ATTACHMENT C

Comments on Cumulative Impact Assessment, Subsidence Assessment, Surface to Seam Fracturing Assessment, Geological Structures Assessment, Impact on Coastal Upland Swamps

Dendrobium Mine Extension Project EIS (SSI-33143123)

Summary

The EIS:

- Needs to provide an adequate cumulative impact assessment for swamps, streams and endangered species on the Woronora Plateau;
- Needs to provide an adequate assessment of consequence for the very real potential for surface to seam connective fracturing above the longwalls;
- Details very high levels of subsidence that will impact (fracture, drain and likely destroy) Coastal Upland Swamp TECs and streams but down-plays the irreversible significance;
- Needs to improve the assessment of the potential for faults, lineaments and other geological structures to interact with subsidence, potentially leading to even greater fracturing and drainage in streams and swamps;
- Needs to be accurate and evidence-based about the inadequate/ineffective remediation of past impacts and clarify what the realistic remediation commitments will be for swamps and streams impacted by the Project;
- Includes models (e.g. swamp leakage model) that are not well calibrated, have not been validated or peer reviewed and which bear little resemblance to the observed hydrological impacts in swamps;

To address these matters:

- South32 need to provide a detailed and comprehensive cumulative impact assessment for the Coastal Upland Swamp TEC, all streams and threatened and endangered species above Dendrobium’s area of operations and on the Woronora Plateau more broadly.
- The mine design and layout re-designed to avoid (or significantly reduce/mitigate) impacts to the Coastal Upland Swamp TEC and streams in the area.
- The width of the longwalls be significantly reduced at a minimum to limit the potential for surface to seam connective fracturing and accompanying subsidence impacts,
- The issue of surface to seam connective fracturing and interaction of subsidence with geological structures be referred to the Mining Expert Panel for further independent expert assessment.
- The HEC (2022) seepage model is not used as a reliable point of reference for this assessment and the model and its predictions be referred to the Independent Mining Panel for further independent expert assessment.
- South32 validate their calculation of the swamp areas above Area 5 and follow the NSW Government Swamp Offsets Policy which requires offsetting of the entire area of the swamp (not an unvalidated proportion of the swamp).

- South32 address/assess the obvious break in continuity in the landscape due to past Elouera and Dendrobium impacts on Coastal Upland Swamp TEC.
- South32 validate the current approach of using factors to adjust subsidence predictions based on older IPM results and compare model predictions to the higher accuracy subsidence monitoring line surveys.
- Remediation is not relied upon as an appropriate or effective post-mining mitigation/ management mechanism.
- The lack of any previous remediation of impacted streams and swamps above Dendrobium longwalls, or appropriate future remediation options[1].

1. Cumulative Impact Assessment

The SEARs issued for Project mentions the requirements for Cumulative Impact Assessments in four main places:

- *an assessment of the likely impacts of all stages of the development, including appropriate worst-case scenarios, consideration of any* ***cumulative impacts****, taking into consideration any relevant legislation, environmental planning instruments, guidelines, policies, plans and industry codes of practice and with consideration to advice provided by agencies in Attachment 2*
- *consideration of the potential* ***cumulative impacts*** *due to other developments in the vicinity (completed, underway or proposed); a*
- *An assessment of* ***any potential cumulative impacts on water resources****, and any proposed options to manage the cumulative impacts;*
- *The EIS should include a* ***cumulative impact assessment*** *and consider all relevant past, present and reasonably foreseeable actions, and programs and policies that are likely to impact water resources. Where impacts from a new project are considered small, these need to be considered with the impacts from existing development and the cumulative impact must be assessed to determine if a threshold of acceptable total impact may be crossed.*

Section 7 of the EIS Main Report identifies that:

Cumulative impacts are considered to be the total impact on the environment that would result from the incremental impacts of the Project in addition to past, present and reasonably foreseeable planned developments that may interact with Project impacts.

Past, present and reasonably foreseeable coal mining impacts is considered readily quantifiable. Mining impacts are also occurring in the Metropolitan Special Areas from operations and nearby Russell Vale and Metropolitan mines.

Neither the subsidence report, biodiversity report or stream report accurately detail the cumulative impacts of operations at the existing Dendrobium mine together with previous

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[1] Noting that there is no scientific evidence that upland swamp TECs can be successfully remediated once impacted by longwall mining (Commonwealth of Australia 2014). Current stream remediation proposals (e.g. WC21 and Donalds Castle Ck remediation plans) lack objective measures/metrics for rehabilitation 'success' and proposed remediation sites are a very small proportion of the overall impacted stream. As a result, once they occur, most if not all longwall impacts are likely to remain in perpetuity.

mining in other areas on the Woronora Plateau (e.g. Elouera Mine, Russell Vale mine, Metropolitan mine).

A simple example of this is that there have been over 700 surface impacts (cracks, fractures, swamp drainage, pool drainage, lack of flow, biodiversity impacts, cliff/rock falls, stream water quality impacts) identified for the Dendrobium Mine Area alone (Longwall 1 to 17 End of Panel Reports; Krogh 2013). An illustration of the identified impacts is provided in Figure 3. It is highly likely that this represents a significant underestimate of the impacts that have occurred in this area[2]. It is also noticeable that a number of these impacts have occurred well outside the footprint of the longwalls themselves. The magnitude of this cumulative damage/impact should have been identified in the EIS documents.

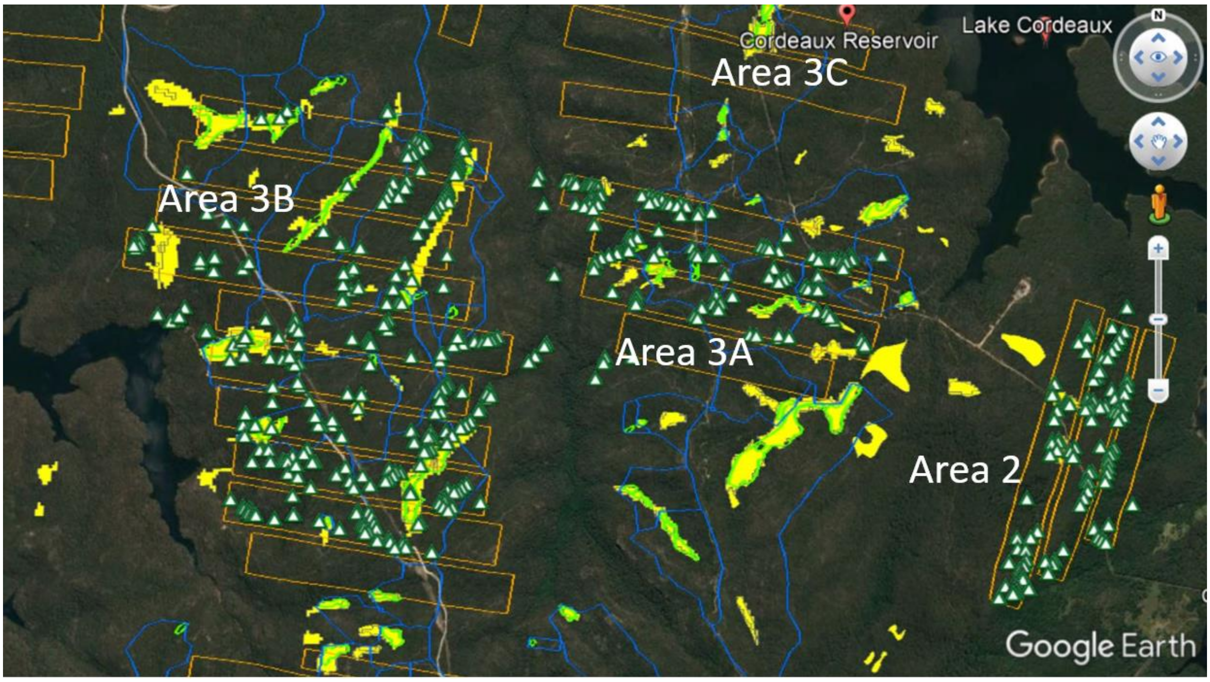

Figure 3. Recorded surface impacts at Dendrobium Mine (green triangles). Longwalls shown in orange. Coastal Upland Swamps shown in yellow.

<u>Cumulative Impacts to Swamps</u>

In terms of swamps, mining at Dendrobium has already irreversibly impacted approximately 45 Ha of the Coastal Upland Swamp TEC; including Swamps 1[3], 12, 15b, 1a, 1b, 5, 8, 10, 11, 13, 14, 23. Illawarra Coal operations at Dendrobium Mine[4] have impacted and potentially destroyed the hydrological processes of every swamp that has directly overlain the longwalls.

Cardno (2022) stated, *"Previous longwall and bord and pillar mines have impacted approximately 5 square kilometres (km2) or 35% of the total 14.3 km2 of swamp habitat within the upper Avon and Cordeaux River catchments. Longwall mining in Areas 1, 2, 3A, 3B at the Dendrobium Mine resulted in increased rates of groundwater recession, reduced soil moisture, reductions in size and/or changes in the vegetation community in swamps.*

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[2] Impacts to swamp hydrology were excluded from the earlier landscape impact assessments.

