures, it is unlikely that the “minor impacts” performance measure for Wongawilli Creek and Sandy Creek will be exceeded due to surface fracturing.

Wongawilli Creek is expected to lose flows due to depressurisation of groundwater and diversion of surface water to the mine void. The numerical groundwater model predicts that cumulative surface flow loss at Wongawilli Creek site WWL due to all longwalls up to LW23 averaged over the intermediate term (2029-2060) is 4% of average baseline period flow at WWL (Table 9 of HGeo 2023c, with corrections as noted in Response to Agency comments, South32 2024d) and 6% averaged over the short-term (18 months after mining of LW21A). These values are time and weather dependent and will be higher in some years. The TARP process has not detected losses at WWL (e.g. the WWL result in Figure 6-12 of Watershed HydroGeo 2023). The Panel considers that these cumulative impacts on flow losses at WWL have been adequately considered. The Panel has no reason to consider that the predicted cumulative flow losses at site WWL are greater than negligible in terms of water resources consequences.

As recognised in the SMP, part of the first and second order tributaries feeding Wongawilli Creek and Lake Cordeaux are expected to have significant subsidence impacts, creek bed fracturing and flow losses and diversions, especially the lengths of LC5 and LC6 that overlie LW21A. Avoiding water impacts in these tributaries is not required under the consent conditions except in relation to performance measures for Wongawilli Creek (addressed by the discussion above) and Lake Cordeaux (discussed below).

The Panel concludes that:

- It is unlikely that the “minor impacts” performance measure (flows and levels) at Wongawilli Creek and Sandy Creek will be exceeded due to surface fracturing associated with LW21A.
- The Panel has no reason to consider that the predicted cumulative flow losses in Wongawilli Creek are greater than negligible in terms of water resources consequences.
- The cumulative impacts on flow losses at the Wongawilli Creek gauge (WWL) have been adequately considered.

6.3. CORDEAUX RESERVOIR

6.3.1. Subsidence impact assessment

The dam wall for Cordeaux Reservoir is located approximately 3.6 km north of LW21A and Avon Reservoir is located more than 4 km west of LW21A. The Panel agrees with the subsidence assessment that these structures are unlikely to experience adverse impacts due to the extraction of LW21A as currently proposed.

Cordeaux Reservoir is located 510 m northeast of LW21A, which places it 110 m beyond a 35° angle of draw and outside of the Dams Safety NSW Notification Area. It is predicted that at this distance, the reservoir will experience less than 20 mm of vertical displacement and that this is not expected to result in measurable conventional tilts, curvatures or strains (MSEC, 2023a). However, (MSEC, 2023a) also reports that far-field movements of up to 160 mm have been measured at distances of 300 m from completed longwall panels at Dendrobium Mine. Similarly, it is reported that non-conventional closure movements up to 35 mm and opening movements up to 40 mm have been measured at distances ranging between 180 m and more than 700 m from completed panels. However, the net strains associated with net movements are expected to be less than ± 0.5 mm/m.

MSEC (2023a) concludes that:

It is unlikely that fracturing will occur in the bedrock beneath Cordeaux Reservoir due to its distance from the proposed LW21A. In the unlikely case that minor and isolated fracturing did occur, it is unlikely that it would be visible in the bed of the reservoir due to alluvial deposits. An assessment of the surface water storage is provided in the report by the specialist groundwater consultant on the project.

The MSEC subsidence assessment does not extend to the potential impact of geological structures, such as dykes and faults, on water seepage from the Reservoir. South32-IMC's response to questions from the Resources Regulator (Attachment 4, Table 3) includes a report from MSEC dated 2019 concerning the possibility of increased subsidence due to geological discontinuities in Area 3B. It concludes that there are no measurable increases in subsidence effects.

The Panel notes that the number and spacing of mapped geological structures in Area 3C, shown in **Figure 8**, are greater than in Area 3B. However, South32 (2024a) provides details of extensive investigation of geological structures and notes that LW21A has been oriented between the two major dykes DD9 and DD7, neither of which have caused anomalous water make when intersected previously (by first workings). Similarly, two smaller dykes - DAD14 striking north-south at the eastern end of the longwall and DD7A – have not caused anomalous water inflow in first workings. The Panel has been advised that studies are ongoing into the dykes in the vicinity of LW21A. Monitoring of all dykes and water make is planned to continue during extraction.

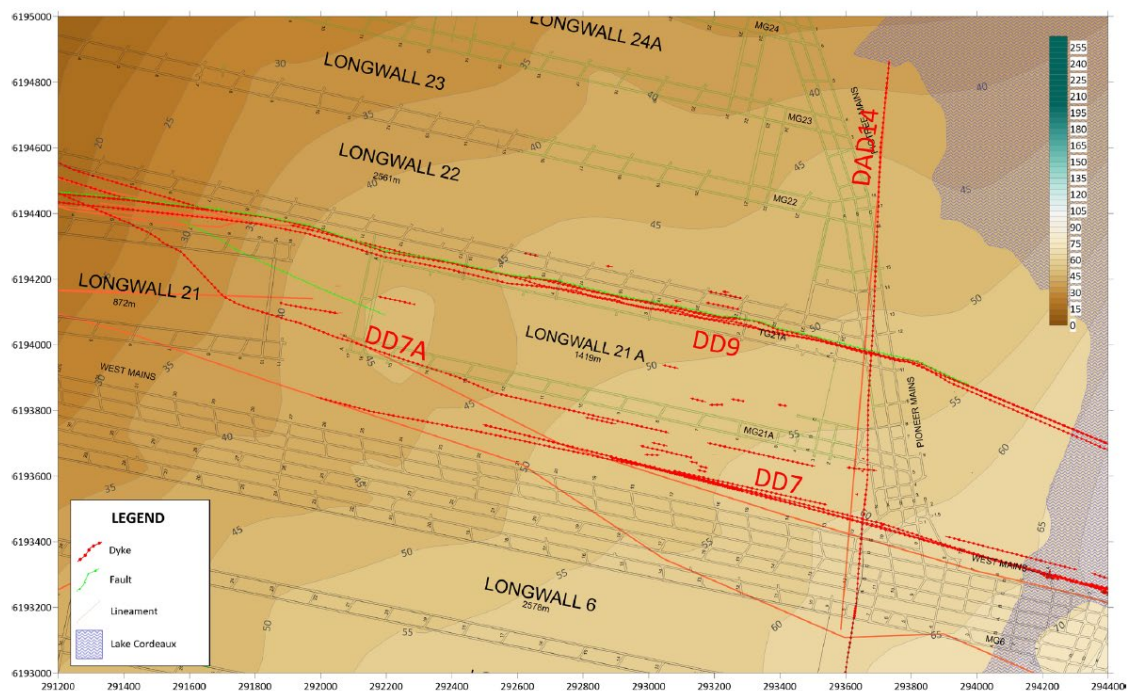


Figure 8: Geological structure and seam floor contours in the vicinity of LW21A (South32, 2024a)

Geological structures are not the only potential source of seepage from Cordeaux Reservoir into mine workings. Field studies in Area 3B adjacent to Avon Reservoir, supported by numerical modelling, have confirmed the potential for seepage as a result of mining-induced slippage on bedding planes and changes in the permeability of the strata between the mine workings and the reservoir.

