SOUTH32

15 June 2020

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Dear Stephen,

RE: DENDROBIUM MINE – WATERNSW RESPONSE TO SUBMISSIONS REPORT

In response to DPIE's letter dated 20 April 2020, please find enclosed (Enclosure 1) South32's responses to residual concerns raised by WaterNSW in its submission on the *Dendrobium Mine – Plan for the Future: Coal for Steelmaking EIS* (the Project) and Submissions Report (letter dated 6 March 2020). Additional supporting information is provided in the enclosed letters prepared by MSEC (Enclosures 2 and 3).

As you would be aware, South32 has conducted ongoing engagement with WaterNSW and Sydney Water to identify preferred options to offset predicted surface water losses for the Project. Consistent with the Minister's recent media statement, the purpose of these offset options is to achieve a net gain to metropolitan water supplies as a result of the Project.

If you have any queries please don't hesitate to contact me (Chris.McEvoy@south32.net or 0407 060 163).

Yours sincerely
SOUTH32 LIMITED

Chris McEvoy
Approvals Manager
Dendrobium Next Domain Project

ENCLOSURE 1

RESPONSE TO WATERNSW COMMENTS

WATERNSW

Comment 1

WaterNSW stated:

> *WaterNSW notes that the RTS makes an unsubstantiated statement that adverse environmental impacts are still anticipated for reduced longwall widths down to approximately 150 metres. No reports or data are provided to support this claim.*
>
> *South32 should be required to provide detailed information on the environmental risk profile from increasing incremental widths of longwalls (e.g. 100 metres, 150 metres, 200 metres and 250 metres).*

South32 Response

The comment that adverse environmental impacts at the surface would occur due to subsidence-related effects for panel widths of 150 m is based on advice from MSEC (2019a) (Enclosure 2).

MSEC (2019a) has undertaken analysis of longwall widths of 150 m at the Dendrobium Mine (Enclosure 2), concluding:

> *.. The predicted conventional strains for the 150 m through to 305 m wide longwalls are greater than 0.5 mm/m tensile and 2 mm/m compressive. Whilst the predicted strains and, hence, the potential for physical impacts decrease with narrower longwall widths, the strains are still of sufficient magnitude to result in the fracturing of bedrock.*
>
> …
>
> *The predicted valley related effects for the 150 m through to 305 m wide longwalls are considered to be sufficient to result in fracturing, shear, dilation and buckling of the strata in the bases of valleys. This is supported by the observation that adverse impacts were observed along the Waratah Rivulet above Metropolitan Colliery, where the longwall void widths were 163 m. Similar impacts would be expected to the streams located directly above Dendrobium Areas 5 and 6 at similar longwall void widths.*
>
> *…*

Consequently, while narrower longwall panels would reduce total vertical subsidence, and correspondingly reduce predicted tilts and strains, the strains due to the valley-related effects would still be sufficient to result in fracturing of rockbars, pools and bedrock above and adjacent to the longwalls (i.e. adverse environmental impacts are still anticipated for reduced longwall widths down to approximately 150 m). More detail is provided in MSEC (2019a) (Enclosure 2).

Comment 2

WaterNSW stated:

> *In addition, it appears that with minor adjustments to the mine layout, it is possible to avoid mining directly under second and third order watercourses, for example:*
>
> - *shifting the western end of LW509 by approximately 150 m to the east,*
> - *shifting the western end of LW516 by approximately 100 m to the east, and*
> - *shifting the northern end of LW510 by approximately 400 m to the south.*

South32 Response

It is not feasible for the Project to avoid directly undermining second and third order streams with minor adjustments to the mine plan (Figure 1).

The three examples provided by WaterNSW would themselves result in sterilisation of 0.73 Mt of ROM coal with an equivalent value of approximately $104M and $6.5M in associated royalties. These three changes would not result in the Project avoiding the direct undermining of all second and third order streams.

This would be in addition to the significant value of coal already sterilised by the adoption of the proposed Project setbacks to avoid direct undermining of key stream features and named watercourses (Table 1).

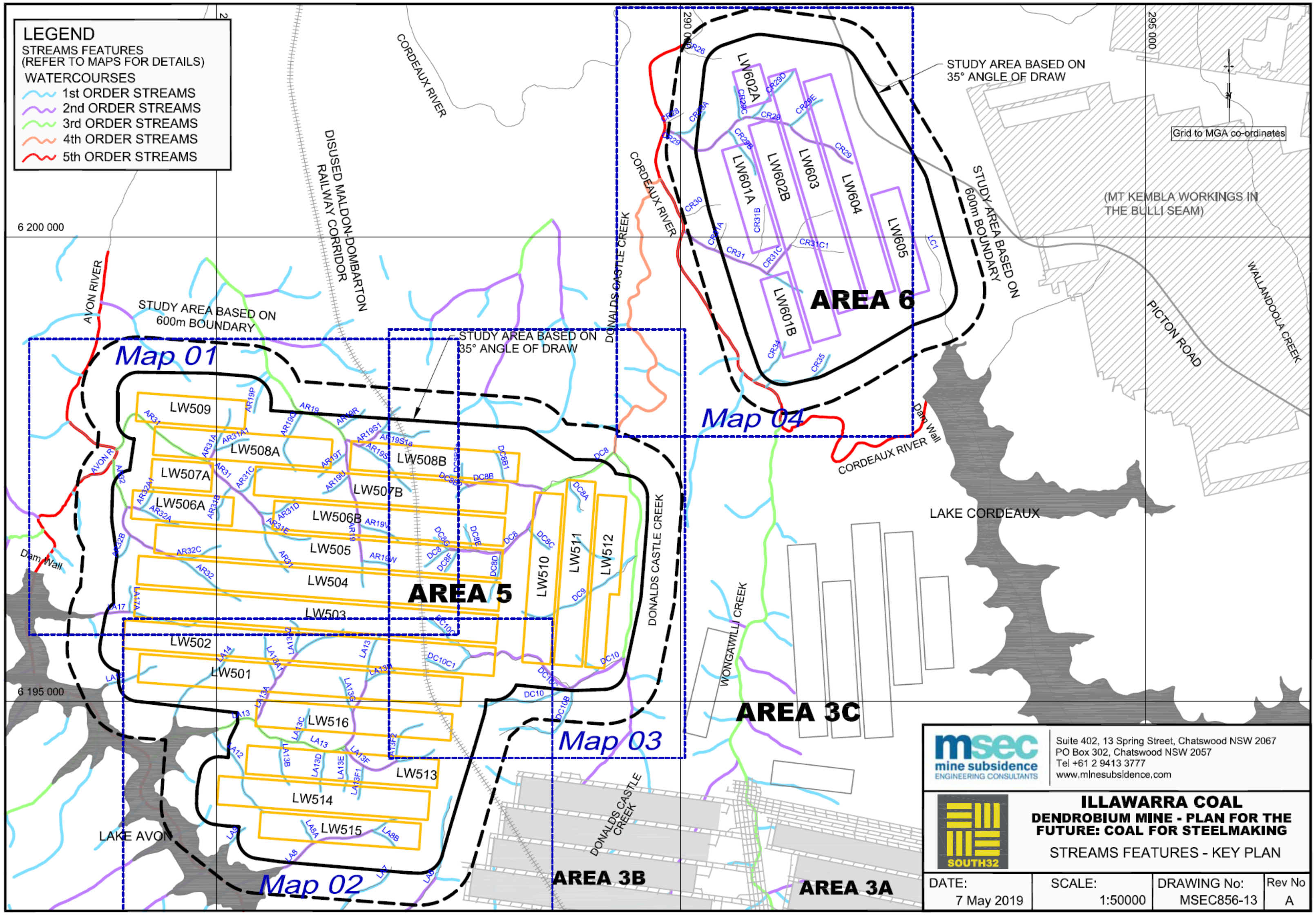

Figure 1: Stream Mapping (Source: MSEC, 2019b)

Table 1: Estimated Value of Coal Sterilised as a result of Project setbacks from Key Stream Features and Named Watercourses

Longwall Setback	Mt ROM Coal Sterilised (Area 5 and Area 6)	Estimated Value*
Key Stream Features (50 m and 100 m)	4.4 Mt	$628 million ($38 million in associated royalties)
Named Watercourses (to achieve 200 mm or less additional Project-related closure)	3.3 Mt	$468 million ($28 million in associated royalties)
Other (e.g. adjustments in mine plan orientation as a result of stream feature/ named watercourse setbacks)	1.77 Mt	$251 million ($15 million in associated royalties)

**Value calculations assume $173/tonne (undiscounted), 82.8% coal recovery and royalties of 6.2% coal value, consistent with the Economic Assessment (Appendix L of the EIS) and previous sterilisation value calculations provided in the Submissions Report.*

South32 has considered the significance of streams on the basis of the following characteristics (generally consistent with the Bulli Seam Operations NSW Planning Assessment Commission [PAC] Report [PAC, 2010]), as a component of the Stream Risk Assessment (Appendix B of Appendix C of the EIS) undertaken for the Project, including:

- permanence of flow (i.e. if the stream is ephemeral or perennial in nature);
- whether the stream is a regulated watercourse for water supply transfer;
- individual stream catchment area;
- importance to catchment yield;
- Strahler stream order;
- environmental quality (e.g. pristine, modified or severely modified); and
- ecological importance (e.g. presence of mapped Key Fish Habitat as per the habitat mapping provided by NSW Department of Planning, Industry and Environment [DPIE] which was confirmed during field surveys, where possible).