[3] In Dendrobium Area 2.

[4] And the earlier Elouera Mine.

Following extraction of Longwalls 9 to 12 in Area 3B, each overlying swamp (at least those monitored: Swamps 1a, 1b, 3, 5, 8 and 10) experienced reductions in shallow groundwater. Reductions in soil moisture was observed in Swamps 5, 8 and 11 (BHP Billiton Illawarra Coal [BHPBIC] 2015, South32 2016b, 2017). Examination of shallow groundwater levels in swamps suggests reductions of up to 1 to 2 m in groundwater levels following longwall extraction. Water levels generally return to baseline levels following large rainfall events, but only for short periods of time (several days following the rainfall event).

Monitoring results of shallow Hawkesbury sandstone aquifers adjacent to swamps or perched aquifers within swamps suggest that the Dendrobium Mine has impacted each swamp that has been mined under and each immediately adjacent swamp (Advisian 2016)".

Scientific evidence to support the assessment that longwall mining causes very significant changes to these upland swamps is available in peer-reviewed papers (e.g. Mason et al 2021, Krogh et al (2022 in press)) and other reports (Keith et al 2020, 2021, 2022). It is noted that the Biodiversity Assessment largely ignores these published papers/reports, despite the Mason et al (2021) paper dealing directly with impacted swamps above Dendrobium mine. In particular, Mason et al (2021) identified that:

Mined wetlands were persistently drier, retained water for shorter durations and exhibited less spatial differentiation than unmined wetlands. This quantitative evidence of severe, persistent hydrological change following resource extraction reinforces earlier observations and has important implications for biodiversity and provision of ecosystem services to a large urban population.

Keith et al (2022)[5] identified that:

Soil moisture showed very strong evidence of decline without recovery in mined swamps, but was maintained in reference swamps through eight years. Relative to burnt reference swamps, burnt and mined swamps showed greater loss of peat via substrate combustion, reduced cover, height and biomass of regenerating vegetation, reduced post-fire plant species richness and abundance, altered plant species composition, increased mortality rates of woody plants, reduced post-fire seedling recruitment, and local extinction of a hydrophilic fauna species. Mined swamps therefore showed strong symptoms of post-fire ecosystem collapse, while reference swamps made available under regenerated vigorously. We conclude that an anthropogenic stressor may diminish the resilience of an ecosystem to recurring perturbations, predisposing it to collapse. Avoidance of ecosystem collapse hinges on early diagnosis of mechanisms and preventative risk reduction. It may be possible to delay or ameliorate symptoms of collapse or to restore resilience, but the latter appears unlikely in our study system due to fundamental alteration of a critical ecosystem driver.

In previous end of panel reports vegetative and total species impacts to swamp TECs have already been identified. For example, Biosis (2016) stated:

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

[5] Whilst Keith et al's (2022) study dealt with upland swamps on the Newnes Plateau, the findings are equally relevant to mining and fire affected swamps on the Woronora Plateau. Indeed, the exact same effects (longwall mining desiccation, peat combustion and erosion) were identified for swamps 18 & 19 above older Elouera longwalls after the Christmas 2000 fires (Krogh 2007). It is simply a matter of time before fire goes through these areas again, at which time the same significant impacts and community changes will almost certainly occur.

Suggestions that the swamp vegetation has not or will not change in relation to the observed hydrological impacts are not scientifically rigorous and lack credibility.

Other mines (e.g. Elouera Mine, Russel Vale Mine, Metropolitan Mine) have also impacted Coastal Upland Swamps on the Woronora Plateau and their contribution to the cumulative impact to the Upland Coastal Swamp TEC should be added to that of the swamps already impacted by Dendrobium Mine, together with those proposed to be impacted by the current Dendrobium Area 5 proposal[6]. The Science Economics and Insights Division (SEI) of the Department of Planning and Environment are currently reviewing all such impacts and the current best estimate of impacted swamps is contained in Table 1. The location of these putatively impacted swamps is illustrated in Figure 4. It should be noted that the swamp area estimate is subject to the mapping procedures used and that these numbers and maps are currently a work in progress. SEI is continuing to refine these numbers/areas. Nevertheless, the obvious break in continuity in the landscape due to Elouera and Dendrobium impacts (red areas; bottom left in Figure 4) is notable. Approving further destruction of Area 5 swamps[7] will simply increase this disconnection.

It is noted that the current 2022 Dendrobium Area 5 longwalls are likely to irretrievably alter the hydrology of an estimated 17 Ha of upland swamp (Table A1, Appendix A), although Niche have discounted[8] this area to ~9 Ha. It is noted that Niche's (2022) mapping has not been validated or peer reviewed and they have not followed the NSW Government Swamp Offsets Policy which requires offsetting of the entire area of the swamp (not an unvalidated proportion of the swamp).

	Area (Ha)	**Number of Swamps**	**Percentage of Total Area**
Total Undermined Impacted	194	54	3.66%
Total Proposed Undermining	151	43	2.85%
Total Undermined, Impact not known	1921	198	36.2%
Total Impacted by mine water	N/A	1	
Total Swamp Area (OEH)	4729		
Total Swamp Area (Fryirs and Hose 2016)	2568		
Total Swamp Area (OEH & Fryirs & Hose 2016)	5294	1000+	

Table 1. Estimated Area of Swamps combined with the number of swamps and proportion of total TEC area impacted. Swamp mapping by OEH and Fryirs & Hose (2016).

[6] And other swamps proposed to be undermined in Area 3A and 3C (and possibly other areas in the future within the mine lease).

[7] And further impacts to swamps in Areas 3A, 3C and 6 in the future.

[8] In SEI's view inappropriately so. Niche's approach to swamp delineation (see the Biodiversity Report) has not been fully detailed (to be repeatable), validated or peer reviewed.

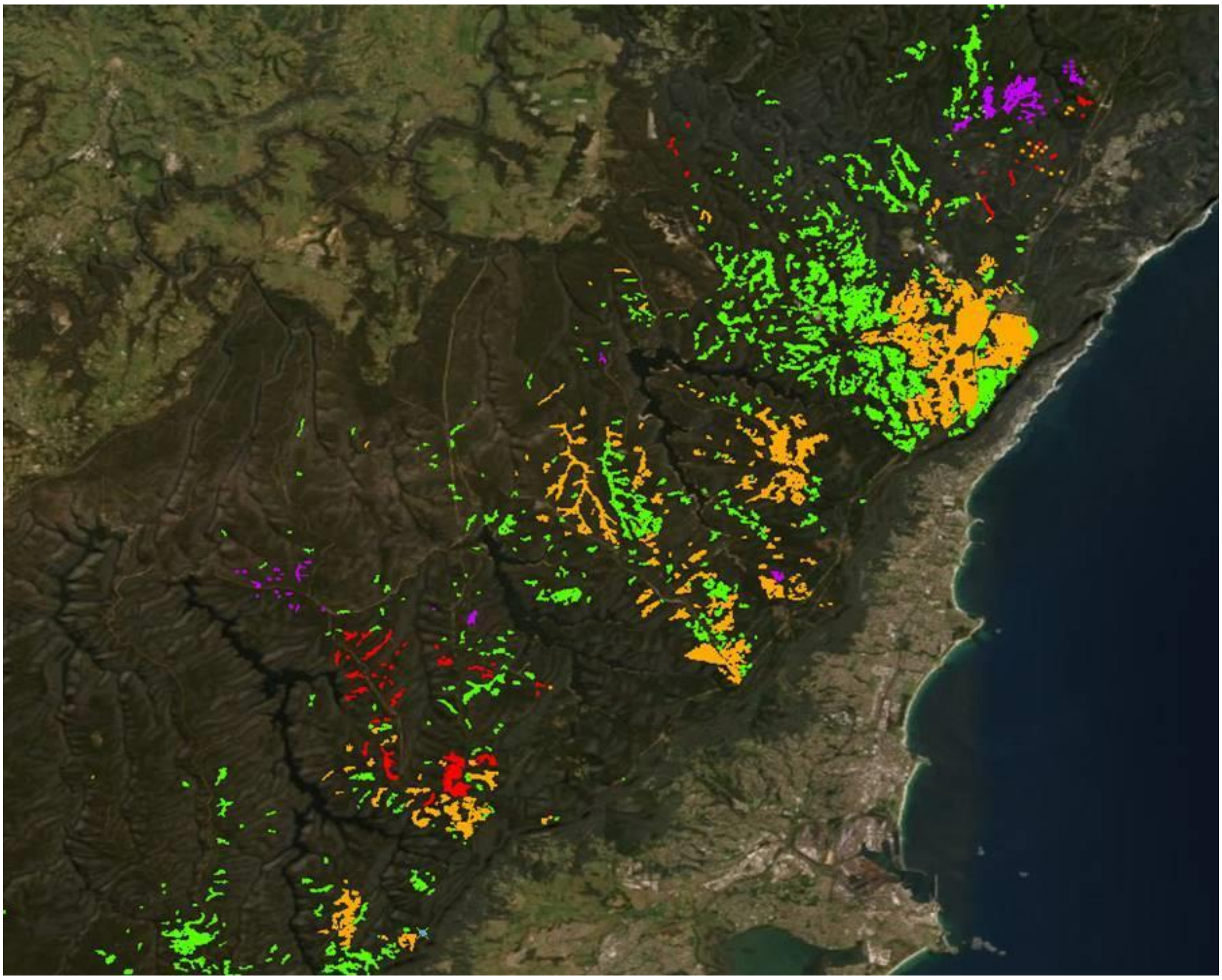

Figure 4. Swamp mapping by Fryirs & Hose (2016) and OEH. Undermined swamps shown in red where some evidence exists to suggest impact – mostly based on piezometer levels and/or observed fracturing. Undermined swamps with no monitoring data available to assess impact shown in orange. Proposed undermined swamps (including Dendrobium Area 5 swamps) shown in purple.

