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Dear Josh,

LONGWALL 13 END OF PANEL REPORT AQUATIC FLORA AND FAUNA REVIEW

Introduction

South32 – Illawarra Coal (South32) is extracting coal using longwall mining techniques from the Dendrobium Coal Mine, situated approximately 15 to 20 km west of Wollongong. Consent for the mine, granted in November 2001, allows extraction from three longwall domains, known as Areas DA1, DA2 and DA3. DA3, situated to the west of Lake Cordeaux, is currently being mined. A modification to the mine layout of DA3, approved in December 2008, allowed the mine to be expanded and Area 3 to be sub-divided into three smaller domains, DA3A, DA3B and DA3C. Mining of DA3B Longwalls is currently underway. Longwalls in DA3B have been extracted as follows:

- Longwall 9 commenced 9 February 2013; completed on 2 June 2014;
- Longwall 10 commenced 21 January 2014; completed 20 January 2015;
- Longwall 11 commenced 18 February 2015; completed 26 January 2016;
- Longwall 12 commenced 22 February 2016, completed 31 January 2017; and
- Longwall 13 commenced 3 March 2017, completed on 19 April 2018.

Cardno NSW/ACT (Cardno) was commissioned by South32 to undertake a review of the status of aquatic flora and fauna in relation to the extraction of Longwall 13 to support the End of Panel reporting for the longwall. Cardno has been undertaking ongoing monitoring of watercourses within the DA3B mining area including the perennial Wongawilli Creek, Donalds Castle Creek and several associated tributaries. The overall objective of the monitoring is to determine whether the extent and nature of observed impacts, primarily subsidence-induced fracturing of bedrock, diversion and loss of aquatic habitat, if any, are consistent with the predictions made in the aquatic flora and fauna review (AFFA) (Cardno Ecology Lab 2012) and Subsidence Management Plan (SMP) (BHPBIC 2012) for DA3B. This review includes:

- An overview of the management of aquatic flora and fauna including monitoring proposed and undertaken;
- Review of observed impacts to aquatic habitat, flora and fauna from South32 impact reports and site visits undertaken by Cardno and a comparison with those predicted in the SMP; and
- Recommendations for any Corrective Management Actions (CMA) and future aquatic flora and fauna monitoring.

This review considers the effects of extraction of Longwall 13 in DA3B and focuses on the findings of ongoing monitoring by South32 and on data from aquatic ecology impact sites in Wongawilli Creek, WC21 and Donalds Castle Creek. Information on Lake Avon tributaries near the western extent of Longwall 13 and on Wongawilli Creek tributary WC15 has also been provided by South32, though these are not routinely monitored by Cardno as part of the ongoing aquatic ecology monitoring.

Any impacts to swamps and amphibians are considered by other specialist consultants.

Aquatic Ecology Management and Monitoring

The monitoring requirements recommended in the AFFA for DA3B and included in the SMP for DA3B incorporates a Before, After, Control, Impact (BACI) sampling design to monitor mine subsidence impacts on the aquatic environment with collection of at least two years of baseline data followed by monitoring during extraction, and at least two years of post-extraction monitoring. The following indicators were monitored at impact and control sites (total of 16) within and outside the SMP area for DA3B as a measure of aquatic health:

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

It was recommended that monitoring in DA3B be undertaken once every two years CEL (2012b).

Table 1-1 summarises the monitoring that has been completed in DA3B in line with the AFFA and SMP. Baseline surveys were undertaken in DA3B in 2010 and 2011, followed by the during-extraction monitoring in 2013, 2015 and 2017. Additional monitoring was undertaken in DA3B in 2011 to support the AFFA, including more extensive fish surveys in WC21. The AFFA also includes a literature review on the physical setting, aquatic habitat, water quality, aquatic macroinvertebrates, fish, threatened species, populations and ecological communities in DA3B. Aquatic habitat in WC21 was also inspected visually during 2014 following the observation of physical mining impacts within the tributary.

The Illawarra Coal Environmental Field Team (ICEFT) undertake weekly monitoring of landscape and natural features in DA3B when they are within 400 m of the active longwall. This includes monitoring during extraction of DA3B longwalls to identify any fracturing, pool water level reduction, changes in flow and water quality in Wongawilli Creek and its tributaries (including WC21, WC15), Donalds Castle Creek, and Lake Avon tributaries.