As a consequence of the above, and in consideration of stakeholder feedback, South32 has identified and adopted longwall setbacks from the following features considered to be relatively more significant:

- named watercourses (i.e. the Avon River, Cordeaux River and Donalds Castle Creek); and
- key stream features identified by South32, which are defined as:
  - pools with volume greater than 100 m^3 and holding water; and
  - steps/waterfalls greater than 5 m height with a permanent pool at the base.

It is noted the Bulli Seam Operations NSW PAC Report (PAC, 2010) acknowledged that determination of ‘significance’ of features was inherently difficult and subjective:

> *… the range of use and non use values of the waterways: water supply, ecological significance, conservation value, community value and recreational value are all recognised. However little progress is made in the EA toward interpreting the catalogue of raw data to provide any link to the significance of an individual stream or a collective of streams in a catchment. Furthermore, only a subset of the values appear to be carried forward for assessment of the acceptability of impacts. The difficulty of these steps is acknowledged by the Panel and it is not suggested that any deterministic process can be called upon to deliver incontestable outcomes. However, without an assignment of values to streams or groups of streams, and without consistent appreciation of all the values in the system, it becomes impossible to make an holistic assessment of the risks to those values from mining.*

There are unnamed drainage lines located above the Project longwalls that are proposed to be directly undermined, and are considered to be less significant than the named watercourses, on the basis that they:

- are ephemeral (i.e. do not exhibit permanent flow);
- are not mapped Key Fish Habitat;

- have relatively small sub-catchments and therefore small associated contributions to total catchment yields; and
- are of lower stream order (generally first and second order with small sections of third order), are common throughout the catchment area and are not regulated watercourses for water supply transfer.

The residual impact of undermining sections of unnamed and ephemeral drainage lines is an increase in low flow days and potential localised water quality impacts and iron staining. At the catchment scale these impacts are expected to be negligible.

The consequences of subsidence-related impacts to relevant threatened fauna species would be offset, as the Project Biodiversity Offset Strategy accounts for potential losses of habitat due to hydrological changes to ephemeral drainage lines overlying the Project underground mining areas.

Comment 3

WaterNSW stated:

> *The IEPMC estimates that surface water losses from existing mines in the Special Areas of the catchment is approximately 8 megalitres (ML)/day, including up to 5 ML/day from existing operations at the Dendrobium Mine.*
>
> *The IEPMC's findings confirm that the existing surface water losses in the catchment are far greater than predicted when the mining was proposed and approved. In fact, the water licensing regime does not provide any mechanism for the mining companies to acquire entitlements for these surface water losses. In that context, WaterNSW considers that any additional surface water losses must be avoided or minimised.*
>
> *However, based on the mining company's predictions, the additional surface water losses from this project would be up to 5.2 ML/day i.e. even more than the existing losses from the mine. Further, WaterNSW is concerned that these predictions may be underestimating the full extent of surface water losses from the catchment.*

South32 Response

These predicted surface water losses for the Project are fully described in the Submissions Report for the Project-only and cumulatively with the approved Dendrobium Mine (Tables 6-3A to 6-3D).

The reasons why the EIS groundwater model is considered to provide conservative estimates of predicted surface water losses is also provided in Section 6.3.4 of the Submissions Report (pp 27-29). Section 6.3.4 of the Submissions Report is provided as Enclosure 4.

Avoidance of incidental surface water losses would not be economically feasible for the project. Incidental surface water loss has been minimised by setbacks from reservoirs, named watercourses and significant stream features. The response to Comment 10, below, outlines South32's commitments in regard to offsetting predicted surface water losses to achieve a net gain to metropolitan water supplies.

South32 would hold appropriate licences under the *Water Management Act 2000* to account for surface water losses for the Project.

South32 currently holds licences (9,530 ML) to account for the volume of predicted groundwater plus surface water that may ultimately be diverted from the surface to the mine workings. However, these licences are all held in the water sharing plan relevant to groundwater sources only. As outlined in the Minister's 18 April media release, the NSW Government intends to implement a "*licensing regime to properly account for any water losses*".

Comment 4

WaterNSW stated:

> *Importantly, the IEPMC estimates that the surface water component of mine inflows could be in the order of 40-50%. However, the groundwater model for this project assumes that surface water accounts for an average of only 15 to 25% of mine inflows.*

South32 Response

The IEP's Initial Part 1 Report[1] estimated historic surface water losses from the Dendrobium Mine of 2.1 to 3 ML/day.

South32's response to the IEP Initial Part 1 Report[2] disputed the IEP's estimates, because the IEP's prediction would mean that this estimated surface water loss (which cannot be measured) would represent 40 to 50% of total mine inflows (which are measured), which was considered in South32's response to the IEP to be unrealistically high and not supported by water geochemistry analysis or South32's groundwater modelling.

The relevant section of South32's response to the IEP is provided below:

> *In regard to potential losses of surface water to the groundwater system, the IEP estimates historic losses of between 2.1 ML/day to 3 ML/day (refer to Section 4.5.1 of the Initial Report).*
>
> *It is unclear how these values have been derived.*
>
> *South32's groundwater modelling indicates losses have been 0.9 ML/day, peaking at 1.6 ML/day. These modelling estimates include conservative assumptions, including the modelling assumption that water is always present in the drainage lines overlying the longwall panels, whereas, in reality many of these drainage lines are ephemeral.*
>
> *It is noted the IEP commends the significant effort that has been undertaken to develop the Dendrobium Mine groundwater model:*
>
> > *There have been major efforts over the last decade by both Dendrobium Mine and Metropolitan Mine to employ up-to-date 3-dimensional groundwater models and best practice modelling methods undertaken by specialists, with expert peer review.*
>
> *In addition, the IEP's upper estimates would mean 40 to 50% of groundwater inflow to mine workings is from surface water. Although there is some uncertainty with water fingerprinting (methods to measure the source of water) science, this level of modern water entering the mine is not supported by water geochemistry.*
>
> *The regional groundwater model remains the best available integrated tool to estimate surface water losses, as it is informed and constrained by site specific data (e.g. groundwater inflows, groundwater levels, pre- and post-mining porosity and permeability data etc). The results of the groundwater model are likely to be conservative and overstate losses, for the reasons outlined above.*

The groundwater model for the EIS predicted surface water losses from the Project would comprise approximately 25-35% of predicted total mine inflow. The prediction of surface water losses is likely to be conservative given the conservative nature of assumptions adopted in the groundwater model (e.g. assuming surface water is 'permanently' lost to the groundwater system, whereas in reality, portions are likely to re-emerge downstream and not report to the mine workings) (refer to pp 99 of the Groundwater Assessment).

Comment 5

WaterNSW stated:

> *WaterNSW remains concerned about the sheer number of streams that are predicted to experience fracturing and potential water losses, including nine major watercourses (3rd order or above) and approximately 100 smaller tributaries.*

South32 Response

Please refer to the responses to comments 1 and 2 above.

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[1] Independent Expert Panel for Mining in the Catchment (2018). *Initial report on specific mining activities at the Metropolitan and Dendrobium coal mines.* Prepared for the NSW Department of Planning, Industry and Environment.

[2] https://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0004/225166/Response-to-IEP-Report-Attachments-1-3.pdf

Comment 6

WaterNSW stated:

> *WaterNSW is particularly concerned about the potential impacts of fracturing in the Avon and Cordeaux Rivers as these rivers are downstream of the reservoirs and feed into Pheasants Nest Weir, which is a major component of the water supply system. Potential loss of water to these rivers from fracturing could affect WaterNSW's ability to supply its customers.*

South32 Response

The Project would setback from (i.e. not directly undermine) the Avon River and Cordeaux River. Relatively short sections of the Avon and Cordeaux Rivers are within 400 m of the Project longwalls (Table 2).

Table 2: Lengths of Avon River and Cordeaux River within 400 m of Project Longwalls and Likelihood of Potential Type 3 Impacts

Watercourse	Total Stream Length	Length of Watercourse Located within 400 m of Project Longwalls	Percentage of Total Stream Length	% of Pools and Channels Predicted to Experience Type 3 Impacts[1]
Avon River	38.4 km	0.4 km	1%	7% (for 0.4 km section)
Cordeaux River	37.7 km	0.25 km	0.7%	5% (for 0.25 km section)

Source: Table 6-5B of the Submissions Report.

[1] Predicted % of impacted pools and channels along stream reaches within 400 m of proposed longwalls.

The Subsidence Assessment for the EIS (MSEC, 2019b) assessed potential impacts to the Avon River as follows:

> *The Avon River is predicted to experience less than 20 mm vertical subsidence due to the extraction of the proposed longwalls. Whilst the river could experience very low-levels of vertical subsidence, it is not expected to experience measurable conventional strains. That is, the strains due to the conventional ground movements are expected to be less than 0.3 mm/m.*
>
> *The maximum predicted closure along the Avon River due to the proposed mining in Area 5 is 200 mm. The maximum predicted compressive strain for the river due to the valley closure effects is less than 2 mm/m based on the 95 % confidence level.*
>
> *…*
>
> *It has been assessed that the likelihood of significant fracturing resulting in surface water flow diversions along the Avon River is very low, i.e. affecting approximately 7 % of the pools and channels along the 0.4 km section of river located within approximately 400 m of the proposed longwalls.*

The Subsidence Assessment for the EIS (MSEC, 2019b) assessed potential impacts to the Cordeaux River as follows:

> *The Cordeaux River is predicted to experience less than 20 mm vertical subsidence due to the extraction of the proposed longwalls. Whilst the river could experience very low-levels of vertical subsidence, it is not expected to experience measurable conventional strains. That is, the strains due to the conventional ground movements are expected to be less than 0.3 mm/m.*
>
> *The maximum predicted closure along the Cordeaux River due to the proposed mining in Area 6 is 80 mm. The maximum predicted compressive strain for the river due to the valley closure effects is 2 mm/m based on the 95 % confidence level.*
>
> *…*
>
> *It has been assessed that the likelihood of significant fracturing resulting in surface water flow diversions along the Cordeaux River is very low, i.e. affecting less than 5 % of the channels located within the Study Area. Minor fracturing could occur elsewhere along the river for distances up to approximately 400 m from the proposed longwalls.*

As the Project would not directly undermine the Avon and Cordeaux Rivers, potential fracturing in the river sections within 400 m of the Project longwalls (the likelihood of which is considered "low") would not interact with the sub-surface fracture network above the longwalls. Surface water flow monitoring in the Southern Coalfield shows surface water re-emerges downstream of streams impacted by streambed fracturing where there is no interaction with the sub-surface fracture network (rather than water being lost to the groundwater system).