Cumulative Impacts to Streams

Cardno (2018) identified that:

- *Mapping by ICEFT indicated that approximately 97 km, or 14 %, of the total 556 km length of watercourse habitat within the upper Avon and Cordeaux Catchments has experienced mine subsidence movements which could have resulted in loss of flow and reduction in pool water level;* and
- *Reductions in water levels and flow in Wongawilli Creek, Donalds Castle Creek, WC21, WC15 and LA4 were associated with a loss of aquatic habitat and a likely reduction in biota. In Wongawilli Creek, the reductions in water levels and flow would have resulted in a direct loss / partial loss of aquatic habitat along approximately 1.4 km of the watercourse, representing about 10 % of its 12 km total length. There had also been a loss of aquatic habitat along the length of Donalds Castle Creek affected by loss of flow and reductions in water levels.*

Cardno (2022) identify that:

Collectively, the length of watercourse that has experienced indirect and direct mining impacts (147.6 km) is estimated to be 21%[9] of that present in the upper Avon and Cordeaux River catchments (717 km). The majority of this would be first and second order drainage lines. However, impacts of groundwater depressurisation have been observed in Wongawilli Creek. During inspections in May 2018, a reduction in flow and a series of disconnected pools were observed within an approximate 1,400 m section of Wongawilli Creek and representing about 10% of the total 12 km length of Wongawilli Creek. This section included Pool 44 to Pool 53. Surface flow was observed just downstream of the confluence with Wongawilli Creek tributary WC21. Although fracturing in one rockbar at Pool 43a in Wongawilli Creek was observed during extraction of Longwall 9 in December 2012, this is not considered to be the cause of the reduced flow and reduction in pool water levels here. Rather, assessment of flow and water level data with rainfall and rates of pool water recession from before and after commencement of mining and the timing of fracturing suggest mining induced groundwater depression coinciding with low rainfall explain the low flow and water levels observed in Wongawilli Creek (HGeo 2018). Low pool water levels were not restricted to Pool 43a but were also observed in Pool 49. Pool water levels also begun to decline 2 years before the fracture was observed. The pool recession rate, calculated as the decline in pool level between consecutive observations averaged over the number of days, was not greater after the observation of the fracture. Mining is considered to be the primary cause of reductions in groundwater levels in the lower Hawksbury Sandstone and upper Bulgo Sandstone. This has contributed to a reduction in baseflow in Wongawilli Creek, which was most noticeable during periods of low rainfall and greater evapotranspiration that occurred in 2018. Extraction of each individual longwall would be expected to contribute to reductions in groundwater levels. HGeo (2018) estimated baseflow capture of approximately 0.3 megalitres per day (ML/d) in Wongawilli Creek, this would be a significant fraction of flow under conditions of very low rainfall such as those that have occurred during 2018 with typical surface flow below 1 ML/day (HGeo 2018).

It is noted that these stream impacts are not placed in the context of all streams impacted by mining on the Woronora Plateau.

Wongawilli Creek and Donalds Castle Creek also currently have a minor environmental consequence performance measure under the Dendrobium approval (Table 2); where '*Minor*' is defined as "*Not very large, important or serious*".

Wongawilli Creek Donalds Castle Creek	Minor environmental consequences including: • *minor* fracturing, gas release and iron staining; and • *minor* impacts on water flows, water levels and water quality.

Table 2. Dendrobium Approval Condition for Wongawilli and Donalds Castle Creeks

Past impacts to Wongawilli Creek and Donalds Castle Creek have already exceeded the minor impact performance measure, with Wongawilli Creek Pool 43a draining completely.

[9] An increase of ~50km (or 7%) from their 2018 estimate.

Photo 1: WC_Pool 43a, looking upstream. Taken on 17/10/2017.

Photo 2: WC_Pool 43a, looking upstream. Taken on 14/11/2017.

Photo 3: WC_Pool 43b, looking upstream (downstream end of pool). Taken on 17/10/2017.

Photo 4: WC_Pool 43b looking (upstream end of pool), looking upstream. Taken on 14/11/2017.

Source: DENDROBIUM AREA 3B, ILLAWARRA COAL UPDATE REPORT 28 November 2017

On 16 December 2016 the Secretary of the former DPIE approved the SMP for Longwalls 14 and 15. *Condition 13* of the Approval required the Applicant undertake remediation programs for WC21 and DCC, to the satisfaction of the Secretary. It is noted that the Area 5 surface water assessment suggests additional losses in Donalds Castle Ck at DCU will occur as a result of Area 5 mining. Flow reductions and pool drainage continue to occur in Donalds Castle Creek and its tributaries due to past mining operations which has implications for future performance measure issues.

The Surface Water Assessment (HEC 2022) states:

surface water flow diversions are likely to occur along the sections of watercourses that are located directly above and adjacent to the proposed longwalls. Watercourses, where sufficient valley closure occurs, may experience dilation fracturing and shearing of rock strata and development of a fracture network beneath the watercourse bed. This would result in the diversion of a portion of streamflow via the fracture network. Where the watercourse is experiencing low flow conditions, it is likely that a higher proportion or all of the surface flow would be re-directed into the fractured strata.

Modelling for the EIS has often been in a perpetual state of 'calibration' and in many cases these models have not been properly validated. HEC (2022) provided several modelled flow exceedance curves which identify significant stream flow losses for potentially affected streams above Area 5. No similar assessment is included for the streams that have already been impacted (apart from Donalds Castel Ck at DCU) and there is no provision of modelled versus measured flow data that demonstrates a validation of the modelled flows; or any assessment of the uncertainty in model estimates. The modelling presented (see Figure 5) suggests a:

- 'short-term'[10] 20% increase in the cease to flow period in DCU
- 'short-term' 30% increase in the cease to flow period in DC8S1
- 'short-term' 50% increase in the cease to flow period in AR32S1
- 'short-term' 50% increase in the cease to flow period in AR19S1
- 'short-term' 30% increase in the cease to flow period in LA13S1
- 'short-term' 55% increase in the cease to flow period in LA8S1

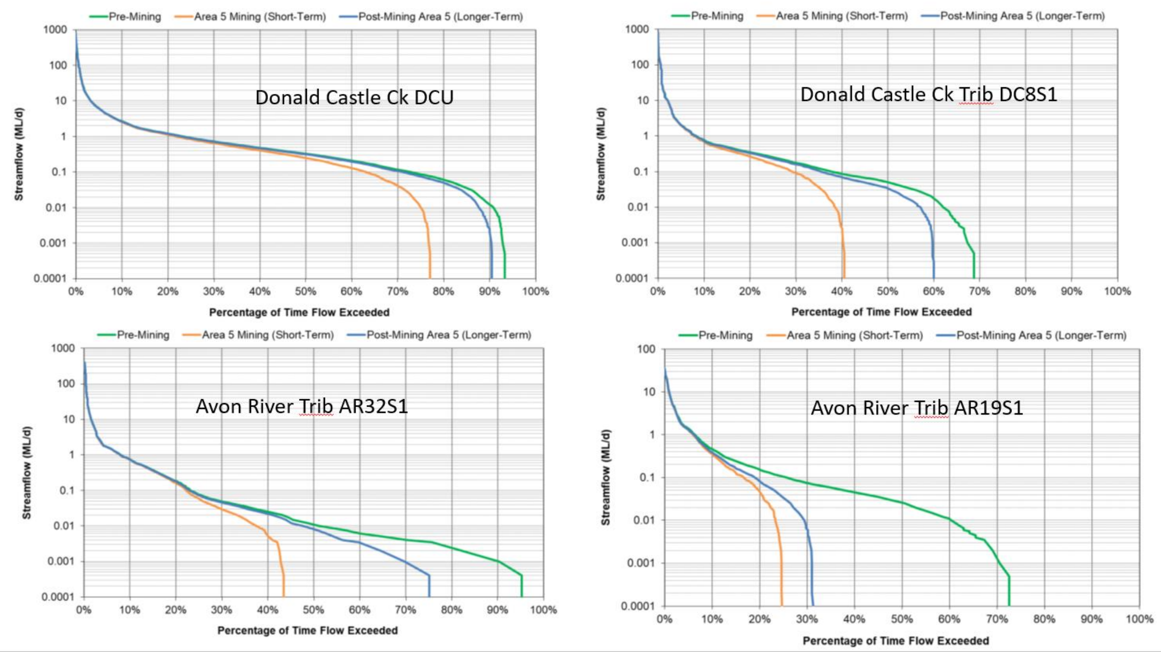

Figure 5. Modelled flow exceedance curves. Source HEC (2022).