In recognition of the potential for seepage from Cordeaux Reservoir into LW22 and LW23, the IAPUM Advice Report for the SMP for LW22 and LW23 recommended that:

Any approval of the SMP for LW22 & 23 should be conditioned on mining not commencing until predictions of seepage from Avon Reservoir due to mining in Area 3B have been validated to the satisfaction of the Department Secretary and found not to provide a basis for increasing the setback distance of 300 m

This recommendation was reflected in the SMP approval for LW22 and 23 (DPE 2022) (Schedule 4 Condition 2) that requires South32-IMC to submit a Seepage Validation Report prior to the commencement of these longwalls (HGeo, 2024). The report concludes that:

Based on the seepage calculations and observations in Area 3B, it is concluded that the current planned setback distances of 512 m and 312 m for Longwalls 22 and 23 in Area 3C is sufficient to prevent significant hydrological connectivity between the mining area and the lake.

Commentary on this conclusion is provided in Section 6.3.2.

6.3.2. Reservoir water losses

Two methods have been used to predict leakage from Lake Cordeaux: numerical modelling (Watershed HydroGeo 2023) and gradient based calculations (HGeo 2024). Numerical modelling predicts that cumulative leakage from Lake Cordeaux due to mining will range from 0.10 to 0.13 ML/day (Table 11 of HGeo 2023c). Less than 0.04 ML/d of that is due to LW21A (Watershed HydroGeo 2023). Total cumulative loss of inflow to Lake Cordeaux is predicted to be in the range 0.71-1.47 ML/day during 2026-2030 (period of highest losses), with approximately 0.08-0.2 ML/day associated to LW21A. These losses are derived from Table 7.5 and Table 7.7 of Watershed HydroGeo (2023). The values are predicted to reduce substantially in the long-term. The cumulative values include impacts of Areas 1, 2, 3A, 3B and 3C (LWs 21-23 and 21A). The predicted leakage of 0.10 to 0.13 ML/day is lower than Dam Safety NSW's (DSC) tolerable loss value of 1 ML/day (DSC 2018). The combined leakage and loss of inflow is therefore up to 1.6 ML/day and at least 0.81 ML/day according to the numerical modelling.

It has been assumed (e.g. Reasons for Approval of LWs 22 and 23) that the DSC tolerable loss of 1 ML/day refers only to leakage rather than also to loss of inflows to the reservoir. DSC (2018) does not distinguish types of loss, defining tolerable loss as "*Tolerable loss is the volume of water that can be lost from a reservoir without causing undue concern to the dam owner, the regulator, government, and the public*". Tolerable losses are most important in drought conditions when the inflow and hence loss of inflow are expected to be low; nevertheless, the sum of losses from Lake Cordeaux is predicted to be at a minimum 0.81 ML/day during 2026-2030. This is close enough to 1 ML/day that uncertainties in the modelling may become important.

A single hydraulic conductivity value has been used to represent the Hawkesbury Sandstone, rather than a range of possible hydraulic conductivities. The value chosen was 1×10^{-03} m/day (lower than the geometric mean of Hawkesbury Sandstone measurements of 1.8×10^{-03} m/day). For uncertainty analysis, only one deterministic scenario was applied based on Section 3.6.3 (Watershed HydroGeo 2023). Two deterministic uncertainty scenarios were applied for LW19 (Watershed HydroGeo 2022) but the higher hydraulic conductivity scenario has been discarded for LW21A. The justification given is "*Previous SMP assessments have simulated other alternatives, however the scenario above is a plausibly conservative estimate based on the data analysed (Section 3.6.3)*". As the hydraulic conductivity is potentially important for determining leakage from Lake Cordeaux, a more explicit justification is warranted. Based on the information provided, the Panel does not consider the groundwater modelling's deterministic uncertainty scenario is sufficient by itself to provide a conservative upper estimate of leakage from Lake Cordeaux.

The following limitations in the gradient (Darcy's Law) based calculations are noted:

- The use of a randomly selected hydraulic gradient for these calculations
- Application of a mean hydraulic conductivity, rather than a range of hydraulic conductivities, based on measurements from Area 3B (lower HBSS, BHCS and upper BGSS)

There is a need to refine the modelling of seepage when data become available from the multiple VWPs and standpipes drilled for the barrier zone investigations (HGeo, 2024).

The groundwater model recharge inputs have increased from 195 ML/day in the modelling undertaken for LW19 (Table 6.1 of Watershed Hydrogeo 2022) to 247 ML/day in the modelling undertaken for LW21A (Table 6.1 of Watershed Hydrogeo 2023) for essentially the same date range. This complicates the interpretation of the changes in the modelled flow losses and other water balance results between the two model versions. While the Panel acknowledges the potential need to update the groundwater model between SMPs, changes affecting interpretation should be explained in the history log (Appendix B of Watershed Hydrogeo 2023).

The Panel concludes that:

- Cumulative losses to leakage from Lake Cordeaux have been adequately considered, except in relation to the lack of hydraulic conductivity scenarios in the groundwater modelling uncertainty analyses.
- There is a need to refine the modelling of seepage when data become available from the multiple VWP and standpipes drilled for the barrier zone investigations.
- Losses (i.e. leakage plus loss of inflow) greater than 1 ML/day from Lake Cordeaux are possible (1 ML/day being the tolerable loss nominated in 2018 by Dam Safety NSW). The likelihood of 1 ML/day being exceeded due to LW21A and cumulative impacts can only be assessed by improved groundwater numerical modelling.

6.3.3. Reservoir water quality

The IEPMC (Section 3.4 of IEPMC 2019) and the previous Panel advice for LW18 (IAPUM 2020) expressed concern over long-term trends in water quality including potential for re-bounding groundwater to lead to seepage of contaminants through subsidence-induced fractures. Adverse trends in water quality in tributaries feeding Lake Cordeaux, which are likely due to mining, are noted in Section 3.4.2 of this Advice Report. If persistent and widespread, the trends could lead to greater than negligible consequences for water inflows and baseflows to Lake Cordeaux. Seepage incidents such as that observed in August 2023 could also affect Lake Cordeaux where groundwater rebound activates a metal-rich spring.

As noted earlier in this advice (Section 4.4.2), there have been adverse trends in water quality, including an increase in flow-corrected total manganese concentration at Sandy Creek Rockbar 5 of approximately 0.3 mg/L. For context, a concentration of total manganese near the reservoir dam greater than 0.05 mg/L would trigger a WaterNSW alert and greater than 0.2 mg/L would trigger a significant incident (Tables 7 and 8 of WaterNSW 2021). Due to the buffering capacity of the reservoir, the observed increase would need to be persistent and widespread before it influenced these triggers.