The SMP includes the following triggers as part of the Trigger Action Response Plans (TARPs) relating to aquatic ecology:

- Level 1 – Reduction in aquatic habitat for 1 year;
- Level 2 – Reduction in aquatic habitat for 2 years following the active subsidence period (i.e. when a Longwall within 400 m of a feature, such as a creek, is completed); and
- Level 3 – Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period.

These trigger specific management actions aim to minimise any further impacts to the aquatic environment, and include requirements for further monitoring, reporting, application of (CMAs), such as grouting and repair of fractures, and notification of relevant stakeholders, as required.

Table 1-1 Monitoring undertaken for DA3B longwalls in line with the DA3B SMP Requirements and Recommendation in CEL (2012)

Report	Survey Date	Sampling Component
Baseline Monitoring		
Dendrobium Areas 3A and 3B. Aquatic Ecology Monitoring 2008 to 2013 (CEL 2014)	Mar / May / Sep Nov 2010 Apr / Jun / Sep / Oct 2011	Habitat assessment, fish, macroinvertebrates, water quality
During Extraction Monitoring		
Dendrobium Areas 3A and B. Aquatic Ecology Monitoring 2008 to 2013 (CEL 2014)	Apr / Jun / Sep / Nov 2013	Habitat assessment, fish, macroinvertebrates, water quality
Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014 (CEL 2015)	Throughout 2014	Observations of mining impacts and effects on aquatic habitat in WC21 in 2014 that were attributed to extraction of Longwalls 9 and 10, undertaken as part of DA3A monitoring fieldwork
Dendrobium Area 3B Aquatic Ecology 2010 to 2015 (CEL 2017)	May / Jun / Oct / Nov 2015	Habitat assessment, fish, macroinvertebrates, water quality
Cardno (2018)	Apr / May / Oct / Nov 2017	Habitat assessment, fish, macroinvertebrates, water quality

Predicted and Observed Impacts

Physical Mining Impacts

Details of the physical and associated water level, flow and quality impacts identified by ICEFT (South32 2018a) during extraction of Longwall 13 are provided in **Table 1-2**.

Table 1-2 Physical and water quality impacts observed by ICEFT during extraction of DA3B Longwall 13

Watercourse	Impact Type	Date	Comment
Wongawilli Creek	Reduction in pool water levels	20/11/2017	Pool 43a water level below baseline. Fracturing was identified in the pool during LW9. Reductions in flow have also been observed.
	Reduction in dissolved oxygen	23/01/2018, 12/02/2018	Site FR6 located downstream of physical mining impacts
	Elevation in electrical conductivity	23/01/2018, 12/02/2018	Site FR6 located downstream of physical mining impacts
Donalds Castle Creek	*None observed during extraction of Longwall 13*		
WC21	Rock fracturing	19/04/2017 to 12/02/2018	
	Iron staining	03/10/2018	
WC15	Rock fracturing	29/03/2018 to 16/05/2018	
	Iron straining	16/05/2018	
LA4	Rock fracturing, iron staining and likely flow diversion	18/05/2018	

In Wongawilli Creek, several physical and water quality impacts have been observed during extraction of Longwall 13. These included an extension of the fracturing within Pool 43a, identified previously during extraction of Longwall 9 in November 2013, and a reduction in the pool water level (below the baseline level)

(South32 2017). Very low pool levels were also observed, downstream of the fracturing, in Pool 43b. These two pools are adjacent to Longwall 9. In December 2017, following a rainfall event in late November 2017, water levels in Pool 43a, and those nearby, were above the baseline level. However, in January and February of 2018, water levels in Pool 43a were again below baseline (South 32, 2018b). During this time levels in Pool 36 (just upstream of Pool 43a) were also much lower than in December 2017, with this pool appearing to be dry in February 2018. 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. This section was adjacent to Longwalls 9, 10 and 11 and included Pool 41 to Pool 44 (Pool 36 lies within this extent). Surface flow was observed just downstream of the confluence with Wongawilli Creek tributary WC21. No additional fracturing was observed within this section of creek.

Changes in water quality first observed at Wongawilli Creek Site FR6 (approximately 2 km downstream) identified during extraction of Longwall 12 were also observed during extraction of Longwall 13 in January to February 2013. There were two occurrences of EC exceedance of baseline levels (between 169 µS/cm and 184 µS/cm) and three occurrences of DO below baseline (30.4 % and 43.3% saturation) (South 32 2018c, d).

Following the initial reduction in the water level of Pool 43a in November 2017, an assessment of surface water levels, flow and water chemistry in Wongawilli Creek was undertaken by HGEO (2018a). The reduction in water level in Pool 43a and changes in water quality further downstream at FR6 were attributed to low rainfall during the extraction of Longwall 13, rather than mining, and there was no significant mining effect on surface flow 2 km downstream (HGEO 2018a).