The '*longer-term*' Post Area 5 increases in cease to flow conditions illustrated in Figure 5 are largely dependent on unvalidated model assumptions, are subject to high uncertainty and may take centuries to eventuate (if at all). It is additionally noted that much of the flow data for this area lacks adequate baseline characterisation, does not adequately consider flow impacts during drought conditions[11] and have not considered historic impacts (e.g. loss of flow in Wongawilli Creek and other streams due to earlier Elouera fracturing and losses of tributary flows).

What is clear is that the losses illustrated in the Surface Water Assessment will be in addition to the already significant surface water losses experienced due to past mining impacts at Dendrobium (and on the Woronora Plateau more broadly). It has also previously been identified that a proportion of surface water losses are going into the Dendrobium Mine itself (PSM 2019, IEPMC 2019a,b) and this is likely to continue for the foreseeable future.

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[10] The term '*short-term*' is not well defined.

[11] Likely to be critical to the survival and persistence of endangered species.

Other impacts have occurred where iron staining has affected streams and pools, or where water quality triggers have been exceeded (e.g. for conductivity). Given previous experiences with the loss of flow, iron staining and water quality trigger notifications, the current development will not achieve a neutral or beneficial effect on water quality.

The Dendrobium Area 5 EIS did not consider the implications for existing cumulative losses from mining at Dendrobium, or further losses due to Dendrobium Area 5 impacts.

The relevance of surface water losses for biodiversity are also understated. When the major pool in Swamp14 was recently fractured and drained by previous 305m wide longwalls, many tadpoles[12] were killed (see Figure 6 below). Under the Dendrobium Approval this pool had a performance measure of '*maintenance or restoration of the structural integrity of the bedrock base'*. At this stage South32 have not advised how they will address this, but the overall approach to impacts and performance measures for swamps (minor changes to ecosystem functionality), pools and rockbars are considered inadequate. Furthermore, Niche (2022) provided little of the context of previous impacts on endangered species (such as *Litoria littlejohni*) in their biodiversity assessment.

Instead of addressing the cumulative impacts to streams from existing mining in the area, South32 is proposing yet further loss of significant quantities of surface water and aquatic habitat within the Sydney Metropolitan Drinking Water Catchment. This has significant ramifications for the persistence of a wide range of endangered species protected under the BC and EPBC Acts.

<u>Conclusion</u>

- A detailed and comprehensive cumulative impact assessment for the Coastal Upland Swamp TEC above Dendrobium's area of operations and on the Woronora Plateau more broadly needs to be provided.
- South32 need to provide a detailed and comprehensive cumulative impact assessment for all streams on the Woronora Plateau above Dendrobium's area of operations and on the Woronora Plateau more broadly.
- South32 need to provide a detailed and comprehensive cumulative impact assessment for threatened and endangered species above Dendrobium's area of operations and on the Woronora Plateau more broadly.
- The DPE's technical guideline, *Cumulative Impact Assessment for State Significant Projects*, needs to be specifically addressed.

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[12] It is likely that these tadpoles were Littlejohns tree frog (*Litoria littlejohni*), Giant Burrowing Frog (*Heleioporus australiacus*), or *Limnodynastes peroni* (Professor M Mahony pers comm.).

Figure 6. Significant permanent pool in Swamp 14 impacted by recent longwall mining using 305m wide longwalls.

2. Subsidence Assessment

MSEC (2022) continue to change their methodology for predicting subsidence over Dendrobium Mine. They have also chosen to compare their subsidence predictions to the less accurate Airborne Laser Scan (ALS) / Light Detection and Ranging (LiDAR) surveys, rather than the higher accuracy subsidence monitoring line surveys.

MSEC (2022) state:

- *The overburden lithology and thicknesses of the strata layers in Area 5 are reasonably similar to those in Area 3B;*
- *It is expected, therefore, that the development of subsidence in Area 5 will have similar relationships to the mining geometry (i.e. longwall width-to-depth ratios and mining heights) as for the other mining areas at the Mine.;* and
- *The longwalls in Area 5 are proposed to be extracted from the Bulli Seam. The depths of cover in this mining area vary between 250 m and 400 m, with an average of approximately 360 m above the proposed longwalls. The range of depths of cover is similar to that for the existing LW9 to LW17 in Area 3B, which vary between 290 m and 410 m, with an average of approximately 380 m. Similarly, the width-to-depth ratios for the proposed longwalls in Area 5 are similar to those for LW9 to LW16.*

It should therefore be expected that with exactly the same longwall pillar and panel dimensions, impacts similar to those over Area 3B will be replicated in Area 5.

More importantly MSEC has stated:

The maximum predicted total vertical subsidence in Area 5 has therefore been based on applying a 12 % increase rather than 30 % to the incremental vertical subsidence, so as to achieve a maximum vertical subsidence of 65 % of the mining height. The new IPM subsidence model calibrated for mining in the Bulli Seam at the Mine is referred to as the 'MSEC1181 prediction curves'.

Rather than re-calibrating the IPM to take account of the wider longwalls currently being used, MSEC currently use a somewhat arbitrary factor to adjust subsidence predictions based on older IPM results (using either 30% for Area 3B or 12% for Area 5). This approach has not been well validated and will obviously lead to lower predicted subsidence levels for Area 5 than those in Area 3B (despite the similar mining dimensions and conditions; depth of cover, longwall width-to-depth ratios and mining heights). Given that lower accuracy (ALS) subsidence survey measurements have been used to assess model fit, there is a distinct possibility that subsidence levels for Area 5 have been underestimated.

In discussing stream impacts, MSEC (2022) identify Type 3A and Type 3B impacts as:

Type 3A where fracturing has directly resulted in water loss, flow diversion or change in pool water level; and Type 3B where there has been noticeable change in pool water level that is not associated with fracturing in the pool, but rather the changes in surface flow further upstream.

MSEC (2022) additionally state:

The experience in Area 3B shows that the impacts on pools along the tributaries generally occur after they have been directly mined beneath. However, pools have also been impacted along sections of the tributaries that are located outside of the longwall mining area.

The longwalls in Area 3B have been extracted directly beneath many tributaries. The majority of the data has come from Drainage Line WC21, above the eastern ends of LW9 to LW13, as large sections of the other tributaries within the longwall mining area are confined within the swamps.

As discussed in Section 5.3.5, it has been assessed that approximately 15 % of the stream controlling features located within 400 m of the proposed longwalls could experience Type 3 impacts.

Later in their review they present subsidence prediction for swamps (Table 5.18 below)

Table 5.18 Maximum predicted total vertical subsidence, tilt and curvatures for the swamps

Location	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Swamps	1950	20	0.35	0.50

These values are stated to be *the maximum predicted subsidence effects within 20 m of the mapped extents of each of the swamps*. The obvious inconsistency in stating *15 % of the stream controlling features located within 400 m of the proposed longwalls could experience Type 3 impacts* but only considering *the maximum predicted subsidence effects within 20 m of the mapped extents of each of the swamps* potentially leads to a significant underestimate of impact for some swamps above or near Dendrobium Area 5 longwalls. Swamps are effectively sediment filled and vegetated streams in these areas and therefore subject to the same subsidence processes as streams in other areas of the mine plan.

It is noted that MSEC (2022) provide a cursory assessment of past swamp impacts above Dendrobium, stating:

Area 2

LW4 and LW5 in Area 2 were extracted directly beneath Swamp Den01, which is both a headwater and valley infill swamp located along stream A2-14. Cracking was observed within the extent of the swamp in three locations and fracturing was observed in the downstream rockbar.

Area 3A

LW7 in Area 3A was extracted directly beneath Swamp Den12, which is a headwater swamp located on the valley side of stream WC17. One fracture was identified in a rock outcrop after mining beneath this swamp. Regular monitoring has been undertaken and, to date, no erosion or other physical changes in the swamp have been observed. Four piezometers have been installed in and around the swamp to measure shallow groundwater levels within the sediments above the sandstone bedrock. One of the piezometers has measured a reduction in the groundwater level, two of the piezometers show no change and one is providing poor quality data.