Section 4.6 of HGeo (2023a) concludes that “*Water quality effects on stored waters of the reservoirs are expected to be negligible and undetectable*”. This is not based on analysis of the significance of trends and potential future incidents on water quality of the reservoir. If adverse trends in water quality continue following LW22 then an increased level of analysis of the potential reasons for the trend and potential consequences is needed. Although it seems that beyond LW23 there will be no further increase in catchment area affected by Area 3C (South32 2024d), trends may exist and increase due to rebounding groundwater levels beyond the end of mining and so selected water quality monitoring should remain long-term.

Continued and long-term water quality monitoring, including trends, is needed to understand the potential consequences for water inflow and baseflows to Lake Cordeaux. The commitment to monitoring water quality for two years post-mining should be supplemented by a longer-term monitoring plan for selected sites.

A performance indicator is proposed at lake sites LC1 and LC2: “*As such, exceedance of the water quality performance measures will be quantitatively defined by “Mining results in two consecutive exceedances or three exceedances of the ± 3 standard deviation level (positive for EC, negative for pH and DO) from the baseline mean within six months... For Lake Cordeaux, the performance measure is applicable to monitoring site LC5_S1, LC_1 and LC_2”* (LC5_S1 is on tributary LC5 near its confluence with the reservoir). It is understood that this performance indicator will also apply at LC6_R1/LCS1 based on Table 1.1 of the WIMMCP (South 32 2023c). The ± 3 standard deviation level represents an extreme deviation. While this water quality TARP may be suitable for identifying contamination incidents, it may not detect trends in Lake Cordeaux water quality that have greater than negligible consequences.

The Panel concludes that:

- Potential long-term (including post-mining) changes in water quality (including that of Lake Cordeaux) remain a concern. Cumulative impacts have been adequately assessed for the purpose of the SMP. The assessment of potential risks and management options should be escalated if monitoring results continue to exhibit adverse trends in water quality.
- Long-term changes in water quality in all watercourses, including post-mining, remain a concern. If persistent and widespread, observed trends in water quality could lead to greater than negligible impact on Lake Cordeaux water quality.
- The proposed surface water monitoring is adequate. Additional reservoir monitoring sites may become advisable if Level 3 TARP triggers or trends are observed at LC1 and LC2.
- A new performance indicator related to trends in lake water quality including metal concentrations is required to supplement the proposed indicator.
- The commitment to monitoring water quality for two years post-mining should be supplemented by a longer-term monitoring plan for selected sites, including Lake Cordeaux sites.

The Panel recommends that any SMP approval for the extraction of LW21A should include a condition that requires:

- South32-IMC to adopt the following recommendations contained in Section 4 of the Seepage Validation Report of HGeo (2024):
 - *Groundwater levels and strata movements within and around dyke DD9 should be monitored as mining progresses in Area 3C. Observations and trends should be documented at each end of panel review and recommendations made with respect to adaptive management and further investigations if required.*
 - *Numerical and seepage models should be updated regularly to incorporate new observations from the barrier zone investigations. Seepage estimates should be reviewed after each longwall is extracted. Model re-calibration should be carried out if groundwater level observations fall outside expected ranges.*
 - *The mine water balance for Area 3C should be reviewed regularly and trends compared with those expected from numerical modelling. Mine water chemistry, including tritium and carbon-14 can provide an early indication of surface water inflows. Review of the water balance and water chemistry for Area 3C should form part of regular reporting.*
- Updated numerical groundwater modelling at the completion of the barrier investigation studies and nearby dyke investigations, including more extensive uncertainty analyses, to improve
 - predictions of baseflow reductions to and seepage losses from Lake Cordeaux and baseflow reductions in Wongawilli Creek, and
 - predictions of drawdown in the shallow and deep aquifers.
- A new performance indicator related to trends in lake water quality to assess against the Lake Cordeaux performance measure, which should include metals (at least total Mn, Fe and Zn, and others if advised by WaterNSW).
- A longer-term water quality monitoring plan for selected sites, including Lake Cordeaux sites, beyond the commitment to monitor water quality for two years post-mining.

6.4. PERCHED GROUNDWATER SUPPORTING SWAMPS

Predictions are for total subsidence of 2250 mm (Swamp 9), 1800 mm (Swamp 156), and 725 mm (Swamp 157). Swamps 9 and 157 lie in valleys and are predicted to experience 200 mm upsidence and 300 mm closure. Swamp 16 to the south-east is predicted to experience total subsidence of 30 mm and upsidence of 50 mm. Swamp 145 to the south will experience less than 20 mm of vertical subsidence.

Swamp 144 is located adjacent to roadways for LW21. A near-surface groundwater trigger was recorded at piezometer 144_01 and soil moisture probe S144_01 during the extraction of LW21 and this was deemed a Level 3 TARP trigger (South32 2023e).

The surface water assessment (HGeo 2023c) discusses the potential mining impacts on swamps and groundwater that sustains these swamps. Impacts are introduced by confirming that fracturing associated with LW21A will extend to the surface over at least part of the longwall footprint, resulting in depressurisation of the Hawkesbury Sandstone and the underlying strata. This fracturing is highly likely to cause the cracking of swamp substrates and the drainage of perched groundwater near surface (potentially affecting those swamps overlying or within 120 m of the longwall). This groundwater will drain laterally and/or vertically to a declining regional water table in the sandstone. The hydrologic impact is that swamps will be drier for longer periods resulting in reduced soil moisture, higher risk of erosion, increased risk of severe fire damage and degraded or changed ecosystems.

The assessment report (Table 13 in HGeo 2023c) confirms that the extraction of LW21A will result in:

- likely impacts to Swamp 9, 156 and 157,
- possible impacts to Swamp 7, 16, 144, 145, and 155, and
- unlikely impact to Swamp 154 (but a possible impact as a result of the extraction of LW22).

Swamp 7 appears to be sustained by the regional water table (in addition to periodic rainfall maintaining perched groundwater) and is also likely to be impacted as deep groundwater depressurisation expands and drainage occurs from the Hawkesbury Sandstone groundwater system. This loss of water is likely to commence with the extraction of LW22 but there will be a cumulative impact on this large swamp with the extraction of LW21A and then LW23.

The Panel agrees with this assessment and notes that the loss of all these swamps (except Swamp 154) has been offset in the SBO (South32, 2023h).

The groundwater assessment (Watershed HydroGeo 2023) provides a detailed assessment of regional groundwater impacts, mostly to those hydrostratigraphic units located below the regional water table in the Hawkesbury Sandstone. While perched groundwater is included in the numerical model and is monitored extensively across Area 3C (see Sections 4.3 and 5.2 of this Advice), the model has very low reliability in being able to predict local impacts to the perched groundwater systems that support headwater and valley fill swamps. This is because:

- the mesh geometry primarily focuses on mine layout and watercourses,
- swamps are not explicitly included in the model as recharge or discharge areas,
- the uncertainty of surface cracking and disturbance to the shallow substrate, and
- the lack of knowledge regarding connectivity with the regional water table.