Regulated flows in the Avon and Cordeaux Rivers (i.e. flows determined by dam releases) have historically been in the order of 10 ML/day. As such, at these flow rates, any Type 3 impacts (the likelihood of which is considered to be "low") are unlikely to cause discernible periods of low or now flow, as the rate of any losses to the surface fracture network would be significantly lower than the regulated flows in the Avon and Cordeaux River.

Therefore, it is not anticipated that the ability of WaterNSW to supply its customers would be affected as a result of potential Type 3 impacts in the relatively short sections of the Avon and Cordeaux River within 400 m of the Project longwalls given:

- the Project longwalls setback from the Avon and Cordeaux Rivers would mean any surface cracks in these relatively short sections of the Avon and Cordeaux Rivers would not interact with the sub-surface fracture network;
- any surface water losses due to a surface fracture network would likely re-emerge downstream rather than be lost to the groundwater system; and
- the relatively high flows in the Avon and Cordeaux Rivers, which are regulated by releases from the dams, would be significantly higher than any loss to the surface fracture network (noting these cracks would become saturated due to the high flows), and as such, discernible periods of low or no flow are unlikely.

Potential surface water losses from the entire catchment area downstream of the Avon and Cordeaux dam walls (including the Avon and Cordeaux Rivers to Pheasant's Nest Weir) as a result of depressurisation of the underlying groundwater system are quantified in Table 6-3C and 6-3D of the Submissions Report (refer to Enclosure 4).

The response to Comment 10, below, outlines South32's commitments in regard to offsetting predicted surface water losses to achieve a net gain to metropolitan water supplies.

Comment 7

WaterNSW stated:

> *The information provided in the RTS has not adequately demonstrated that the project will achieve a NorBE on water quality.*

South32 Response

No material impacts to drinking water supplies are predicted as a result of localised impacts to water quality from streambed cracking. This conclusion is based on measurements from the existing mining operations in the catchment, including at the Dendrobium Mine and elsewhere and is supported by the findings of previous studies (refer to Section 9.3.6 of the EIS for further details).

It is noted the IEP's Part 2 Report (2019)[3], which was released after lodgement of the EIS, concluded:

> *Although surface fracturing elevates metal loads in watercourses, there is no evidence that mining in the Special Areas is currently compromising the ability of WaterNSW to meet raw water supply agreement standards.*

Details of South32's water quality offset commitments to satisfy the 'Net Neutral or Beneficial Effects' (NorBE) test under the *State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011* (Sydney Drinking Water Catchment SEPP) are outlined in Section 9.3.6 of the EIS and Section 6.7 of the Submissions Report.

Fell (2014)[4] identifies that sedimentation is a parameter of concern to drinking water supplies. Similarly, the *Special Areas Strategic Plan of Management 2015* (WaterNSW and Office of Environment and Heritage [OEH], 2015[5]) identifies sedimentation as a key water quality risk to the Special Catchment Areas.

Therefore, although streambed cracking can result in localised increases in concentrations of metals (which have not been observed to compromise WaterNSW's ability to meet raw water standards), South32 proposes a number of additional water quality improvement actions as part of the Project that target sedimentation control.

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[3] Independent Expert Panel for Mining in the Catchment (2019). *Report of the Independent Expert Panel for Mining in the Catchment: Part 2 – Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment*. Prepared for the NSW Department of Planning, Industry and Environment.

[4] Fell. C (2014). *Water Treatment and Sydney Catchment*. Discussion Paper for Office of NSW Chief Scientist and Engineer, May 2014.

[5] WaterNSW and Office of Environment and Heritage (2015). *Special Areas Strategic Plan of Management 2015*.

The water quality improvement actions proposed by South32 are:

1. Transfer of 28.5 hectares (ha) of South32-owned land within the Metropolitan Special Area to WaterNSW, which would enable WaterNSW to manage and protect this land to maintain water quality values.
2. Direct implementation (by South32), or funding (to WaterNSW), of water quality improvement works, as outlined in Table 2.

Table 2: Proposed Water Quality Improvement Works

Water Quality Improvement Work	Estimated Financial Contribution (if works not conducted by South32)
Fire Management: • Slashing grass and vegetation for fire breaks (100 km and 200 ha). • Mulching trees and woodland along fire trails to maintain fire breaks (at least 22.5 km). • Conducting hazard reduction burns (at least 100 ha) in consultation with relevant authorities.	$371,500[a]
Inspect and Maintain Unsealed Road Network: • Inspect 150 km of unsealed roads. • Repair and upgrade 40 km of unsealed roads within the Special Catchment Areas.	$146,000[a]
Install and Maintain Appropriate Barriers and Fences: • Install barriers as required around any land transferred to WaterNSW. • Install barriers and fences to replace those that are damaged or vandalised.	$100,000[b]
Total	**$617,500**

Source: Table 9-3 of the EIS.

[a] Based on conducting an additional 50% of WaterNSW's Planned Activities for Fire Management and Unsealed Roads Program as per the *Catchment Protection Work Program 2018-19: Sydney Catchment Area*.

[b] Estimation only.

The consent authority can be confident that the proposed water quality improvement actions would benefit water quality in the catchment, as the actions are based on (but additional to) the funding and works outlined in the *Special Areas Strategic Plan of Management 2015* (WaterNSW and OEH, 2015) to improve water quality.

It is acknowledged that projects that target sedimentation control do not directly offset localised increases in metal concentrations. However, the Project would have a net neutral or beneficial effect on the surface water quality of the Special Catchment Area for the following reasons (Section 6.7 of the Submissions Report):

- The potential localised effects to surface water quality as a result of Project-related subsidence can themselves be considered environmentally neutral, given spikes in metal concentrations occur naturally (refer to Table 6-7A of the Submissions Report) in the catchment, and the lack of evidence that localised effects to date have resulted in adverse impacts to drinking water supplies.
- Water quality parameters that would potentially be impacted by Project-related subsidence (e.g. iron and manganese) are not identified as priority parameters when considering the potential impacts to the quality of drinking water supplies.
- By comparison, South32's proposed water quality improvement works target sedimentation, which is identified by Fell (2014) and WaterNSW and OEH (2015) as a priority surface water quality risk. Therefore, the implementation of the proposed water quality improvement works for the Project would result in an overall benefit to the water quality of drinking water supplies.

Comment 8

WaterNSW stated:

> *WaterNSW reiterates its position that the project could potentially affect its ability to construct and operate proposed infrastructure projects, such as the Lower Cordeaux Dam and Avon Deep Water Access projects. Such projects must not be compromised by mining activities and WaterNSW requests that South32 continue to consult with it on such matters.*

South32 Response

South32 will continue to consult with WaterNSW in regard to its future projects.

It is understood the Avon Dam Deep Water Access project is in the planning phase, and the pipeline would cross the approved Dendrobium Mine Area 3B and proposed Area 5 for the Project (Figure 2) to supply water to the Illawarra Filtration Plant.

As the proposed pipeline crosses Area 3B and Area 5 for the Project, it is likely to experience mining-induced ground movements due to subsidence (WaterNSW has advised South32 that the pipeline would be buried). As such, if it were to be constructed, it should be designed to accommodate the predicted range of subsidence movements and appropriate mitigation and management measures be prepared in the relevant Subsidence Management Plans (Area 3B) and Extraction Plans (Area 5).