Area 3B

LW9 in Area 3B was extracted directly beneath Swamp Den05, which is a valley infill swamp located along the alignment of Donalds Castle Creek. The impacts to this swamp were described in the End of Panel Report (IMC, 2014) which states "Site DA3B_LW9_006: Multiple fractures and uplift on DC_RB33 at basal step of Swamp 5; up to 0.015m wide, 2m long and 0.040m of uplift. Exfoliation from the step. Associated flow diversion" and "TARP triggers in relation to shallow groundwater levels (reduction and recession rates) in Swamps 1a, 1b and Swamp 5 were also reported during Longwall 9 extraction".

Impacts were also observed to the swamps due to the extraction of LW10 to LW16 which were described in each of the End of Panel Reports (IMC, 2015, 2016, 2017, 2018, 2019, 2020 and 2021). The groundwater levels were lower than baseline and recession rates greater than baseline for Swamps Den03, Den05, Den10, Den11, Den13, Den14 and Den23. Soil moisture levels below baseline were also reported in Swamps Den05, Den11 and Den23.

This summary misses the obvious impacts to Swamp 15b in Area 3A and Den08 in Area 3B. It also fails to provide any detailed discussion of risk (consequence and likelihood) of impact in relation to quantitative subsidence predictions, even though MSEC developed these predictions for individual swamps above Area 5. Using past MSEC predictions for Coastal Upland Swamp TECs and identifying swamps that have already been impacted; and then comparing current subsidence predictions for swamps in Area 5; all swamps above the 305m longwalls are almost certainly going to be fractured and drained (see Krogh 2013; Cardno's 2022 review of swamp impacts; and Figure 7). A more detailed assessment for Area 5 swamps at risk of impact is provided in Table A1, Appendix A).

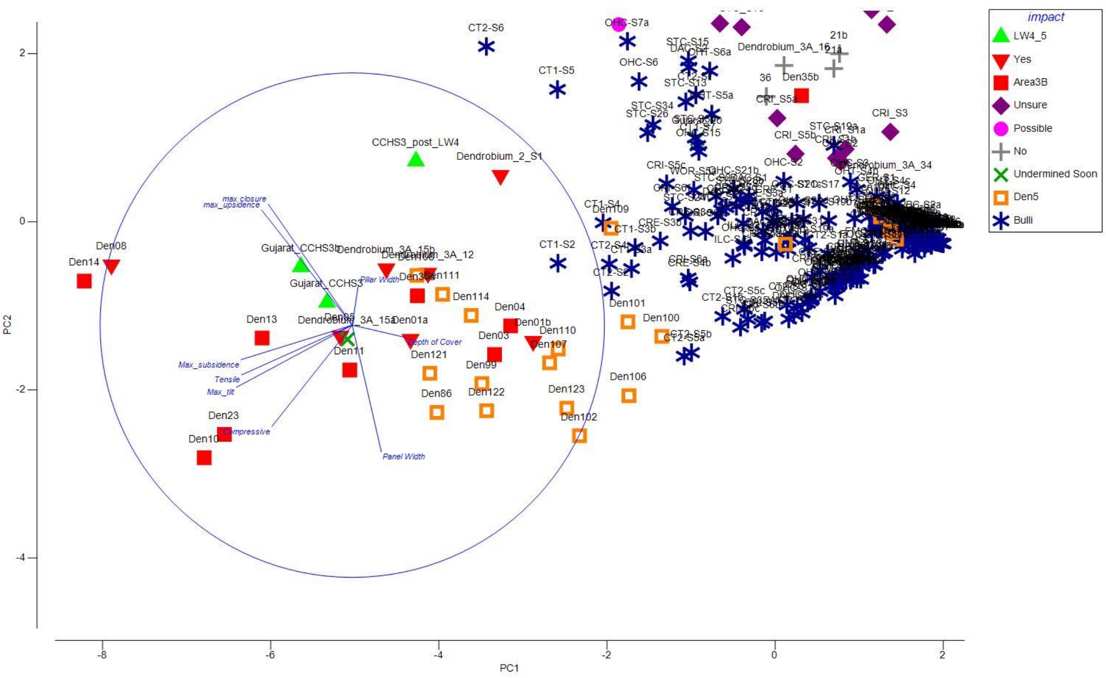

Figure 7. Principal components analysis plot – conventional and non-conventional subsidence predictions. Impacted swamps=red; possible impacts=pink dot; no impacts=plus sign; undermined soon=green X; unsure (no monitoring data available)=maroon diamonds; Bulli Seam swamps (as originally proposed)=blue asterisks; Russell Vale swamps originally targeted for longwall extraction=green triangles; Dendrobium Area 5 swamps=open orange boxes.

<u>Conclusion</u>

- MSEC need to validate the current approach of using arbitrary factors to adjust subsidence predictions based on older IPM results (using either 30% for Area 3B or 12% for Area 5).
- MSEC should compare their model predictions to the higher accuracy subsidence monitoring line surveys.

3. Surface to Seam Fracturing Assessment

The SEARs for the Project require:

a scientifically robust assessment of predicted height of fracturing above longwall panels and the vertical distance separating the fracture zone from the surface cracking zone, including consideration and assessment of alternative mine design options to maximise the vertical distance separating the height of connective fracturing with the surface cracking zone and minimise surface water losses.

South32 state:

There is no predicted "seam to surface" fracturing when calculated using the Tammetta Equation.

This statement is not strictly true since MSEC identify a minimum depth of cover of 250m and a maximum seam height of 3.2m for Area 5.

If the full seam height of coal (3.2m) is extracted under the shallowest depths of cover (250m) Tammetta's (2013) equation identifies that the height of connective fracturing will reach the surface. If this predicted surface to seam fracturing occurs, or fracturing moving up from the coal seam meets fracturing moving downwards from the incised river valleys due to subsidence/upsidence/valley closure, surface water will be lost and move into the mine itself (as it already has in Dendrobium Areas 2 & 3; PSM 2019, IEPMC 2019a,b). The Dendrobium Area 5 assessment is not considered to have provided a *scientifically robust assessment of predicted height of fracturing above longwall panels* or *the vertical distance separating the fracture zone from the surface cracking zone*[13].

Conclusion

- The issue of surface to seam connective fracturing should be referred to the Independent Mining Panel for further detailed consideration.

4. Geological Structures Assessment

There is a significant discrepancy in what PSM (2022) assessed in terms of geological structures in Area 5 and that used by MSEC (2022) in their impact assessment - the latter missing almost all PSM mapped structures (particularly the Cordeaux Lineament and Unmapped Fault 1 - see Figure 8). Geological structures potentially have a significant role to play in impacts and consequences (especially for swamp and stream fracturing and drainage), including impacts extending a great distance away from the longwalls. On the Newnes Plateau the interaction of subsidence with geological structures (lineaments) led to impacts up to 2km away from the advancing longwall face (Springvale Expert Panel, MSEC 2021). It is possible that Type 3 pool impacts up to 400 m from longwalls identified by MSEC could be related to geological structures. Very little scientific data is provided to prove that geological structures do not interact with subsidence in the areas above Dendrobium mine (or the Southern Coalfield more generally). MSEC's portrayal and assessment of geological structures is considered to have serious shortcomings.

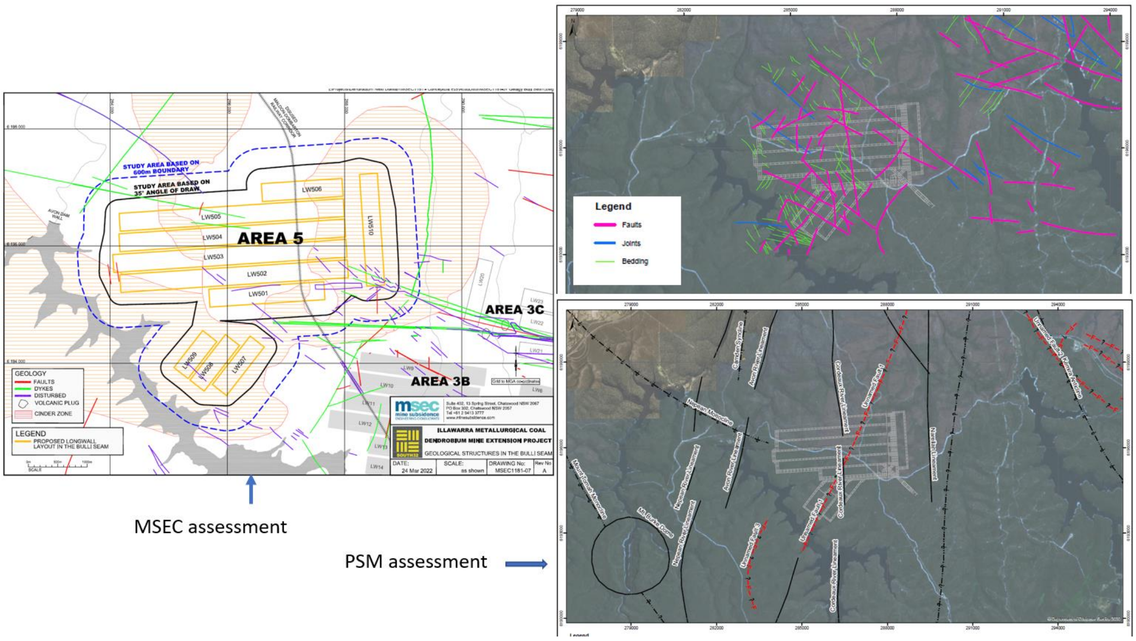

Figure 8. Geological structures (faults, dykes and lineaments) mapped by PSM (2022; right) and MSEC (2022; left).