Perched groundwater impacts are not discussed in the scenario modelling for the extraction of LW21A, with the emphasis being on matching observed and modelled water levels in shallow and deep groundwater systems, and predicting mine inflow volumes. However, Watershed HydroGeo 2023 does make the point that surface cracking may mean that perching in the near surface above each of the extracted panels may not occur post mining.

The Panel supports the current monitoring and management approach of identifying mining-induced impacts to perched groundwater within the swamps by maintaining extensive spatial monitoring and impact reporting via TARPs for selected locations and the required EoP reports.

The Panel concludes:

- near surface fracturing is highly likely to cause the cracking of swamp substrates and the drainage of perched groundwater (potentially affecting those swamps overlying or within 120 m of the longwall),
- there will be more than a minor change to the size, hydrology and ecosystem functionality of all swamps overlying LW21A (Swamps 9, 156 and 157), and
- cumulatively with the extraction of LWs 21 to 23, including LW21A, all of the remaining swamps across Area 3C are likely to be subject to more than a minor change to their size, hydrology and ecosystem functionality.

The Panel recommends that any SMP approval for the extraction of LW21A should include a condition that requires:

- the TARPs to be amended and expanded as discussed in Section 7.1.

6.5. REGIONAL GROUNDWATER

Predicted regional groundwater impacts (in both shallow and deep aquifers) are presented in Sections 6.4 and 6.5 (calibration) and Sections 7.3 and 7.4 (forecasting) of the groundwater assessment (Watershed HydroGeo 2023). The match between modelled and observed hydrographs across the broader area of Area 3C is reasonable although, the predictions at the closest VWP location (S1969) are less than optimal for the reasons explained in Section 4.4.3.

The predicted cumulative drawdown is presented as spatial drawdown contours at specific times for the water table in the upper Hawkesbury Sandstone and the lower Hawkesbury Sandstone (Section 6.4.4/ Section 7.3.2 and Appendix G - Figures G1 to G8 of Watershed HydroGeo 2023). The predicted drawdown is tens of metres across Area 3C, centred on each of the mined longwalls. The model predicts that hydraulic gradients will be maintained towards the major drainage lines and Lake Cordeaux over the life of mining, albeit at much shallower gradients. The model also predicts that water levels “*could recover after mining to be 5-20 m above pre-mining levels around much of Longwall 21A, primarily due to changes in permeability in the shallow strata*”. The Panel agrees that some recovery in the regional water table will occur but considers that such a prediction is premature given the increased fracturing/shearing along bedding planes and enhanced vertical and horizontal permeability is likely to increase groundwater discharge and delay shallow groundwater recovery for decades post-mining.

The predicted cumulative drawdown in the deep groundwater system is presented as spatial drawdown contours at specific times for the upper Bulgo Sandstone and the Wongawilli Seam (Section 6.4.4/ Section 7.3.2 and Appendix G - Figures G9 to G16 of Watershed HydroGeo 2023). The extent and magnitude of depressurisation is significant with predicted depressurisation levels in excess of 100 m. With the installation of bulkheads in the mine workings post-mining to contain rising groundwater, the model is predicting deep piezometric levels to fully recover by 2200. In the vicinity of the current longwall panels in Area 3C, levels are expected to be higher than the FSL of Cordeaux Dam.

No groundwater quality impacts are expected with the extraction of LW21A. If anything, mine water quality may become less saline with the leakage of fresher groundwater from the shallow groundwater system.

The predictive model suggests that inflow to Area 3C is likely to peak at approximately 4.5 ML/d at the completion of LW23. The model also suggests that the incremental inflow to Area 3C arising from

LW21A would be approximately 1.3 ML/d during and at the end of the extraction period. These estimates would appear reasonable based on a return to more average rainfall conditions.

The groundwater assessment (Watershed HydroGeo 2023) is comprehensive and provides a reasonable regional assessment of likely water level and depressurisation impacts to shallow and deep groundwater systems in Area 3C. However as per the Panel's most recent advice for Area 3C (IAPUM 2022), it is still concerned that long-term recovery of groundwater levels and pressures may not be adequately represented by the current modelling outputs.

The Panel recommends that any SMP approval for the extraction of LW21A should include a condition that requires:

- the numerical model be refined once the dyke investigations adjacent to LW21A are complete so as to more accurately predict the drawdown in the shallow and deep aquifers, and to quantify the impact on baseflows and leakage from Lake Cordeaux, and
- longer term, the post mining predictions of water level and pressure recovery be updated as validation data are obtained from historically mined areas that are permanently sealed.

6.6. BIODIVERSITY

The Reasons for Approval for LWs22 and 23 confirmed *“that the SBO satisfies impacts to the vegetation communities of the upland swamps, as well as other environmental attributes such as 1st and 2nd order stream and threatened fauna species (including the Littlejohn’s Tree Frog and Red-crowned Toadlet)”*. As per the Panel’s Advice re LWs22 and 23 (IAPUM 2022,) this renders performance measures for natural features offset under the SBO largely irrelevant.

For the immediate LW21A area, Swamp 9 is identified in Table 3-1 of the SBO while Swamps 145, 156 and 157 are shown in Figure 1 of the SBO (albeit with different boundaries and subcommunity mapping). The swamp mapping includes sedgelands and banksia thicket that will be impacted by any loss or perched groundwater. Swamp 154 is not identified in the SBO. It is the Panel’s view that impacts to this swamp have not been offset.

Threatened fauna likely to be impacted due to extraction of LW21A and listed as ‘predicted or known to occur’ at the Maddens Plains offset site are Giant burrowing frog, Littlejohn’s Tree Frog, Red-crowned Toadlet and Giant Dragonfly. The Panel notes that, to date, the Madden’s Plain offsets provide limited to no known habitat for the Littlejohn’s Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet or Giant Dragonfly. The Panel therefore raises concerns that impacts to these species have not been adequately considered and offset.

The Panel recommends that any SMP approval for the extraction of LW21A include the following:

- A requirement to undertake monitoring of Swamp 154 to determine whether greater than negligible impacts to ecosystem functionality occur and, if so, that this swamp is then offset.

A requirement to demonstrate that the Madden’s Plains offsets provide suitable habitat to offset impacts to the Littlejohn’s Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet or Giant Dragonfly. If this cannot be demonstrated then South32 be required to prepare a plan outlining how impacts to these species will be remediated or offset, if they occur.

7.0 PERFORMANCE MEASURES AND INDICATORS

Proposed performance measures have been derived from the Consolidated Consent and the LW 22 and 23 SMP Approval Conditions and consolidated in the LW21A SMP (South32 2023a). These performance measures are presented in Table 6.