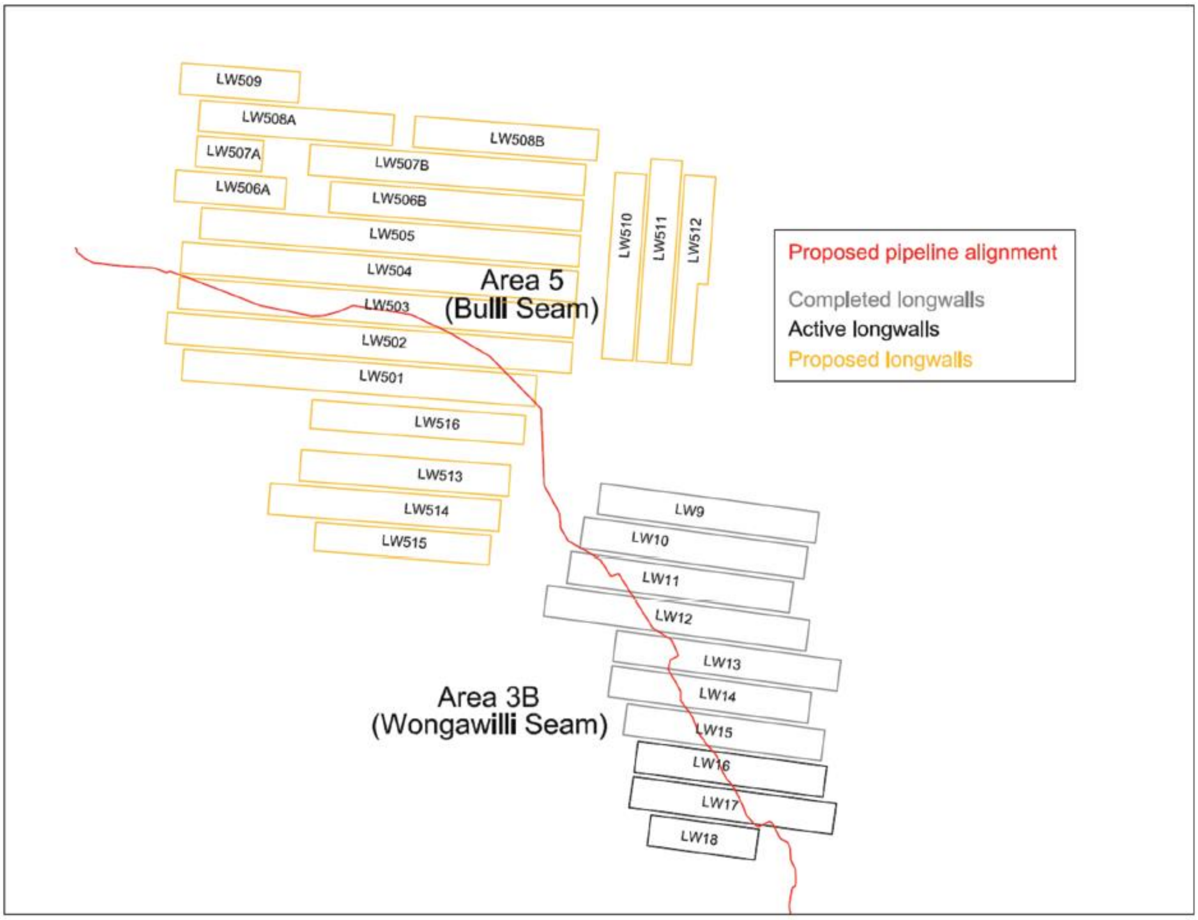

Figure 2: Proposed Pipeline Alignment

The potential future Lower Cordeaux Dam (Plate 1) was considered in MSEC (2019b) and the Submissions Report (pp 71-72).

WaterNSW advised South32 during the preparation of the EIS that one of the long-term water supply options under consideration by WaterNSW is the "Lower Cordeaux Scheme", comprising a potential new water supply reservoir known as the Lower Cordeaux Dam.

Based on the information provided to South32 by WaterNSW, the Project is not expected to be incompatible with the potential future reservoir.

The potential Lower Cordeaux Dam Wall would be located on the Cordeaux River approximately 2.8 km west of the proposed longwalls in Area 6 and approximately 3.7 km north of the proposed longwalls in Area 5, and is not expected to experience measurable far-field horizontal or valley-related effects at these distances.

Although the Full Supply Level (FSL) of the potential Lower Cordeaux Dam could overlap small portions of the Area 5 and Area 6 longwalls (as well as previously mined areas associated with Area 2, Area 3 and other historic mining operations), the mining setbacks proposed for the Project in relation to named watercourses and key stream features already limit the potential for overlap between the Project longwalls and the potential FSL.

Notwithstanding, the FSL of the potential Lower Cordeaux Dam would flood a number of features the Project seeks to protect via its mine design constraints (e.g. sections of Wongawilli Creek and Donalds Castle Creek would be inundated).

It is understood that the potential Lower Cordeaux Dam would still be subject to further analysis and assessment, and as such, there is still significant residual uncertainty in regard to the feasibility, environmental assessment, design, approvability and timing of the potential infrastructure.

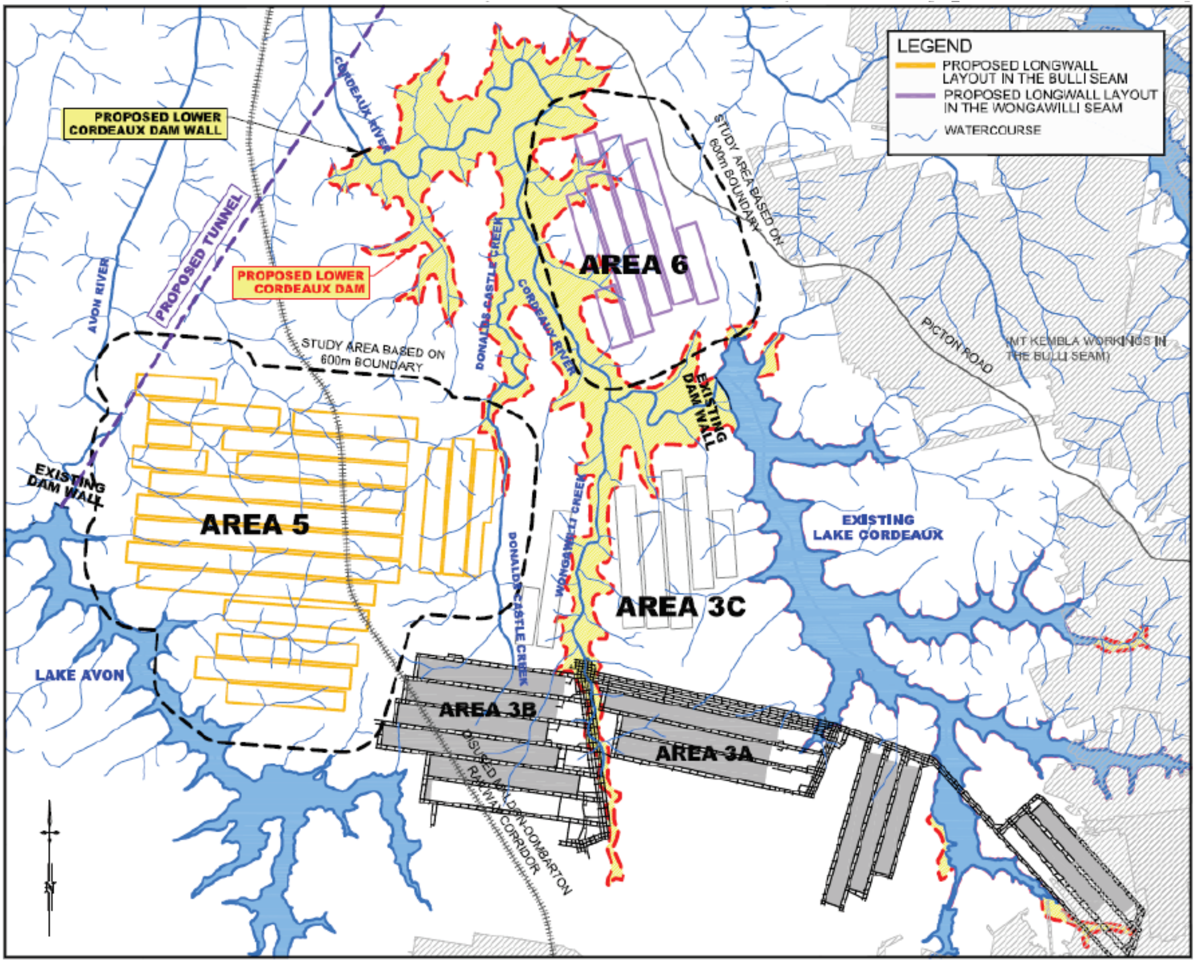

Plate 1: Potential Future Lower Cordeaux Dam
Source: MSEC (2019b)

Comment 9

WaterNSW stated:

> *WaterNSW also reiterates its position that the setbacks from the two dam walls should be increased to at least 1,500 metres due to potential far-field differential movements. Should any impacts occur to these dams, there is the potential that the risks and consequences could be extreme. This is an area that warrants further careful consideration.*

South32 Response

The key mechanism for the potential for impacts on the Avon and Cordeaux dam walls is not absolute far-field horizontal movement, but differential horizontal movements (i.e. strain).

Based on currently available information, differential movements at the Avon and Cordeaux dam walls at 1,000 m from secondary extraction are expected to be negligible and within the range of survey tolerance (i.e. are not anticipated to be measurable).

These predictions are based on monitoring data. While there is limited strain monitoring data at Dendrobium Mine, there is extensive data elsewhere in the Southern Coalfield. The monitoring data shows that at distances of 1,000 m or greater from extracted longwalls, the majority of the measured strains (i.e. 94 % of cases) are less than the nominal survey tolerance of 0.25 mm/m (nominal survey tolerance for strain represents a change in length [i.e. horizontal distance] of 3 mm to 5 mm measured over a 20 m survey bay) (MSEC, 2020).

South32 has previously outlined its commitments and assessment in regard to protecting the Avon and Cordeaux dam walls in the EIS and the Submissions Report, in particular the minimum 1,000 m setback from secondary extraction to avoid adverse impacts to the dam walls.

Further to this commitment, South32 commits to achieving a subsidence performance measure such that the safety and serviceability of the Avon and Cordeaux dam walls is always maintained, and that there is negligible additional risk to public safety as a result of the Project.

This commitment will be achieved through the implementation of appropriate monitoring and adaptive management measures throughout the life of the Project. Specific details of monitoring requirements, adaptive management measures, Trigger Action Response Plans (TARPs) and contingency measures would be included in Extraction Plans for the Project, which would be developed in consultation with Government, as well as WaterNSW, Dams Safety NSW (DSN) and an appropriately qualified Dams Engineer (where appropriate).