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[13] As required by the SEARs.

Conclusion

- The issue of geological structures (including faults, dykes, lineaments and joints) interacting with subsidence leading to adverse outcomes should be referred to the Independent Mining Panel for further detailed consideration.

5. Coastal Upland Swamp assessment

Coastal Upland Swamp (CUS) TEC impacts have been discussed above in terms of cumulative impacts and quantitative risk assessment. Mining at Dendrobium has already irreversibly impacted approximately 45 Ha of the CUS TEC, including Swamps 12, 15b, 1a, 1b, 5, 8, 10, 11, 13, 14, 23.

It is noted that the Project's proposed longwalls are likely to irreparably alter the hydrology of an estimated 19 Ha of CUS (Table A1, Appendix A), although Niche (2022) have heavily[14] discounted this area to ~9 Ha. It is noted that Niche's (2022) mapping has not been validated or peer reviewed and they have not followed the NSW Government Upland Swamp Offsets Policy (see Attachment B for more detail).

Of potential greater concern is the inadequacy of the HEC (2022) model developed to predict seepage rates from swamps.

HEC (2022) stated that:

Seepage models were developed for swamps using the VADOSE/W (GEO-SLOPE, 2004) software - a finite element, two-dimensional unsaturated/saturated groundwater seepage model. The model was used to assess the potential impact of the proposed Project (subsidence and associated fracturing) on enhanced horizontal and vertical drainage beneath the potentially affected swamps.

Very little justification is provided for the horizontal and vertical hydraulic conductivities used in the model (Table 18) or the uncertainty/sensitivity of the model to these conductivity values.

Table 18 Horizontal and Vertical Hydraulic Conductivity

Layer Material Type	Without Project		With Project	
	Horizontal Saturated Hydraulic Conductivity (m/day)	Vertical Saturated Hydraulic Conductivity (m/day)	Horizontal Saturated Hydraulic Conductivity (m/day)	Vertical Saturated Hydraulic Conductivity (m/day)
Swamp Sand Sediment	1	1	1	1
Weathered Bed-rock	0.03	0.003	0.15	0.15
Fresh Bed-rock	0.01	0.0001	0.1	0.1

For Model Calibration and Verification HEC (2022) states:

- *The water level records for a swamp with median gradient (Den 98 – refer Figure 8 for location and Table 8 for swamp characteristics) were used for the model calibration. A representative recessionary period (June to November 2017) was selected for the calibration period. The model was calibrated by modifying the leaf area index and plant*

[14] In SEI's view inappropriately so. Niche's arbitrary approach to swamp delineation (see the Biodiversity Report) has not been fully detailed, validated or peer reviewed.

root depth parameters. Recorded water levels were compared with simulated water levels until a reasonable fit was achieved

- *A comparison was also made between the reported recession rates in Area 3 swamps (see Section 4.2.2) which have been monitored by IMC during pre-mine and post-mine periods and the simulated recessions under 'With Project' and 'Without Project' cases.*

The methodology described in the HEC (2022) falls well short of an adequate model calibration (based on only 5 months data for one swamp in 2017) or validation. Of major concern is the obvious lack of agreement between modelled seepage rates (and swamp levels) and that observed for impacted swamps above Dendrobium Area 3B (e.g. see Figure 9). Multiple documents including End of Panel Reports for Area 3B identify longwall mining impacts cause the complete drainage of upland swamp TECs with only the occasional rise in swamp levels in response to intense rainfall events before water levels subsequently drop below the bedrock base of the swamps (e.g. Krogh 2014, Young 2017; HGEO 2022, Cardno 2022). HEC's model does not replicate this behaviour and clearly does a very poor job at predicting water levels in swamps that are impacted by longwall mining. It is not therefore considered fit for the purpose of assessing mine impacts on swamps in Area 5 or drainage rates in the underlying bedrock.

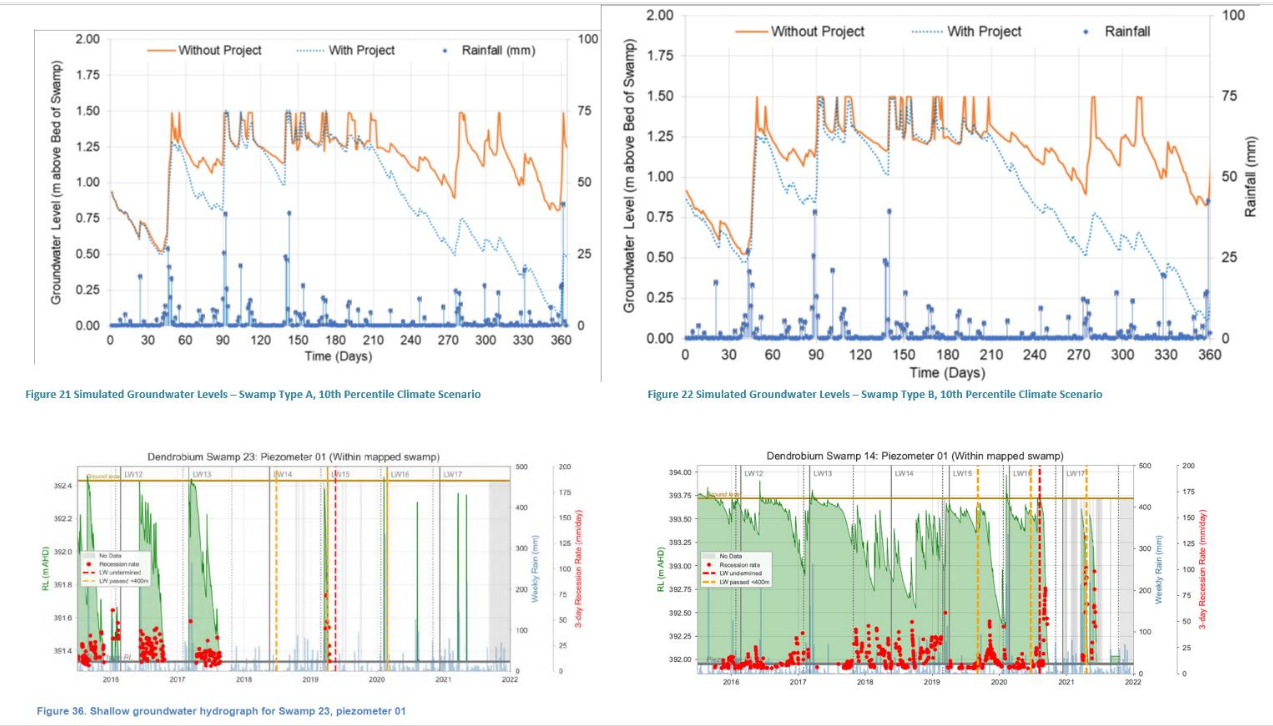

Figure 9. Seepage rate predictions for swamps above Area 5 (HEC 2022 above) and observed swamp level responses impacted by previous longwall mining in Area 3B (HGEO 2022).

<u>Conclusion</u>

- The HEC (2022) seepage model should not be used as a reliable point of reference for this assessment and the model and its predictions should be referred to the Independent Mining Panel for more detailed consideration.

6. Biodiversity impact assessment

As identified above, the Project EIS has not undertaken a comprehensive cumulative impact assessment for the area in terms of swamp, stream and aquatic and terrestrial habitats. It has also failed to assess the cumulative impact of all mining on threatened and endangered species populations within the Dendrobium mining domain and more broadly on the Woronora Plateau. There have been well over 700 surface impacts (cracks, fractures, swamp drainage, pool drainage, lack of flow, biodiversity impacts, cliff/rock falls, stream water quality impacts) identified for the Dendrobium Mine Area alone (Longwall 1 to 17 End of Panel Reports; Krogh 2013).

Approximately 36% of the Coastal Upland Swamp (CUS) TEC has already been undermined but there is no available information available to determine impacts (or otherwise) to these swamps. Mining at Dendrobium has already irreversibly impacted approximately 45 Ha of the CUS, including Swamps 1[15], 12, 15b, 1a, 1b, 5, 8, 10, 11, 13, 14 and 23.

Approximately 3.7% of the CUS has been irreparably damaged by longwall mining, with a further 2.9% of the CUS likely to be damaged by approved future mining or further mining associated with the proposals for Dendrobium Area 3A and Area 5. Future mining proposals are likely to cause yet further losses of the CUS TEC.