Table 6: Proposed Subsidence Impact Performance Measures (reproduced from Table 4.1 in South32 2023a)

Dendrobium Development Consent	
Condition 1 – Schedule 3	
- 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 consequence; and - negligible diversion of water occurs from the lip of the waterfall to the satisfaction of the Secretary.	
Condition 2 – Schedule 3	
The Applicant must ensure that underground mining operations do not cause subsidence impacts at Sandy Creek and Wongawilli Creek other than "minor impacts" (such as minor fracturing, gas release, iron staining and minor impacts on water flows, water levels and water quality) to the satisfaction of the Secretary.	
Condition 3 – Schedule 3	
The Applicant must ensure the development does not result in reduction (other than negligible reduction) in the quality or quantity of surface water or groundwater inflows to Lake Cordeaux or Lake Avon or surface water inflow to the Cordeaux River at its confluence with Wongawilli Creek, to the satisfaction of the Secretary.	
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.	
Longwalls 22 and 23 SMP Approval Conditions	
Condition 6 – Schedule 3	
The Applicant must ensure that the development does not cause any exceedance of the performance measures in Table 1, to the satisfaction of the Secretary.	
<i>Table 1: Subsidence Impact Performance Measures</i>	
Swamps	
Swamps Den09, Den144, Den145, Den154	Minor environmental consequences including: - negligible erosion of the surface of the swamp; - minor changes to the hydrology of the swamp; - minor changes in the size of the swamp; - minor changes in the ecosystem functionality of the swamp; and - maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rockbar within the swamp.
Watercourses	
Wongawilli Creek	Minor environmental consequences including: - minor fracturing, gas releases and iron staining; and - minor impacts on water flows, water levels and water quality
Avon-to-Macarthur 330 kV transmission line and associated transmission towers (including tower TWR17-21)	- Always safe and serviceable; and - Damage that does not affect safety or serviceability must be fully repairable, and must be fully investigated and repaired at the cost of the Applicant.

The Panel notes in the new SIMMCP for Area 3C (South32 2023d, p35), South32-IMC has provided an updated definition of ecosystem functionality to address the concerns raised by the Panel in its last advice for LW19A. In this new SIMMCP, degraded ecosystem functionality is defined as:

“In addition to the size of groundwater dependent communities within a swamp, ecosystem functionality for specified swamps in Area 3C is measured by Area 3C mining induced hydrological changes (shallow groundwater) that results in piezometer remaining dry and not recovering following completion of mining and a year of average (or above) rainfall.”

A slightly more robust definition to adopt in the future might be:

In addition to a reduced size of groundwater dependent communities within a swamp, ecosystem functionality for specified swamps in Area 3C is measured by Area 3C mining induced hydrological changes (both perched and shallow groundwater) that result in an accelerated rate of groundwater level decline and the measured water levels at key piezometer sites not recovering following completion of mining and a year of average (or above) rainfall.

7.1. SWAMPS

A detailed list of the performance measures, and indicators/triggers relating to the swamps is included in the TARPs for the new SIMMCP for Area 3C (Appendix A: Table 1.2 of South 32 2023d). The Performance Measures in the table are grouped under:

- erosion,
- ecosystem function, and
- structural integrity of controlling rockbars.

each with their own performance triggers that apply to different swamps. The cross referencing between Table 1.1 (the entire Dendrobium monitoring program) and Table 1.2 (the Swamp TARPs) is difficult to interpret.

For Area 3C, the listed swamp performance measures, triggers and responses mostly apply to just Swamps 7, 9, 16, 144, 145 and 153. These don't align with the four swamps nominated in the SMP (Swamps: 9, 144, 145 and 154 – See Table 6 above). To cater for all cumulative impacts that are likely to occur across the current Area 3C area when LW21A is being extracted, the following swamps should be listed as impact swamps at least for those performance measures listed under 'Ecosystem Function': Swamps 7, 9, 16, 144, 145, 153, 154, 155, 156, and 157.

There are potential cumulative impacts to all these swamps as most are within 120 m of individual longwalls or associated roadways. Those swamps overlying LW21A (Swamps 9, 156 and 157) will experience more than a minor change to their size, hydrology and ecosystem functionality due to the extraction of LW21A. Those immediately adjacent to this longwall (Swamps 7, 16, 144, 145, 153 and 154) are likely to experience more than a minor change to their size, hydrology and ecosystem functionality due to the extraction of adjacent longwalls.

The Panel notes that the impacts to these headwater and valley fill swamps (except Swamp 154) have been offset in the SBO (South 32 2023h) and therefore the only enforceable swamp condition in the LW22 and 23 approval (DPE 2022) and any subsequent SMP approvals effectively relates to just one site - Swamp 154.

The nominated triggers are reasonable for identifying potential impacts, however the trigger responses are weak and will not protect swamps from more than minor (mining-induced) changes. The impacts will be more than minor so the existing TARPs are effectively just a reporting mechanism for the expected mining-induced impacts because of the SBO that is in place.

The Panel recommends that the TARP tables in Appendix A of the SIMMCP be amended and expanded in any SMP approval to include:

- the larger swamps (Swamps 7, 9, and 16), the overlying swamps (Swamps 156 and 157) and even the smaller remote swamps (Swamps 144, 145, 153, 154 and 155), so that the ‘more than minor’ impacts are reported in a timely manner and data are available for modelling and research purposes,
- a performance indicator/trigger relating to mining induced changes to the water table in the shallow groundwater system (i.e. at the additional standpipe monitoring locations at Swamps 7 and 9 as recommended in Section 5.2),
- the TARP for ‘Ecosystem Function – Minor changes in the size of the swamp’ be modified to make it clear that it is the extent of the whole swamp being considered in this TARP,
- the TARP ‘Ecosystem function – Minor changes in the ecosystem functionality of the swamp’ be modified to add ‘Area 3C mining-induced changes hydrological result in:
 - changes in the extent of sub-communities, particularly cyperoid heath and teatree thicket, within a swamp
 - changes in species composition and total species richness within a swamp as a whole and within sub-communities within the swamp

It is important that the swamp monitoring network and frequency be maintained to comply with Schedule 3 of the Consolidated Consent and the intent of the requirements in Condition 6.

7.2. WATERCOURSES AND ROCK BARS

A detailed list of the performance measures and indicators/triggers relating to the water courses is included in the TARPs for the new WIMMCP for Area 3C (Appendix A: Table 1.2 of South 32 2023c). The performance measures, triggers and responses are summarised under the headings of:

- Observational monitoring,
- Water quality,
- Pool water level,
- Surface water flow,
- Aquatic ecology, and
- Terrestrial fauna – Threatened frog species

Performance indicators (as represented by Exceeding Predictions in Table 6.1 and Table 1.2 of Appendix A of the WIMMCP) for water quality are commented on in Section 6.3.3 of this advice.