Specifically, TARPs will form a key component of the monitoring and adaptive management approach to manage potential impacts to the dam walls. The development of TARPs and relevant triggers would be informed by a risk assessment undertaken during the preparation of Extraction Plans, which would include input from an appropriately qualified Dams Engineer and may include the following:

- assessment of the existing condition, structural integrity and stability of the dam walls;
- provision of advice of the allowable mining-induced movements that the dam walls can accommodate and appropriate factors of safety, noting that the dam walls would already experience, and have been designed to account for the following movements:
    - movements due to thermal expansion/ contraction; and
    - movements induced by changes in the water load against the structures as the dam levels vary; and
- recommendations of preventative measures that may be implemented.

South32 would monitor the potential subsidence-related impact mechanisms for the dam walls using real-time monitoring methods to inform ongoing assessment against the established trigger levels for the Project. Further detail is provided in South32's letter to DSN dated 15 June 2020.

It is anticipated that an independent committee would be established to assess the results of the ongoing monitoring against established trigger levels for the Project.

Notwithstanding, South32 acknowledges the concerns raised by WaterNSW and DSN in regard to the selection of a setback distance from the Avon and Cordeaux dam walls to the Project longwalls. As described in the Submissions Report, the intention of South32's existing commitment regarding a minimum distance of 1,000 m from dam walls is for the protection of this infrastructure (i.e. the Project is not seeking approval to damage the dam walls).

However, the conclusions of the Subsidence Assessment described above would remain the same if the minimum setback distance to the dam walls was revised to 1,500 m (i.e. differential movements would be negligible and within the range of survey tolerance, and an adaptive management approach to confirm performance measures would be required).

The consequence of a 1,500 m setback from the Avon and Cordeaux dam walls would be the sterilisation of an additional 5.1 Mt of ROM coal worth some $723 million and $45 million in associated royalties.

The ultimate setback distance from the dam walls to the Project longwalls will be determined by the requirement to achieve South32's additional commitment, as well as the performance measures in any development consent for the Project.

<u>Comment 10</u>

WaterNSW stated:

> *In relation to surface water licensing, WaterNSW recommends that there should be no allowance for "additional" surface water losses unless:*
>
> - *every effort is made to avoid or substantially reduce surface water losses*
> - *a 'precautionary approach' is applied to mine design and surface water losses (as recommended by the IEPMC)*
> - *independent expert advice (both scientific and economic) supports the case, and*
> - *any residual surface water losses are fully offset, so there is a net environmental benefit.*

South32 Response

South32 agrees with this comment.

To minimise potential surface water losses, the Project mine layout has been designed to incorporate setbacks from the Metropolitan Special Area water storages (Avon and Cordeaux Dams), named watercourses and key stream features.

The consequence of this decision is the sterilisation of approximately 25 Mt of ROM coal within South32's existing mining tenement (CCL 768), worth some $3.58 billion and $222 million in associated royalties (refer to Section 6.3 of the Submissions Report).

To maximise value in the remaining mining areas within CCL 768, continuation of mining with panels at the width consistent with the existing Dendrobium Mine is proposed for the Project (subject to dam wall, named watercourse and key stream feature setbacks).

A mine plan with 150 m wide panels within Areas 5 and 6 is uneconomic. Section 9.4.4 of the EIS describes the consequences of not carrying out the Project.

The Project mine plan is predicted to result in surface water losses, which are quantified in the EIS and Section 6.3.4 of the Submissions Report (Enclosure 4). These losses are predicted to be negligible at the catchment scale.

The IEP's Part 2 Report notes that its estimates of cumulative losses from Sydney's drinking water catchment from the Dendrobium, Russell Vale and Wongawilli mines of 8 ML/day are "low" when compared to other components of the drinking water network (by comparison the maximum predicted surface water losses from the Project are 5.2 ML/day):

> *The* [surface water] *losses referred to in Section 3.2.3 are low compared to other components of Sydney's supply and demand, for example recent losses from the Dendrobium, Russell Vale and Wongawilli mines of less than 8 ML/day on average compare to the Sydney Desalination Plant capacity of approximately 250 ML/day (Sydney Desalination Plant, 2019) and estimated leaks from the Sydney Water supply infrastructure of approximately 130 ML/day (Sydney Water, 2018).*

Similarly, the Independent Expert Scientific Committee (IESC) in their submission on the Project, notes the predicted reduction to Sydney's drinking water supply is "*unlikely to be of material concern*".

Notwithstanding, South32 outlined its commitments to offset predicted surface water losses in the Submissions Report such that the Project would result in a net gain to metropolitan water supplies.

South32 notes that DPIE supports South32's commitment to implement or fund works such that the Project results in net gain to Sydney's drinking water supplies from subsidence-related surface water losses from the Metropolitan Special Area (refer letter dated 20 April 2020):

> *The Department fully supports the following high-level commitment by South32 in the RTS, and notes that it is consistent with recent statements from the Minister for Planning and Public Spaces about the need for mining companies in the Special Areas to ensure they make a positive contribution to the broader metropolitan water supply …*
>
> *To allow the Department to consider this issue in the assessment of the project, it would be appreciated if you could provide details about the proposed offsets …*

In response to the DPIE's comments, South32 provided further detail in regard to the proposed offsets (refer letter dated 2 June 2020).

South32's commitments over the life of the Project and post-mining to achieve a net gain to metropolitan water supplies are summarised in Table 3 and are consistent with the recent media statement by the Minister for Planning (18 April 2020). South32's water offset options are consistent with the options recommended by the IEP (2019b).

Table 3: Summary of South32 Commitments to achieve Net Gain to Metropolitan Water Supplies

Timing	**South32 Commitments to Address Surface Water Losses**						
	1. Achieve "net gain" to metropolitan water supplies			**AND**	**2. Compensate WaterNSW for lost revenue**	**AND**	**3. Hold appropriate licences**
	1a. "Direct" offsets	**OR**	**1b. "Indirect" offsets**				
Already occurred							✓ Groundwater licences (>$6M)
Commencement of Project	✓ Capital ($34M)	OR		AND		AND	✓ Surface water ($TBC by Govt)
During Project life	✓ Annual operating costs	OR	✓ Annual funding contribution to NSW Govt based on $2.30/kL ("base") or $3.12/kL ("drought")	AND	✓ Annual funding contribution to WaterNSW based on $49.90/ML ("base") or $59.70/ML ("drought")	AND	✓ Hold licences
Post-mining	✓ Gift treatment facility (capital of $34M already spent)	OR	✓ Relinquish funds of $34M to NSW Govt at the end of the mine life	AND		AND	✓ Retire licences

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ENCLOSURE 2

MSEC LETTER REPORT (2019a)

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30 September 2019

Gary Brassington
South32 Illawarra Coal
PO Box 514
Unanderra NSW 2526

For the attention of: Mr. Gary Brassington, Principal Approvals

Dear Gary,

RE: Dendrobium Mine – Plan for the Future: Coal for Steelmaking
Influence of longwall void width on the predicted subsidence effects

Illawarra Coal South32 (South32) has prepared an Environmental Impact Statement for the proposed longwalls in Dendrobium Areas 5 and 6, referred to as *Dendrobium Mine – Plan for the Future: Coal for Steelmaking*. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC856 (Rev. B) which provided the predicted subsidence effects and assessed impacts in support of that application.

The void widths of the proposed longwalls in Areas 5 and 6 are generally 305 m. South32 has engaged MSEC to review the predicted subsidence effects and the potential for physical impacts (i.e. surface cracking and rock fracturing) based on narrower longwall void widths. This letter report provides a summary of the maximum predicted subsidence effects and physical impacts due to varying longwall void widths in Areas 5 and 6.

Vertical subsidence

The maximum predicted values of vertical subsidence based on 305 m wide longwalls are 2050 mm for Area 5 and 2450 mm for Area 6. The maximum predicted vertical subsidence in Area 5 is less than the maximum predicted value for Area 6 due to the smaller mining height in the Bulli Seam. The maximum predicted vertical subsidence represents 64 % of the mining height in Area 5 and 63 % of the mining height in Area 6.

The relationships between longwall void width and maximum predicted vertical subsidence are illustrated in Figure 1. The predicted vertical subsidence has been obtained using the Incremental Profile Method (IPM) which is described in Sections 3.5 and 3.6 of Report No. MSEC856.

The shapes of the curves for Area 5 and Area 6, shown in Figure 1, differ due to the mining geometry. The proposed longwalls in Area 5 are at shallower depths of cover (i.e. 360 m average) compared with the depths of cover in Area 6 (i.e. 440 m average), whereas the proposed mining heights in Area 5 are lesser (i.e. 2.5 m to 3.2 m in the Bulli Seam) compared with the proposed mining heights in Area 6 (i.e. 3.9 m in the Wongawilli Seam).

The maximum predicted vertical subsidence decreases as longwall void width reduces. The maximum predicted vertical subsidence, as percentages of the maximum predicted value for the 305 m wide longwalls, are approximately 70 % to 80 % for 250 m longwalls, 50 % to 60 % for 200 m wide longwalls and 30 % for 150 m longwalls.

The potential for physical impacts (i.e. surface cracking and rock fracturing) is not dependant on absolute vertical subsidence. Physical impacts develop due to differential movements, which are described by curvature and strain. The predicted curvatures and strains based on varying longwall void widths are described in the following sections.