Cardno (2018) previously identified that:

Mapping by ICEFT indicated that approximately 97 km, or 14 %, of the total 556 km length of watercourse habitat within the upper Avon and Cordeaux Catchments has experienced mine subsidence movements which could have resulted in loss of flow and reduction in pool water level

While Cardno (2022) identify that:

Collectively, the length of watercourse that has experienced indirect and direct mining impacts (147.6 km) is estimated to be 21%[16] of that present in the upper Avon and Cordeaux River catchments (717 km).

Biosis (2016) stated:

- *Within Dendrobium Area 3A, adult Littlejohn's Tree Frogs have not been recorded at WC17 for two consecutive years following subsidence related impacts. Following an assessment of WC17 against the TARPS for terrestrial fauna - threatened frog species within the Dendrobium Area 3 Watercourse Monitoring Trigger Action Response Plan (TARP) (dated 12 October 2015) it was determined that a Level 3 TARP has been triggered for WC17. Following heavy rains during the breeding season Littlejohn's Tree Frog was recorded at SC10C for the first time since 2012. When assessing the presence of Littlejohn's Tree Frog at SC10C over the course of time, it is clear that despite detecting the species in 2015, a local reduction in the available breeding habitat has occurred where mining impacts have occurred. This reduction in habitat has been evident for three consecutive winter monitoring surveys and documented in stream monitoring data collected by the Illawarra Coal Environmental Field Team (data provided by Illawarra Coal Environmental Field Team January 2016). Following an assessment of SC10C against the TARPS for terrestrial fauna - threatened frog species within the Dendrobium Area 3 Watercourse Monitoring Trigger Action Response Plan (TARP)*

[15] In Dendrobium Area 2.
[16] One fifth of all streams and an increase of ~50km (or 7%) from their 2018 estimate.

(dated 12 October 2015) it was determined that a Level 3 TARP had been triggered for SC10C. and

- *Similarly for Dendrobium Area 3B, Littlejohn's Tree Frogs were recorded at DC13 for the first time since 2012 following subsidence related impacts in 2013 following the extraction of Longwall 9 (Illawarra Coal 2014). Adult frog abundance was very low (one frog) and following an assessment against the TARPS for terrestrial fauna - threatened frog species within the Dendrobium Area 3 Watercourse Monitoring Trigger Action Response Plan (TARP) (dated 12 October 2015) it was determined that a Level 2 TARP had been triggered for DC13.*

The current EIS provides no reliable estimate of the cumulative impact to all streams after inclusion of impacts associated with the Area 5 longwalls. It does, however, identify the very real potential for further significant flow losses, pool drainage and loss of aquatic habitat in streams above the longwall panels. Various end of panel reports have identified significant impacts to endangered frog species (e.g. Littlejohns tree frog) and Giant dragonflies are now highly unlikely to find any suitable breeding habitat in the already impacted swamps above Dendrobium longwalls[17].

Further discussion of biodiversity offsets and the BDAR is available in Attachment B.

<u>Conclusion</u>

- South32 need to validate their calculation of the swamp areas above Area 5[18].
- South32 should follow the NSW Government Upland Swamp Offsets Policy (see Attachment B).
- South32 needs to address the obvious break in continuity in the landscape due to Elouera and Dendrobium impacts on Coastal Upland Swamp TECs.
- South32 should undertake a comprehensive cumulative impact assessment for the area and better justify the quantum of offsets required for Coastal Upland Swamp TEC and other threatened and endangered species likely to suffer adverse consequences from the proposal.

7. Remediation of impacted streams and swamps

After the experience of significant impacts to Coastal Upland Swamp TECs from earlier longwall mining at Dendrobium, the Approval Conditions for Dendrobium Longwalls 14 & 15 specified the need for a Swamp Rehabilitation Research Program

17. The Applicant must prepare and implement a Swamp Rehabilitation Research Program to the satisfaction of the Secretary. This program must:

(a) be prepared in consultation with OEH, Water NSW and DRE;

(b) be submitted by 31 October 2013 to the Secretary for approval;

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[17] Including Area 5 longwalls if approved.

[18] Discrepancies between the swamp and TEC areas were noted between the current proposal and that of the original Area 5 & 6 assessment. The greatest discrepancy is for Swamp Den98 where the Area 5 & 6 report identifies a swamp area of 2.9 Ha, whereas the Area 5 Assessment identifies a swamp area for Den98 of 0.8Ha. OEH mapping suggests that this swamp is likely closer to the 2.9 Ha estimate.

(c) investigate methods to rehabilitate swamps subject to subsidence impacts and environmental consequences within Areas 3A and 3B, with the aim of restoring groundwater levels and groundwater recharge response behaviour to pre-mining levels;

(d) establish a staged field trial (for a 5-year duration or longer) for rehabilitation techniques at swamps that have been impacted by subsidence, commencing with Swamp 1b, including:

· drilling a series of piezometers adjacent to targeted swamps to characterise groundwater levels and the bedrock fracture network;

· implementing a trial of directional drilling and grouting underneath targeted swamps;

· undertaking electrical resistivity tomography surveys before and after rehabilitation attempts at targeted swamps; and

· undertaking a detailed evaluation of the success of the first stage of the trial, prior to the commencement of further stages.

It is noted that Swamp 1B has never received the required remediation and continues to be dry and desiccated.

Stream remediation has also been required under the Approval for Dendrobium due to excessive levels of impacts:

- On 28 August 2015 the Secretary wrote to IMC to request, under *Schedule 3, Condition 4*, that IMC prepare a remediation program for the impacts to WC21.
- On 16 December 2016 the Secretary of DPIE approved the SMP for Longwalls 14 and 15. *Condition 13* of the Approval requires the Applicant undertake remediation programs for WC21 and DCC, to the satisfaction of the Secretary.

South32 provided OEH with a remediation plan for WC21 and Donalds Castle Creek.

The South32 remediation plan for WC21 specifically identified 41 pools in WC21[19] in the **APPENDIX A – SITES** Section. Despite the remediation plan identifying that:

Along WC21, 77% of mapped stream features within the mining area are affected by water loss. Along DCC, 67% of mapped stream features are affected by water loss.

The remediation plan states that 19 pools (46.3% of pools) will have no remediation and 8 (19.5%) will not have remediation '*at this stage*'. This means that ~66% of pools in WC21 are not currently identified to be remediated.

The remediation plan specifically identified 7 pools (34, 33, 32, 30, 29, 23, 19) in Donalds Castle Creek[20] in the **APPENDIX A – SITES** Section. Of these, only pool 33 is proposed to have '*targeted remediation*'. The other 6 (86%) are stated not to be remediated.

Statements were also made about "*Reassessment of surface flow conditions on the rockbar are proposed following return of surface flow to upstream features*.". It is highly unlikely that a return of connectivity and surface flow is possible with 66% of pools in WC21 receiving no remediation and only one pool in Donalds Castle Creek receiving remediation. Under such circumstance, it is considered that the current rehabilitation plan will likely fail to address the underlying issues (fracturing, loss of pool water and lack of flow) for many areas in WC21 and Donalds Castle Creek. Impacts to unremediated areas are likely to remain in perpetuity and highly unlikely to provide the aquatic habitat and flow that once existed in these areas. This has long-term implications for the persistence of threatened and endangered species

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[19] It was additionally noted that there appeared to be no mention/description of WC21 pools 52 or 19.

[20] It is additionally noted that there appears to be no mention/description of pools 31, 28-24, 22, 21 or 20.

(such as Littlejohns tree frog, Giant Burrowing frog, Red Crowned toadlets and Macquarie perch) in these areas.

It is noted that no substantial progress has been made to date in rehabilitating WC21 or Donalds Castle Creek[21]. Furthermore, proposed remediation works do not target all (or even a majority) of impacted pools. There is limited discussion of rehabilitation in the EIS and, based on the deficiencies in the existing rehabilitation plan, remediation obviously cannot be relied upon as an effective mitigation mechanism.