In its advice for LWs 22 and 23 (IAPUM 2022), the Panel noted that greater than “minor impacts on water flows, water levels” may be caused by cumulative groundwater depressurisation, which was not captured by the performance indicator for pool water levels. The Panel notes the response to this is provided in Table 9.1 of the WIMMCP (South32 2023c) and that relevant additional Level 3 and Exceeding Prediction triggers have been added to Table 1.2 of the WIMMCP. While not fully addressing the concern raised by the IAPUM in its previous advice, they do incorporate loss of baseflow into the Level 3 and Exceeding Prediction trigger. Considering the complexity of arriving at an ideal solution, they are considered to be a sufficient attempt to address the concern. The recommendation in the Panel’s LWs 22 and 23 Advice relating to “an appropriate threshold for changes in cease-to-flow days should be specified” has been addressed in the WIMMCP (Table 9.1) by clarification of the Method D application.

As explained in previous advice (IAPUM 2020), although the flow TARP process is reasonable for detecting changes to flow percentiles, the Panel does not consider it to be reliable for quantifying flow

volume losses, and considers that the groundwater modelling at present is the best practicable approach to that estimation.

Regarding surface water flow, the Panel repeats the previous advice of the IAPUM (IAPUM 2020) that the proposed TARPs and performance indicator are appropriate for detecting impacts but are not sufficient for quantifying volumetric losses. At present the best available volumetric loss estimates are those of the numerical groundwater model.

The surface flow loss TARP table in Appendix A of South32 (2023c) contains a footnote that explains calculation of flow loss into Lake Cordeaux: “*Surface water inflows calculation = [Impacts at gauged catchments (SCL2) + LC5 + LC6 + estimated impacts at ungauged but undermined catchments] / [total estimated inflow to LC].*” It is unclear how this relates to the performance indicators in Table 1.2 of the TARP and it is unclear what threshold of the calculated value is considered to constitute an exceedance of “negligible” flow reduction. The flow gauges at LC5 and LC6 are unlikely to be suitable for measuring volumetric losses because of measurement uncertainty at medium to high flows. The intended use of this performance indicator should be clarified.

The Panel concludes that:

- The nominated surface water performance indicators (as represented by Exceeding Prediction triggers) in the updated Area 3C WIMMCP are reasonable for the primary creeks and their tributaries.
- For surface water flow, the proposed TARPs and performance indicator are appropriate for detecting impacts but are not sufficient for quantifying volumetric losses. At present the best available volumetric loss estimates are those derived from the numerical groundwater model.

The Panel recommends that:

- The intended use of the flow loss performance indicator in the footnote in the WIMMCP, “*Surface water inflows calculation=...*” should be clarified.

8.0 SUMMARY CONCLUSIONS

The Panel has completed a detailed assessment and review of the historical data, technical reports and supplementary information supplied that relate to the subsidence management plan for LW21A together with recent site data related to adjacent dyke and Cordeaux Reservoir investigations. The Panel has focused its analysis on the cumulative impacts of LW21A and the adjacent approved or extracted LWs 21, 22 and 23 in Area 3C.

It notes that future assessment of cumulative impacts in general could be improved by provision of planned longwall layouts and baseline data for any expanded Area 3C (rather than individual longwalls) and by provision of summary data about cumulative impacts across all extracted longwalls within the area in successive End of Panel reports and SMP applications.

The following conclusions are grouped against each of DPHI's required scope items:

Adequate consideration of the cumulative impacts of the extraction of LW21A

The Panel has concluded that:

1. The SMP adequately assesses conventional surface subsidence effects and impacts associated with the extraction of LW21A. Connective fracturing to surface may occur over the shallower areas of LW21A, but if it did, the consequences would default to the wider adjacent LW22.
2. It is unlikely that Wongawilli Creek will experience adverse physical impacts due to the mining of the proposed LW21A.
3. There will be a reduction in surface flows for tributaries draining Area 3C due to surface fracturing associated with LW21A and the other approved longwall panels in Area 3C.
4. Seepage losses greater than 1 ML/day from Lake Cordeaux (i.e. leakage plus loss of baseflow inflow) are possible. This can only be assessed by improved numerical modelling.
5. Potential long-term changes in (reservoir) water quality, including post-mining, remain a key concern.
6. Near surface fracturing is likely to cause the cracking of swamp substrates and the drainage of perched groundwater potentially affecting those swamps overlying or within 120 m of any of the proposed longwall panels in Area 3C.
7. There will be more than a minor change to the size, hydrology and ecosystem functionality of all swamps overlying LW21A (Swamps 9, 156 and 157).
8. The cumulative impact of the extraction of LWs 21 to 23, including LW21A is that all of the remaining swamps east of Wongawilli Creek in the southern part of Area 3C (including Swamp 154 which is not offset) are possibly or likely to be impacted by more than a minor change to their size, hydrology and ecosystem functionality.
9. LWs 21 to 23 are likely to result in more than minor impacts to a number of fauna species known or predicted to occur over these longwalls, including the Littlejohn's Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet and Giant Dragonfly. There is concern from the Panel that these values have not been adequately offset by the SBO.
10. The groundwater assessment is comprehensive and provides a reasonable regional assessment of likely water level and depressurisation cumulative impacts to shallow and deep groundwater systems across Area 3C. However, the Panel is still concerned that long-term recovery of groundwater levels and pressures may not be adequately represented by the current modelling predictions.
11. Potential impacts on aquatic fauna are likely to be negligible.

Achieving the performance measure in Schedule 3 Condition 3 of the Consolidated Consent

The Panel has concluded that:

1. It is unlikely that the “minor impacts” performance measure (flows and levels) at Wongawilli Creek and Sandy Creek will be exceeded due to surface fracturing associated with LW21A.
2. The Panel has no reason to consider that the predicted cumulative flow losses in Wongawilli Creek are greater than negligible in terms of water resources consequences.
3. There will be a reduction in surface flows for tributaries draining Area 3C due to surface fracturing associated with LW21A and the other approved longwall panels in Area 3C however the impact on inflows is unlikely to be measurable.
4. Losses (i.e. leakage plus loss of inflow) greater than 1 ML/day from Lake Cordeaux are possible (1 ML/day being the tolerable loss nominated in 2018 by Dam Safety NSW). The likelihood of 1 ML/day being exceeded due to LW21A and cumulative impacts can only be assessed by improved groundwater numerical modelling.
5. Long-term changes in water quality in all watercourses, including post-mining, remain a concern. If persistent and widespread, observed trends in water quality could lead to greater than negligible consequences on Lake Cordeaux.