Plate 1. Pool 43a in Wongawilli Creek in December 2017 (top left) and January 2018 (top right) (South32 2018a) and WC21 in 2012/2013 (bottom left) and in October 2017 (bottom right).

The fracturing of bedrock and diversion of flow at Site X1 on Donalds Castle Creek was first observed in September 2013 and was restricted to the upstream extent of the site where the watercourse emerges from

an upland swamp. As of July 2018 approximately 1.4 km of Donalds Castle Creek was dry had experienced water level reductions.

In WC21, the mining related fracturing and flow diversions first observed by South32 during extraction of Longwall 9 in December 2013 have continued to affect WC21. Several additional fractures were observed in in Pools 45, 46, 47, 48, 53 and 54 in WC21 during extraction of Longwall 13 in October 2017, resulting in flow diversion and the reduction of pool levels (excluding Pool 54) (South32 2018a).The fracturing observed in WC21 during extraction of Longwall 13 has been within predictions (HGEO 2018b). By May 2018, the length of complete habitat loss in WC21 was 1 710 m, an increase of around 100 m since April 2017. Iron staining was also observed downstream of Pool 38 in October 2017.

In WC15 several fractures were also observed during extraction of Longwall 13. A diversion of surface flow was evident at one of these fractures; though potential flow diversion was not evident at the other fractures due to absence of flow. It is possible that they may result in flow diversions during non-drought conditions (South32 2018a).

In LA4, a tributary to Lake Avon, rock fractures resulting in flow diversion were observed during extraction of Longwall 13.

Impacts on Aquatic Habitat and Biota

The impacts to aquatic habitat and biota observed by ICEFT and Cardno associated with the physical and water quality impacts described above are summarised in **Table 1-3**. They are compared with the impacts to aquatic habitat and biota predicted to occur in the in the AFFA (CEL 2012). These predictions were based on the maximum predicted subsidence parameters for the sections of Wongawilli Creek, Donalds Castle Creek and the tributaries that flow through the DA3B SMP Area, their predicted impacts on the physico-chemical characteristics of the waterways (MSEC 2011), and the assessment of potential impacts on surface water quality (Ecoengineers 2011).

Reductions in water levels and flow in Wongawilli Creek, Donalds Castle Creek, WC21, WC15 and LA4 are 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 has also been a loss of aquatic habitat along the length of Donalds Castle Creek affected by loss of flow and reductions in water levels.

The physical mining impacts observed in Lake Avon tributary LA4 were associated with some reduction in the amount aquatic habitat. Based on the abundance of first and second order stream habitat in the local area, in isolation these impacts are relatively minor in the context of the Metropolitan Special Area Catchment. The cumulative impact due to extraction of longwalls in DA3B and the wider Metropolitan Catchment, should, however, be considered. Mapping by ICEFT indicates 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 (Cardno 2018). It is noted that a large proportion of this is expected to be ephemeral first and second order watercourses that provide more limited habitat for aquatic biota compared with larger and more permanent watercourses such as Wongawilli Creek. Nevertheless, these watercourses would still provide connectivity for some species at times of naturally high rainfall.

Reductions in water levels in creeks and tributaries would be expected to reduce longitudinal connectivity of aquatic habitat. This would impact the ability of aquatic fauna, such as fish and large mobile invertebrates, to move in search of food and habitat and could isolate individuals to small sections where water remained. Although water levels may recover temporally following rainfall thereby allowing movement of biota through the creek during these times, this would restore connectivity only temporarily. The direct loss of habitat due to reductions in water levels and loss of connectively through remaining habitat, could potentially impact on the population size of aquatic biota.

Monitoring of aquatic macroinvertebrates in DA3B was undertaken during April to November 2017. Some changes in macroinvertebrates were indicative of mining impacts in WC21; in particular, reductions in

Table 1-3 In WC21, loss of aquatic habitat, following fracturing and flow diversions, has occurred in approximately 80 % of its approximate 3 km length. Loss of aquatic habitat has also occurred in WC15 and LA4. The extent of habitat loss attributable to mining induced flow diversion, however, is difficult to quantify during the current period of low rainfall and associated low natural flow in these ephemeral watercourses. Predicted and observed impacts to aquatic ecology associated with Longwall 13

Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology	Observed Impacts to Aquatic Ecology
Wongawilli Creek			
Ponding, flooding and scouring of stream banks due to tilt	No significant change predicted.	No measurable effects due to tilt.	None identified during observations at aquatic ecology monitoring sites on Wongawilli Creek in 2017.
Fracturing of bedrock and diversion of surface flows	No significant fracturing resulting in surface water flow diversions. Minor, isolated fractures of the streambed may occur within 400 metres from the proposed Longwalls. Minor fracturing of the creek bed and subsequent diversion of flows would not have significant geochemical effects. Formation of ferruginous springs is unlikely, but could occur at the margins or upslope of swamps (Ecoengineers 2011).	No significant changes in the quantity or quality of permanent aquatic habitat.	Reduction in pool water levels and flow have resulted in a reduction in aquatic habitat (full or partial loss of pool water) in approximately 1.4 km of Wongawilli Creek. This represents around 10 % of the 12 km long creek. Loss of some aquatic biota (fish and macroinvertebrates) would likely also have occurred here. Indirect impacts to aquatic biota would include a loss of longitudinal habitat connectivity.
Donalds Castle Creek and drainage lines (WC21, WC15 and LA4)			
Ponding, flooding and scouring of stream banks due to tilt	Reversals in grade may occur along Tributary WC21, adjacent to the tailgates of Longwalls 10 and 11. These could result in small increases in the levels of ponding, flooding and scouring of stream banks in highly localised areas along the tributaries. The impacts resulting from such changes are expected to be small relative to those that occur naturally during floods.	Localised changes in habitat availability and connectivity may occur along the tributaries due to tilt, but will be difficult to detect because of the large variability in natural flows within these ephemeral systems.	No impacts observed due to tilt.
Fracturing of bedrock and diversion of surface flows	Fracturing of the bedrock is likely to occur. In ephemeral creeks with alluvial deposits, fractures are likely to be in-filled by deposits during flow events. In areas with exposed bedrock, some diversion of surface flows into underlying strata and drainage of pools may occur, particularly during low flows. It is unlikely, that this would result in a significant impact on the overall quantity or quality of water flowing from the catchment.	There is unlikely to be any significant long-term changes in the quantity, quality or connectivity of aquatic habitats. Any losses of habitat and connectivity that do occur would be minor, localised and transient.	Rock fracturing observed in WC21 during extraction of Longwall 13 has potentially exacerbated impacts (fracturing and associated reduction in the water level of pools and reductions in the quantity and connectivity of aquatic habitat) identified during extraction of previous DA3B longwalls. These impacts were first observed in 2013, have persisted since and have been observed in 1.7 km (over 50 %) of the total length of watercourse. This is a relatively severe impact at the scale of the individual watercourse. Fracturing of bedrock and diversion of flows in Lake Avon tributaries is likely to have resulted in some minor reduction in quantity and connectivity of aquatic habitat.

abundance associated with pool drainage following observed physical mining impacts. There was also some limited evidence (a reduction in the abundance of one taxon) of changes occurring in Wongawilli Creek. Data from Wongawilli Creek and WC21 also suggested that impacts to aquatic macroinvertebrates are localised to

the pools directly affected by physical mining impacts. Mining related impacts were not detected by macroinvertebrate indicators at downstream monitoring sites.

Quantitative aquatic ecology monitoring was last undertaken in Wongawilli Creek in November 2017 and the more extensive reductions in water levels have occurred in Wongawilli Creek after that date. Changes in water quality that have been recorded in Wongawilli Creek appear to have been temporary and are minor relative to measures of water quality observed prior to mining and are unlikely to represent a risk to aquatic habitats and biota. These changes in water quality also appear to be related to recent low rainfall and associated low flow in these watercourses, rather than low flow due to mining (HGEO 2018).

It is unlikely that the threatened Macquarie perch previously identified downstream in Wongawilli Creek has been put at risk by extraction in DA3B. Macquarie perch has been recorded in Dendrobium Area 3 in the mid to lower reaches of Wongawilli Creek, including pools just upstream and downstream of the Fire Road 6 crossing (Cardno 2018 and references therein). However, this species was not identified further upstream in Wongawilli Creek where the reduction in flow and water levels have been observed. This was despite extensive sampling here as part of this and previous surveys in Wongawilli Creek for the DA3B monitoring program. It is possible that this species is unable to pass the natural barrier in the form of a cascade / waterfall present a few hundred metres upstream of the Fire Road 6 crossing, at least not in any appreciable numbers. There was no evidence of changes in abundance of other native fish at the site visited in 2017.