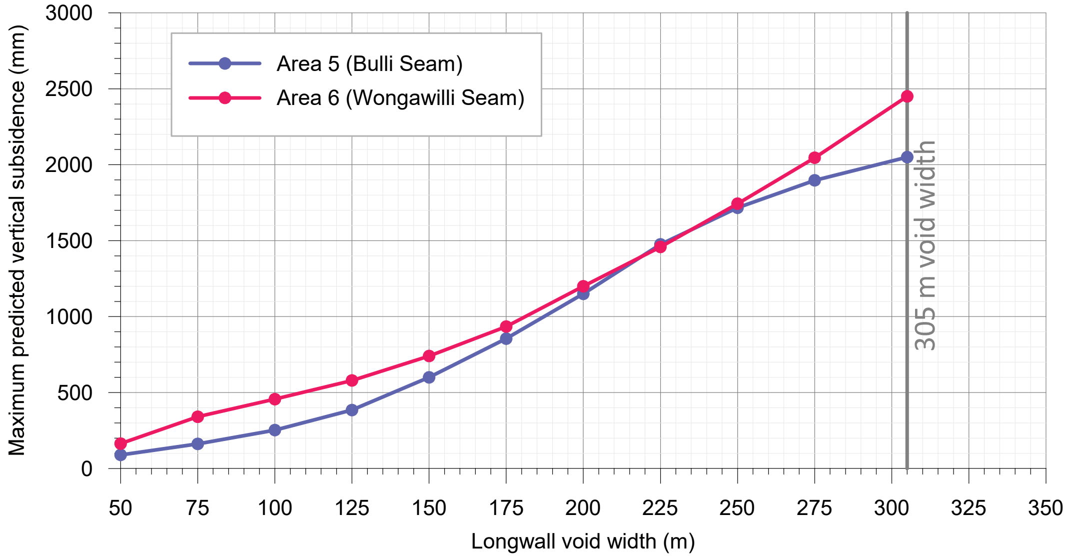

Figure 1 Maximum predicted vertical subsidence versus longwall void width

Curvature and conventional strain

The maximum predicted curvatures based on 305 m wide longwalls are 0.5 km^{-1} hogging (i.e. 2.0 km minimum radius) and 0.6 km^{-1} sagging (i.e. 1.7 km minimum radius) for Area 5, and 0.3 km^{-1} hogging (i.e. 3.3 km minimum radius) and 0.5 km^{-1} sagging (i.e. 2.0 km minimum radius) for Area 6. The maximum predicted curvatures are similar in these two mining areas, as the shallower depths of cover in Area 5 are offset by the smaller mining heights within the Bulli Seam, when compared with Area 6.

The relationships between longwall void width and maximum predicted hogging curvature and maximum predicted sagging curvature are illustrated in Figure 2 and Figure 3, respectively. The predicted curvatures have been obtained using the IPM as described in Report No. MSEC856. The shapes of the curves shown in these figures for Areas 5 and 6 differ due to the mining geometry, similar to that described above for vertical subsidence.

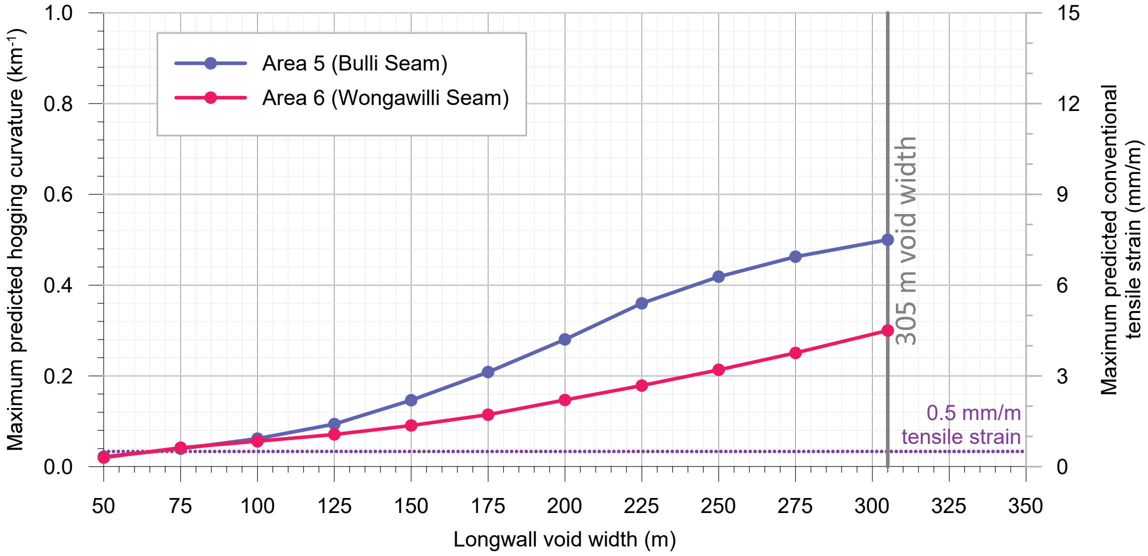

Figure 2 Maximum predicted hogging curvature and conventional tensile strain versus longwall void width

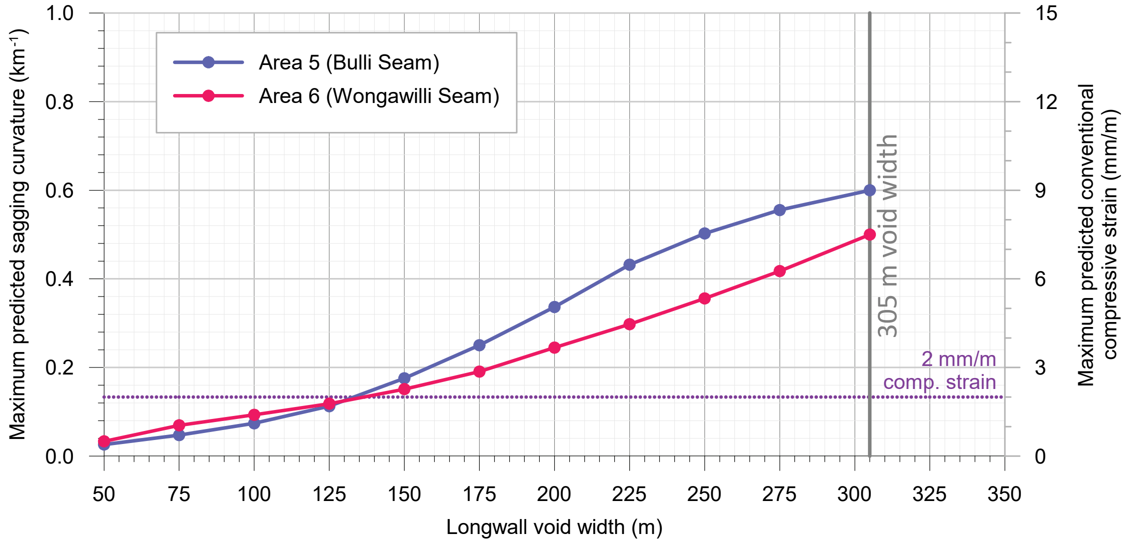

Figure 3 Maximum predicted sagging curvature and conventional compressive strain versus longwall void width

The predicted curvatures represent the conventional ground movements, i.e. the overall or macro bending of the surface. The predictions do not include the non-conventional ground movements, i.e. localised or micro movements, due to irregular or anomalous ground movements.

The conventional strains (i.e. typical values that do not include the irregular ground movements) can be derived by multiplying the predicted curvatures by a factor of 15. It is noted that measured strains can exceed the predicted conventional values by factors of two to three times due to localised irregular ground movements. However, the conventional strains represent the average or typical values and, therefore, can be more readily used to compare strains from different mining areas or based on different mining geometries.

The vertical axis on the righthand sides of Figure 2 and Figure 3 show the values of the predicted conventional tensile and compressive strains, respectively, based on a factor of 15 times the predicted conventional curvatures. Again, the predicted conventional strains represent the typical or average values and these can be exceeded by irregular ground movements. Areas of hogging curvature are associated with net tensile zones and areas of sagging curvature are associated with net compressive zones.

The maximum predicted conventional tensile strains are between 4.5 mm/m and 7.5 mm/m based on 305 m wide longwalls, between 3 mm/m and 6.5 mm/m based on 250 m longwalls, between 2 mm/m and 4 mm/m based on 200 m longwalls and between 1.5 mm/m and 2 mm/m based on 150 m longwalls.

The maximum predicted conventional compressive strains are between 7.5 mm/m and 9 mm/m based on 305 m wide longwalls, between 5.5 mm/m and 7.5 mm/m based on 250 m longwalls, between 3.5 mm/m and 5 mm/m based on 200 m longwalls and approximately 2.5 mm/m based on 150 m longwalls.

Surface cracking and rock fracturing are generally not observed in the Southern Coalfield where the predicted tensile strains are less than 0.5 mm/m and the predicted compressive strains are less than 2 mm/m. The predicted conventional strains for the 150 m through to 305 m wide longwalls are greater than 0.5 mm/m tensile and 2 mm/m compressive. Whilst the predicted strains and, hence, the potential for physical impacts decrease with narrower longwall widths, the strains are still of sufficient magnitude to result in the fracturing of bedrock. These physical impacts will be visible at the surface where the bedrock is shallow (i.e. surface cracking in the overlying soils) or where it is exposed.

Valley related effects

Valley related effects result in high compressive strains developing near the bases of valleys. These effects can result in fracturing, shear, dilation and buckling of the strata along the streams in the bases of valleys.

The predicted valley related upsidence and closure effects for Dendrobium Areas 5 and 6 have been predicted using the method outlined in Australian Coal Industry's Research Program (ACARP) Research Project No. C9067, referred to as the 2002 ACARP method. These effects have also been reviewed based on the more recent ACARP Research Project No. 18015, referred to as the 2014 ACARP method, as described in Section 3.4.3 of Report No. MSEC856.