Adequacy of water and biodiversity monitoring programs

The Panel has concluded that:

1. The proposed surface water monitoring is adequate. Additional reservoir monitoring sites may become advisable if Level 3 TARP triggers or trends are observed at LC1 and LC2.
2. The commitment to monitoring reservoir water quality for two years post-mining should be supplemented by a longer-term monitoring plan for selected sites.
3. The swamp piezometer/soil moisture and groundwater monitoring networks are adequate for monitoring perched, shallow and deep groundwater trends in the vicinity of LW21A except for identifying the recharge and any mining-induced trends in the shallow Hawkesbury Sandstone groundwater system.
4. Monitoring of ecosystem functionality, particularly swamp size, does not extend to all swamps with potential to be impacted.
5. Not all biodiversity monitoring is being established in time to provide a minimum of two years of baseline data and swamps previously deemed to be reference/control swamps have become or will become impact swamps, compromising long-term analysis of possible impacts.
6. It is essential that floristic monitoring be conducted to allow comparison with both previous and future mining activities, given that it is well understood that long-term data are needed to distinguish natural and mining-related changes in vegetation.
7. Monitoring of threatened fauna, especially Littlejohn’s Tree Frog and Giant Dragonfly, does not appear to be adequate in timing or extent to date.

Commentary on the water and biodiversity TARPS

The Panel has concluded that:

1. The Strategic Biodiversity Offset (SBO) that is in place for all swamps except Swamp 154 negates the need for any management or remedial actions in the relevant TARPs, however ongoing monitoring and reporting is important to assess the severity of impacts, and to collect data for modelling and research purposes.

2. There are inconsistencies in the proposed performance measures in the SMP and those performance measures described in the SIMMCP. The performance measures and performance indicators/triggers in any updated SIMMCP should prevail.
3. The nominated performance measures listed in the updated Area 3C Swamp Impact Monitoring, Management and Contingency Plan) SIMMCP are reasonable for the both the ridgeline and valley-fill swamps, with the exception of the absence of a Performance Measure relevant to ecosystem functionality previously used in Areas 3A and 3B.
4. The nominated surface water performance measures in the updated Area 3C Water Impact, Monitoring, Management, and Contingency Plan (WIMMCP) are reasonable for the primary creeks, their tributaries and the receiving waters of Lake Cordeaux.
5. The nominated aquatic ecology and threatened fauna performance measures in the updated WIMMCP requires improved performance indicators.
6. There are no performance measures in the WIMMCP relating to shallow groundwater in the Hawkesbury Sandstone. A performance measure and water level trigger describing declines in the regional water table in this aquifer would be useful in assessing reduced creek flows and baseflow volumes discharging to Lake Cordeaux.
7. In regard to the explicit performance indicators and TARPs in the SIMMCP and WIMMCP:
 - 7.1. the nominated perched groundwater triggers are reasonable to identify potential impacts to each of the swamps, however the trigger responses are weak and will not protect swamps from more than minor (mining induced) changes.
 - 7.2. the impacts to swamps will be more than minor so the existing SIMMCP TARPs are effectively just a reporting mechanism for the expected mining-induced impacts.
 - 7.3. the performance indicators and TARPs for Ecosystem Function in the SIMMCP need to be improved by focussing on swamp extent and ecosystem health.
 - 7.4. for surface water flow, the proposed WIMMCP TARPs and performance indicator are appropriate for detecting impacts but are not sufficient for quantifying volumetric losses. At present the best available volumetric loss estimates are those derived from the numerical groundwater model.
 - 7.5. a new performance indicator related to trends in lake water quality including metal concentrations is required to supplement the proposed indicator.

9.0 SUMMARY RECOMMENDATIONS

The following summary recommendations are those that the Panel considers appropriate for inclusion in any SMP approval for the extraction of LW21A in Area 3C. Other recommendations are included in the body of this Advice which would assist South32-IMC in the preparation of future SMPs, SIMMCPs, WIMMCPs, EoP reports and groundwater modelling updates.

Based on the assessment of available information, the Panel recommends that DPHI consider the following for inclusion in any SMP approval conditions:

- The construction of a nested (standpipe) monitoring site at a suitable location (subject to site access) at each of Swamp 7 and Swamp 9 to monitor perched groundwater levels in the weathered rock and the regional water table in the Hawkesbury Sandstone, for the purpose of improved groundwater model calibration, long-term assessment of mining-induced drawdown and recovery and quantification of baseflow losses to Lake Cordeaux.
- Adoption of the recommendations contained in Section 4 of the Seepage Validation Report of HGeo (2024) being:
 - o *Groundwater levels and strata movements within and around dyke DD9 should be monitored as mining progresses in Area 3C. Observations and trends should be documented at each end of panel review and recommendations made with respect to adaptive management and further investigations if required.*
 - o *Numerical and seepage models should be updated regularly to incorporate new observations from the barrier zone investigations. Seepage estimates should be reviewed after each longwall is extracted. Model re-calibration should be carried out if groundwater level observations fall outside expected ranges.*
 - o *The mine water balance for Area 3C should be reviewed regularly and trends compared with those expected from numerical modelling. Mine water chemistry, including tritium and carbon-14 can provide an early indication of surface water inflows. Review of the water balance and water chemistry for Area 3C should form part of regular reporting.*
- Updated numerical groundwater modelling at the completion of the barrier investigation studies and nearby dyke investigations, including more extensive uncertainty analyses, to improve
 - o predictions of baseflow reductions to and seepage losses from Lake Cordeaux and baseflow reductions in Wongawilli Creek, and
 - o predictions of drawdown in the shallow and deep aquifers.
- Longer term, that the post mining predictions of water level and pressure recovery be updated as validation data are obtained from historically mined areas that are permanently sealed.
- A longer-term water quality monitoring plan for selected sites, including Lake Cordeaux sites, beyond the commitment to monitor water quality for two years post-mining.
- The SIMMCP be updated to better acknowledge the role and influence of approved offsets, and the reasoning behind current swamp monitoring programs.
- Update the SIMMCP and WIMMCP documents as soon as practical but no later than 6 months prior to the commencement of LW21A.
- A requirement to update the TARPS in the SIMMCP to include:
 - o the larger swamps (Swamps 7, 9, and 16), overlying swamps (Swamps 156 and 157) and even the smaller remote swamps (Swamps 144, 145, 153, 154 and 155), so that the ‘more than minor’ impacts are reported in a timely manner and data are available for modelling and research purposes,
 - o for ‘Ecosystem Function – Minor changes in the size of the swamp’ be modified to make it clear that it is the extent of the whole swamp being considered in this TARP,

- o for ‘Ecosystem Function – Minor changes in the ecosystem functionality of the swamp’ be modified to add ‘Area 3C mining induced hydrological changes result in:
 - changes in the extent of sub-communities, particularly cyperoid heath and teatree thicket, within a swamp
 - changes in species composition and total species richness within a swamp as a whole and within sub-communities within the swamp

and in the WIMMCP to include:

- o a new performance indicator related to trends in lake water quality to assess against the Lake Cordeaux performance measure, which should include metals (at least total Mn, Fe and Zn, and others if advised by WaterNSW).
- o a performance measure and indicator related to mining induced changes to the water table in the shallow groundwater system any at newly established standpipe locations.
- o clarification of the intended use of the flow loss performance indicator in the footnote in the WIMMCP, “*Surface water inflows calculation=...*”.
- A requirement to undertake monitoring of Swamp 154 to determine whether greater than negligible impacts to ecosystem functionality occur and, if so, that this swamp is then offset.
- A requirement to demonstrate that the Madden’s Plains offsets provide suitable habitat to offset impacts to the Littlejohn’s Tree Frog, Giant Burrowing Frog, Red-crowned Toadlet or Giant Dragonfly. If this cannot be demonstrated then South32 be required to prepare a plan outlining how impacts to these species will be remediated or offset, if they occur.