It is difficult to quantify the impact to aquatic habitat and biota that may have occurred in Wongawilli Creek, WC21, WC15 and LA4 due to extraction of Longwall 13. In particular, the physical mining impacts observed in WC21 during extraction of this longwall occurred following several other mining related impacts that occurred here during extraction of previous DA3B Longwalls 9, 10, 11 and 12. At the very least, it is probable that the additional fracturing observed in WC21, and any that were not observed, has exacerbated the existing impacts to water levels and flow. If related to mining, the reductions in flow and pool water levels that occurred in Wongawilli Creek during extraction of Longwall 13 in 2017 and 2018 were almost certainly associated with extraction of previous longwalls. It is difficult to link any physical mining related impact with associated impacts on aquatic habitat and biota with extraction of individual longwalls. Physical mining impacts that have occurred may be associated with individual longwalls or a cumulative effect of several longwalls. In such cases, it is unclear if impacts are due to a delayed response following extraction of earlier longwalls, a cumulative effect of extracting multiple longwalls, or a combination of mining impacts with prevailing environmental conditions e.g. prolonged reduced rainfall periods.

Further investigation is to be undertaken by South 32 and other specialists to ascertain what proportion of reductions in flow and water levels is due to mining and patterns in rainfall.

Aquatic Ecology TARP

Table 1-4 compares observed impacts to aquatic ecology with the TARP levels to determine if these have been triggered and what management actions associated with extraction of Longwall 13 may be appropriate, if any. These TARPS are applicable only to watercourses where aquatic ecology monitoring sites are located (Wongawilli Creek, Donalds Castle Creek and WC21).

For Site X1 on Donalds Castle Creek, the active subsidence period ended on 24 October 2013 when Longwall 9 was more than 400 m away from this site. For Site X2 on WC21, the active subsidence period ended when Longwall 10 was completed on 20 January 2015. Thus, the reduction in aquatic habitat observed at these sites constitute a Level 3 Trigger. Actions for a Level 3 Trigger include notification of stakeholders and the development and implementation of CMAs. Such actions are currently underway as part of a remediation program for the impacts to WC21 (DPE 2015). The reductions in pool water levels and aquatic habitat in Wongawilli Creek were first observed less than 1 year previously and do not constitute a trigger.

Table 1-4 TARP levels applicable to aquatic features relevant to Longwall 13 as of May 2017. It is noted that the TARP triggers here relate to mining of the domain as a whole, rather than individual longwalls.

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

Conclusion and Recommendations

The reductions of pool water levels and flow in Wongawilli Creek, WC21, WC15 and LA4 following the extraction of DA3B Longwalls 9 to 13 represent a local loss of aquatic habitat and biota. The loss of habitat in WC21 and Wongawilli Creek are relatively severe at the scale of individual pools / watercourses. The loss of aquatic habitat in these watercourses is expected to have resulted in a reduction in connectivity of remaining habitat and a loss of aquatic biota. Due to the impacts observed during extraction of Longwalls 9, 10, 11 and 12, it is difficult to quantify what proportion of the observed impacts are associated with extraction of Longwall 13 alone. Nevertheless, it is likely that extraction of this longwall has contributed to the observed physical mining impacts, reductions in aquatic habitat and assumed loss of some associated aquatic biota. No TARPs have been triggered with respect to Wongawilli Creek as there has not been a loss in aquatic habitat for longer than 1 year. The reductions in aquatic habitat for over 2 years in WC21 constitute a level 3 trigger.

Due to the limited aquatic habitat provided by LA4 and WC15, and the abundance of these stream types in the Metropolitan Special Area, the fracturing and flow diversions observed represent a minor impact to aquatic ecology. At this stage, no specific recommendations associated with these tributaries is required.

It is recommended that further during and post mining aquatic ecology monitoring is completed in DA3B and in Wongawilli Creek and WC21 in line with the AFFR and SMP. South32 should continue to monitor watercourses that have been affected by extraction of Longwall 13 and previous longwalls and the findings of these will be used to assess whether TARPs will subsequently be triggered. Further assessment should also be undertaken to determine what component of reductions in flow and water levels in Wongawilli Creek is attributed to patterns in rainfall and physical mining impacts.

Furthermore, the triggering of aquatic ecology TARPs associated with the impacts observed in Donalds Castle Creek and following extraction of previous longwalls in DA3B should continue to be reviewed, as these are likely to have been triggered, and management actions and CMAs may be appropriate.

Yours sincerely,

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