The 2002 and 2014 ACARP methods do not provide prediction methods for compressive strains due to valley related effects. The predicted valley related strains are determined from the analysis of ground monitoring data based on previous longwall mining beneath valleys with similar effective heights, similar locations relative to mining and similar mining geometries. The review of the influence of longwall void width on predicted valley closure has therefore been based on monitoring data from previous longwall mining in the Southern Coalfield.

The relationships between longwall void width and maximum measured closure are illustrated in Figure 4. The data have been measured in valleys located directly above previous longwall mining at Appin, Dendrobium, Metropolitan, Tahmoor and West Cliff Collieries. The effective valley heights range between 20 m and 60 m, which are similar to the effective valley heights for the streams located directly above the proposed longwalls in Areas 5 and 6.

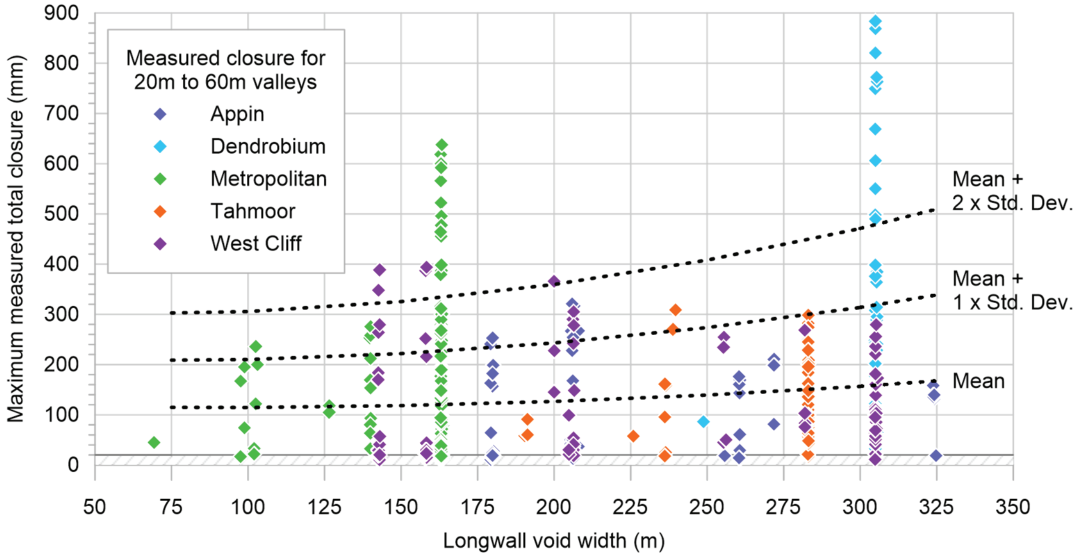

Figure 4 Measured valley closure versus longwall width

The measured valley closure effects are up to approximately 900 mm at Dendrobium (Area 3B) and up to approximately 650 mm at Metropolitan Colliery. Lower valley closure effects have been measured at Appin, Tahmoor and West Cliff Collieries as the effective valley heights are generally towards the lower end of the selected range.

The mean and standard deviation of the data are shown in Figure 4. These curves help illustrate the relationship between longwall void width and maximum measured valley closure for this dataset.

The maximum measured valley closure decreases as longwall void width reduces. The measured closure (mean plus one standard deviation), as percentages of the measured value for the 305 m wide longwalls, are approximately 85 % for 250 m longwalls, 75 % for 200 m wide longwalls and 70 % for 150 m longwalls.

The longwall void width has less influence on valley closure when compared with the conventional subsidence effects (i.e. vertical subsidence, curvature and conventional strain). The 2002 ACARP method indicates similar behaviour, where the predicted closure does not significantly change when the predicted vertical subsidence is greater than approximately 0.7 m.

The potential for impacts on the named streams in Dendrobium Areas 5 and 6 have been obtained using the rock bar impact model developed for Dendrobium Mine, which is described in Section 5.3.4 of Report No. MSEC459. This method relates the likelihood of Type 3 impacts (i.e. fracturing in a rockbar resulting in a reduction in the standing water level of the upstream pool) with the predicted valley closure. However, the rockbar impact model can only be used for streams that are located outside of the mining area.

The potential for physical impacts for the streams located directly above the proposed longwalls in Dendrobium Areas 5 and 6 has been assessed based on case studies of previous longwall mining directly beneath streams. The review of the influence of longwall void width on the compressive strain due to valley related effects has therefore been based on monitoring data from previous longwall mining from the Southern Coalfield.

The strains due to valley related effects at Dendrobium Area 3B have been measured using monitoring lines including the tributary cross-lines and the swamp cross-lines. The distribution of the compressive strains measured in the valleys located directly above the previous longwall mining at Dendrobium is illustrated in Figure 5. The histogram (grey boxes) shows the relative frequency of the measured strains and the blue line shows cumulative distribution of the measured strains.

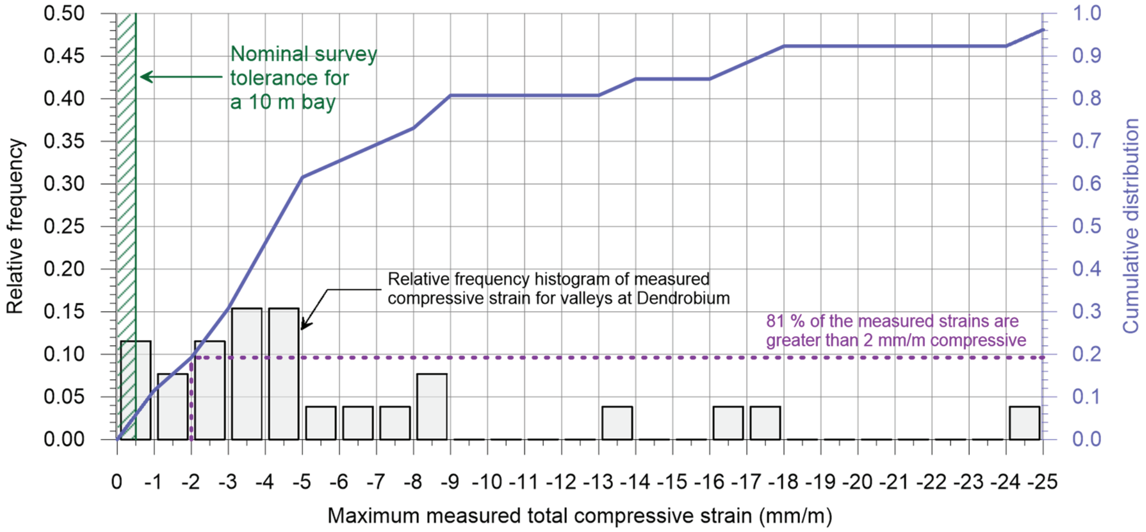

Figure 5 Measured valley closure strain from Dendrobium Area 3B

The measured compressive strains due to valley related effects directly above the previously extracted longwalls at Dendrobium Area 3B were greater than 2 mm/m in 81 % of cases. That is, the majority of the measured strains are considered to be sufficient to result in the fracturing of bedrock in the bases of the streams.

The strains have also been analysed for other previous longwall mining from the Southern Coalfield based on narrower longwall void widths. The distribution of the compressive strains measured in valleys located directly above previous longwall mining, with void widths ranging between 125 m and 175 m (i.e. 150 m average) from the Southern Coalfield, is illustrated in Figure 6. The histogram (grey boxes) shows the relative frequency of the measured strains and the blue line shows cumulative distribution of the measured strains.

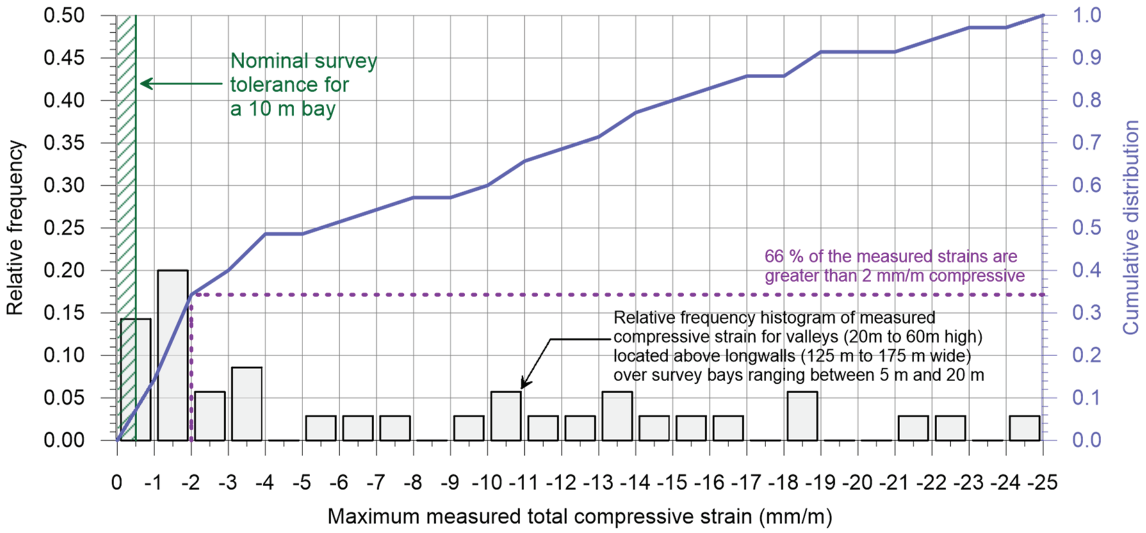

Figure 6 Measured valley closure strain for 125 m to 150 m longwalls from the Southern Coalfield

The measured compressive strains due to valley related effects directly above the previously extracted longwalls, with void widths ranging between 125 m and 175 m, were greater than 2 mm/m in 66 % of cases. That is, the majority of the measured strains are still considered to be sufficient to result in the fracturing of bedrock in the bases of the streams. It is noted that these measured strains include data measured over bay lengths ranging between 5 m and 20 m, with higher strains measured with smaller bay lengths. In any case, the majority of strains are considered to be sufficient to fracture bedrock.