The Bulli Seam PAC Panel were also highly sceptical of remediation proposals stating (PAC 2010):

the Panel cannot recommend the proposed extensive reliance on remediation as a wholesale and primary measure to protect stream related values. There are several considerations that have led the Panel to this assessment, including:

- *To be effective at restoring the range of stream values that have been discussed above, remediation would have to be intense and extensive.*
- *The values to be protected in the sandstone gorge parts of the Study Area are strongly associated with naturalness. Remediation proposals conflict with naturalness values.*
- *Remediation is proposed at controlling rockbars and between controlling rockbars …where feasible. The where feasible condition is so open ended as to be ineffectual.*
- *If remediation is not applied successfully between rockbars as well as at rockbars, the range of stream values cannot be restored. The proposed remediation measures are an extension of grouting techniques that have been trialed at some specific locations as a means of restoring pools behind rockbars. While the Panel acknowledges some success at sealing subsurface fractures at specific rockbars, the universal applicability of this technique to restore flow throughout entire lengths of streams is speculative at best. Even where some success has been demonstrated at restoring pools behind specific rockbars, the longevity of the technique has been questioned in submissions and remains unproven.*
- *The remediation proposal has a focus on restoration of pools behind rockbars. Table 17 demonstrates that for some important streams, more pools form behind boulder fields than form behind rock bars. The feasibility of restoring pools behind boulder fields is unproven.*
- *Remediation proposals have developed from efforts to restore pools behind rockbars – principally in response to concerns about the importance of pools for visual amenity and ecological values. The effectiveness of remediation proposals for dealing with other consequences to other values is doubtful.*
- *Some ecological values depend on continuity within the stream. Even short lengths of unremediated stream may cause loss of ecological value.*
- *Timing of implementation of remediation measures is not specified. Where multiple longwalls affect a length of creek remediation, measures may have to wait until impacts from multiple longwalls are complete, or remediation measures may have to be repeated.*

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[21] A similar situation exists in the Upper Georges River where South32 is required to remediate impacts due to earlier West Cliff longwalls, but remediation is being delayed, despite the requirement to undertake this work '*as soon as reasonably practicable*'.

- *The NSW Minerals Council has submitted that remediation in areas of difficult access may cause more harm than the subsidence impacts themselves. Much of the terrain under discussion would be classed as being difficult to access.*
- *Monitoring programs proposed in the EA will not reveal the need for, or effectiveness of, remediation for all values.*

Conclusion

Remediation cannot be relied upon as an effective post-mining mitigation or management mechanism and impacts to streams and swamps should be avoided by a rethink of a more balanced alternative mine design and extraction method. At a minimum, the longwall panel width needs to be significantly reduced for the Project to limit any reliance upon ineffective remediation.

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Attachment C – Appendix A

Swamp	Easting	Northing	type	above LW	subsidence	tilt	hog curv	sag curv	valley height	upsidence	closure	conv closure	Tensile[3]	Comp[3]	Impact[1]	Swamp	type	presence	MU42 – Banksia	MU43 – Tea-tree	MU44b – Restioid	MU45 – Eucalypt Fringing	Swamp area (Ha)	TEC area (Ha)	Imp-acted Swamp Area (Ha)	Impacted TEC Area (Ha)	Area5_6 Swamp Area (Ha)[2]	Area5_6 TEC Area (Ha)[2]
Den100	286770	6197040	Headwater	Above	650	15	0.25	0.11	0 to 5	40	40	40	3.75	1.65	y	Den100	Headwater	Present	0	0	0.46	0.38	0.84	0.46	0.84	0.46	0.8	0.5
Den101	285930	6196350	Headwater	Above	1450	12	0.25	0.08	5	70	70	< 20	3.75	1.2	y	Den101	Headwater	Present	0	0	0.4	0.41	0.81	0.4	0.81	0.4	0.8	0.4
Den102	286030	6196530	Headwater	Above	1800	16	0.13	0.5	No valley	-	-	-	1.95	7.5	y	Den102	Headwater	Present	0	0	0.27	0.24	0.51	0.27	0.51	0.27	0.5	0.3
Den103	285860	6196715	Headwater	Outside	175	6	0.13	0.01	10 to 15	60	100	< 20	1.95	0.15	y	Den103	Headwater	Present	0	0	0.53	0.63	1.16	0.53	1.16	0.53	1.1	0.5
Den104	285405	6196865	Valley Infill	Outside	< 20	< 0.5	< 0.01	< 0.01	20	50	100	< 20	0.15	0.15	Possible due to closure	Den104	Valley In-fill	Absent	0	0	0.16	0.34	0.5	0.16	0.5	0.16	0.5	0.2
Den105	285305	6196775	Headwater	Outside	< 20	< 0.5	< 0.01	< 0.01	No valley	-	-	-	0.15	0.15	unlikely	Den105	Headwater	Absent	0	0	0.16	0.23	0.39	0.16				
Den106	287455	6195075	Headwater	Above	950	15	0.25	0.3	No valley	-	-	-	3.75	4.5	y	Den106	Headwater	Present	0	0	0.66	0.42	1.08	0.66	1.08	0.66	1	0.7
Den107	286325	6195175	Headwater	Above	1550	13	0.25	0.4	5 to 10	125	125	100	3.75	6	y	Den107	Headwater	Present	0	0	0	0.54	0.54	0	0.54	0	0.5	0
Den108	286595	6195135	Valley Infill	Above	1600	18	0.3	0.4	20 to 25	375	375	200	4.5	6	y	Den108	Valley In-fill	Present	0.11	0	0	0.3	0.41	0.11	0.41	0.11	0.4	0.1
Den109	286285	6195730	Headwater	Above	1400	11	0.16	0.07	10 to 15	225	250	50	2.4	1.05	y	Den109	Headwater	Present	0.04	0	0.37	0.55	0.96	0.41	0.96	0.41	0.9	0.4
Den110	285875	6195785	Headwater	Above	1950	12	0.19	0.35	5 to 10	125	125	40	2.85	5.25	y	Den110	Headwater	Present	0	0.18	0.07	0.24	0.49	0.25	0.49	0.25	0.5	0.3
Den111	285950	6195580	Valley Infill	Above	1600	16	0.35	0.35	15 to 20	300	325	100	5.25	5.25	y	Den111	Valley In-fill	Present	0	0	0.17	0.19	0.36	0.17	0.36	0.17	0.4	0.2
Den114	285235	6195590	Headwater	Above	1550	14	0.3	0.45	15 to 20	250	300	< 20	4.5	6.75	y	Den114	Headwater	Present	0	0	0	0.61	0.61	0	0.61	0	0.5	0
Den120	287035	6197320	Headwater	Outside	< 20	< 0.5	< 0.01	< 0.01	5	< 20	20	< 20	0.15	0.15	unlikely	Den120	Headwater	Present	0	0	0.61	0.34	0.95	0.61				
Den121	284605	6196505	Valley Infill	Above	1700	20	0.35	0.45	15 to 30	200	225	300	5.25	6.75	y	Den121	Valley In-fill	Present	0	0	0.46	0.73	1.19	0.46	1.19	0.46	1.2	0.5
Den122	284895	6196585	Headwater	Above	1300	20	0.35	0.45	5 to 15	100	125	150	5.25	6.75	y	Den122	Headwater	Present	0	0	0.35	0.26	0.61	0.35	0.61	0.35	0.6	0.4

Den123	285670	6196275	Headwater	Above	1600	17	0.35	0.19	No valley	-	-	-	5.25	2.85	y	Den123	Headwater	Present	0	0	0.13	0.27	0.4	0.13	0.4	0.13	0.4	0.1
Den85	288110	6194985	Headwater	Outside	< 20	< 0.5	< 0.01	< 0.01	5 to 15	20	20	< 20	0.15	0.15	unlikely	Den85	Headwater	Absent	0	0	2.1	0.67	2.77	2.1				
Den86	286550	6196490	Headwater	Above	1800	20	0.35	0.5	5 to 15	150	150	200	5.25	7.5	y	Den86	Headwater	Present	0	0	2.37	2.29	4.66	2.37	4.66	2.37	4.3	2.4
Den97	286870	6197535	Headwater	Outside	< 20	< 0.5	< 0.01	< 0.01	5 to 15	20	20	< 20	0.15	0.15	unlikely	Den97	Headwater	Present	0	1.03	0	0.36	1.39	1.03				
Den98	289265	6196420	Valley Infill	Outside	< 20	< 0.5	< 0.01	< 0.01	30	30	70	< 20	0.15	0.15	Possible due to closure	Den98	Valley In-fill	Absent	0	0.59	0	0.21	0.8	0.59	0.8	0.59	2.9	2.2
Den99	285210	6196095	Headwater	Above	1850	16	0.3	0.45	5 to 10	150	150	300	4.5	6.75	y	Den99	Headwater	Present	0	0	2.03	1.18	3.21	2.03	3.21	2.03	3	2
																								Total	**15.93**	**7.32**	**17.3**	**9.2**

Table A1. Swamps Above Dendrobium Area 5, subsidence predictions and areal extent. Source: MSEC (2022) and Niche (2022).

1. Impact assessment based on subsidence thresholds from PAC 2010 or where upsidence and valley closure are close to or greater than 100 mm/m.
2. Discrepancies between the swamp and TEC areas were noted between the current proposal and that of the original Area 5 & 6 assessment. The greatest discrepancy is for Swamp Den98 where the Area 5 & 6 report identifies a swamp area of 2.9 Ha, whereas the Area 5 Assessment identifies a swamp area for Den98 of 0.8Ha. OEH mapping suggests that this swamp is closer to the 2.9 Ha estimate. If the Area 5 & 6 assessment areas were used, the potentially impacted area of Coastal Upland Swamp increases to ~17 Ha (compared to 16 Ha for the current proposal).
3. Tensile and compressive stress calculated using 15 times curvature.