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APPENDIX A – DPHI REQUEST FOR ADVICE

Department of Planning, Housing and Infrastructure

Our ref: DA60-03-2001-PA-253

Emeritus Professor Jim Galvin

Chair - Independent Expert Advisory Panel for Mining

By email: j.galvin@bigpond.net.au

3 April 2024

Subject: Request for Advice – Dendrobium Mine LW21A Subsidence Management Plan

Dear Prof Galvin

I am writing to you to request advice from the *Independent Expert Advisory Panel for Mining* (the Panel) in relation to the Dendrobium Coal Mine (DA 60-03-2001).

South32 is seeking approval for a Subsidence Management Plan (SMP) for secondary coal extraction from Longwall (LW) 21A in Area 3C at the Dendrobium Coal Mine. A copy of the SMP application is provided as **Attachment 1**. The proposed longwall panel would be 256 metres (m) wide with a maximum cutting height of 3.9 m.

South32 has consulted with a number of agencies in the preparation of this SMP. A copy of agency advice and South32's response to this advice is attached for your consideration (see **Attachment 2-4**). Further feedback is being sought from these agencies by the Department and will be provided to the Panel when received.

The Department considers the key technical issues for LW21A relate to the potential impacts to surface water loss, water courses and swamps, as raised in the advice from WaterNSW and the Biodiversity and Conservation Division (see **Attachments 2 and 3**). In particular, the cumulative impacts of mining on water quality and quantity, and biodiversity have been raised as specific concerns.

I also draw the Panel's attention to changes made to the swamp trigger action response plan (TARP) following assessment of the most recent SMP for LW19A. The Panel may wish to review these changes and consider any recommendations for improvements to this and other TARPs.

As such, the Department is seeking advice from the Panel on:

- the cumulative impacts of the extraction of LW21A on water quality and water quantity, including:
 - whether these cumulative impacts have been adequately considered;

Department of Planning, Housing and Infrastructure

- whether the development would achieve the performance measure required under Schedule 3 Condition 3 of the development consent, with the extraction of LW21A;
- the adequacy of the water and biodiversity monitoring programs;
- the water and biodiversity TARPs and whether they:
 - enable measurement of compliance with relevant performance measures; and
 - have triggers (and associated performance indicators) that adequately reflect the relevant performance measures established under the consent, and that adequately inform the mine's overall performance with respect to environmental consequences.

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

To assist the Panel, I have attached a copy of the recent LW21 End of Panel Report (see **Attachment 5**) and most recent Four Monthly Impact Monitoring Report (**Attachment 6**).

It would be appreciated if the Panel can provide advice on the SMP by **3 May 2024**. Please contact me on 8274 1274 or jessie.evans@dpie.nsw.gov.au if you have any questions or require additional information for your review.

Yours sincerely,

A handwritten signature in black ink that reads "J Evans".

Jessie Evans

Director

Energy and Resource Assessments

Attachments:

1. LW21A SMP
2. WaterNSW pre-lodgement advice
3. BCD pre-lodgement advice
4. South32 response to agency pre-lodgement advice
5. LW21 End of Panel Report
6. Four Monthly Impact Monitoring Report (31 January 2024)

APPENDIX B – PANEL BIOGRAPHY

Emeritus Professor Jim Galvin (Chair)

Professor Galvin is an Emeritus Professor (University of New South Wales) in Mining Engineering and former member of the NSW Planning Assessment Commission. Professor Galvin is one of the world's foremost experts on underground coal mining and subsidence and has extensive experience in geomechanics, mine management and risk management. He was a member of the Independent Panel for the Southern Coalfield Inquiry (2008), several subsequent reviews of mining projects in the Southern Coalfield and most recently, Chair of the Independent Expert Panel on Mining in the Catchment.

Mr John Ross

John Ross is a Senior Principal Hydrogeologist with over 40 years' experience specialising in water resource, site contamination, infrastructure and natural resource management. John has held specialist management roles in public and private corporations and environmental consultancies. He has a Bachelor of Science (Geology) and a Certificate in Engineering Hydrology and Groundwater Hydrology.

John provides technical hydrogeological expertise and advice across the spectrum of water resource development, environmental/water planning, assessment and management projects, including environmental impact assessments, environmental audits and technical peer reviews, monitoring programs, remedial action plans, and groundwater licensing. John also has extensive experience in community and regulatory consultation across the eastern seaboard.

Associate Professor Lucy Reading

Lucy Reading is an Associate Professor of Hydrogeology at the Queensland University of Technology (QUT). She has completed a Bachelor of Applied Science (Honours) at QUT and a PhD in Environmental Engineering at the University of Queensland. Dr Reading now specialises in setting up groundwater monitoring networks with communities, assessing groundwater and surface water resources (quantity and quality) and assessing impacts of mining activities on groundwater. Lucy has over 20 years of experience in groundwater investigations, including roles with the University of Queensland and the Queensland Government.

Professor Neil McIntyre

Neil McIntyre is Professor of Water Resources at The University of Queensland and holds an MSc and PhD from Imperial College London. He specialises in the field of surface hydrology and has focussed on researching water security and impacts of mining on hydrology and water quality. His advisory roles have included serving on the Institution of Civil Engineer's Water Expert Panel (UK), the Steering Committee of the Commonwealth Leading Practice Sustainable Development Program, and the Independent Expert Panel for Mining in the Catchment.

Dr Ann Young

Dr Young is a retired academic who worked at the University of Wollongong's School of Earth and Environmental Sciences. Her PhD was a seminal study into the upland swamps on the Woronora Plateau. Between 2006 and 2017, she made submissions to the NSW Government on the environmental assessment of underground coal mining and, for some of that time, was a member of community consultative committees at the Dendrobium and Russell Vale mines. She was appointed to the NSW Government's Independent Expert Panel for Mining in the Catchment.

Nathan Garvey

Nathan is an experienced ecologist with over 20 years' practice in ecological assessment and approvals across eastern Australia. Nathan holds a Bachelor of Science and Graduate Diploma in Biological Science from the University of NSW and is a Certified Environmental Practitioner and a BAM accredited assessor. Nathan has delivered projects across a diverse range of sectors including mining, oil and gas, linear infrastructure, renewable energy and residential development. Nathan is practitioner of biodiversity assessment and approvals, including biodiversity assessment for major projects and EPBC Act referrals. He has strong expertise and experience in the assessment impacts to biodiversity arising from subsidence, including impacts to groundwater dependent ecosystems, and is one of NSW's leading experts in biodiversity approvals and offsetting. His services are actively sought by public and private sector clients.