The maximum measured compressive strain due to valley related effects decreases as longwall void width reduces. However, longwall void width has less influence on valley closure strain when compared with the conventional subsidence effects (i.e. vertical subsidence, curvature and conventional strain).

The predicted valley related effects for the 150 m through to 305 m wide longwalls are considered to be sufficient to result in fracturing, shear, dilation and buckling of the strata in the bases of valleys. This is supported by the observation that adverse impacts were observed along the Waratah Rivulet above Metropolitan Colliery, where the longwall void widths were 163 m. Similar impacts would be expected to the streams located directly above Dendrobium Areas 5 and 6 at similar longwall void widths.

Summary

A summary of the findings from this letter report is provided below:

1. The maximum predicted vertical subsidence decreases as longwall void width reduces;
2. **Vertical subsidence versus physical impacts**. The potential for physical impacts (i.e. surface cracking and rock fracturing) is not dependant on absolute vertical subsidence. Physical impacts develop due to differential movements, which are described by curvature and strain;
3. **Conventional strains sufficient to fracture bedrock at narrower longwall widths**. The predicted conventional strains for the 150 m through to 305 m wide longwalls are greater than 0.5 mm/m tensile and 2 mm/m compressive. Whilst the predicted strains and, hence, the potential for physical impacts decrease with narrower longwall widths, the strains are still of sufficient magnitude to result in the fracturing of bedrock. These physical impacts will be visible at the surface where the bedrock is shallow (i.e. surface cracking in the overlying soils) or where it is exposed;
4. **Valley related effects are influenced less by longwall width**. The maximum measured compressive strain due to valley related effects decreases as longwall void width reduces. However, longwall void width has less influence on valley closure strain when compared with the conventional subsidence effects (i.e. vertical subsidence, curvature and conventional strain);
5. **Measured strains sufficient to fracture bedrock due to valley related effects are clearly seen at narrow longwall widths**. The measured compressive strains due to valley related effects directly above the previously extracted longwalls in the Southern Coalfield, with void widths ranging between 125 m and 175 m, were greater than 2 mm/m in 66 % of cases. That is, the majority of the measured strains are still considered to be sufficient to result in the fracturing of bedrock in the bases of the streams and similarly bedrock under swamps; and
6. **Valley related effects are clearly seen at narrow longwall widths**. The predicted valley related effects for the 150 m through to 305 m wide longwalls are considered to be sufficient to result in fracturing, shear, dilation and buckling of the strata in the bases of valleys. This is supported by the observation that adverse impacts were observed along the Waratah Rivulet above Metropolitan Colliery, where the longwall void widths were 163 m. Similar impacts would be expected to the streams located directly above Dendrobium Areas 5 and 6 at similar longwall void widths.

If you have any questions or require further information, please do not hesitate to call me on (02) 9413-3777.

Yours sincerely

James Barbato

Dr James Barbato
Mine Subsidence Engineering Consultants

ENCLOSURE 3

MSEC LETTER REPORT (2020)

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15 June 2020

South32 Illawarra Coal
Dendrobium Mine
Wollongong NSW 2500

For the attention of: Mr Gary Brassington, Approvals Manager

Dear Gary,

RE: Dendrobium – Plan for the Future: Coal for Steelmaking
Dams Safety NSW Submission

Illawarra Metallurgical Coal, a wholly owned subsidiary of South32 Limited (South32), has submitted an Environmental Impact Statement for proposed mining in Areas 5 and 6 at Dendrobium Mine, referred collectively as *Dendrobium – Plan for the Future: Coal for Steelmaking* (the Project). Mine Subsidence Engineering Consultants (MSEC) prepared the subsidence report (MSEC, 2019) that provides the predicted subsidence effects and assessed impacts for the Project.

Dams Safety NSW (DSN), formally the Dams Safety Committee, has provided comments on the Project (DSN, 2019). The comments relate to the predicted subsidence effects and assessed impacts on the Avon Dam and Cordeaux Dam walls. South32 has provided responses to these comments in their submissions report (South32, 2020a) and supplementary letter (South32, 2020b). This letter supports the submissions report and supplementary letter prepared by South32.

The proposed secondary extraction in Areas 5 and 6 are located at minimum distances of 1000 m from the Avon Dam and Cordeaux Dam walls. The dam walls are predicted to experience far-field horizontal movements towards the proposed mining areas. The measured incremental far-field horizontal movements due to the extraction of longwalls at Dendrobium Mine and elsewhere in the Southern Coalfield are illustrated in Fig. 4.4 of the subsidence report (MSEC, 2019) and it has been reproduced in Figure 1. These data represent absolute horizontal movements.

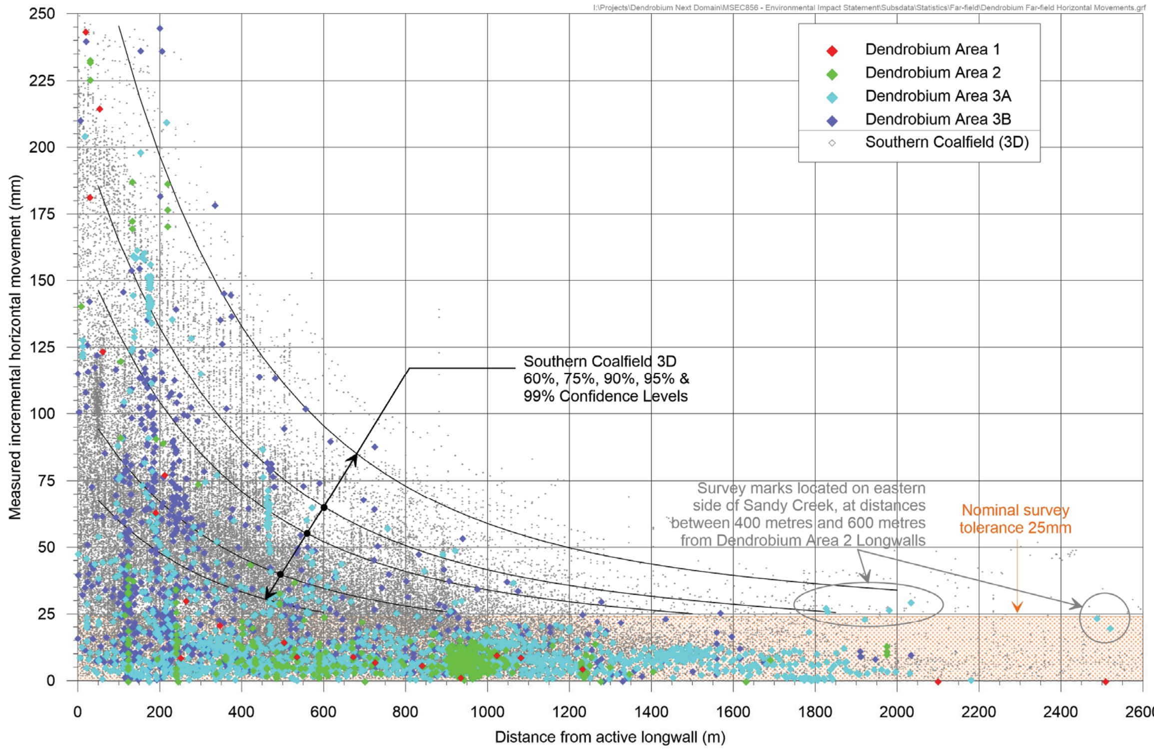

Figure 1 Measured incremental far-field (absolute) horizontal movements at Dendrobium Mine and elsewhere in the Southern Coalfield (Source: Fig. 4.4 from MSEC, 2019)

The far-field horizontal movements measured at Dendrobium Mine are shown as the red, green, cyan and blue diamonds in Figure 1. At distances of 1000 m or greater from the extracted longwalls at the mine, the majority of the measured far-field movements (i.e. 98 % of cases) are less than the nominal survey tolerance of 25 mm for absolute position. The survey tolerance for far-field horizontal movements is greater than that for other subsidence parameters, such as strain, as it is measured using GPS. In a small number of cases, far-field horizontal movements greater than the nominal survey tolerance have been measured at distances of 1000 m or greater, in the order of 25 mm to 60 mm.

The far-field horizontal movements measured elsewhere in the Southern Coalfield are shown as the grey diamonds in Figure 1 for comparison. At distances of 1000 m or greater from the extracted longwalls, the movements measured at Dendrobium Mine are less than those measured elsewhere in the Southern Coalfield. The reason is the shallower depths of cover at Dendrobium Mine result in greater subsidence effects directly above the mining area but lesser effects further afield outside the mining area.

The potential for impacts on the Avon and Cordeaux Dam walls do not result from the absolute far-field horizontal movement but from differential horizontal movements. Differential horizontal movements are represented by various parameters including strain, as measured by changes in long bays (including valley closure or valley opening).

There is limited strain monitoring data at Dendrobium Mine; however, there is extensive data elsewhere in the Southern Coalfield. At distances of 1000 m or greater from the extracted longwalls, the majority of the measured strains (i.e. 94 % of cases) are less than the nominal survey tolerance of 0.25 mm/m. The nominal survey tolerance for strain represents a change in length (i.e. horizontal distance) of 3 mm to 5 mm measured over a standard survey bay length of 20 m.

The far-field horizontal movements are expected to be global (i.e. en-masse) movements that are associated with very low levels of strain. The potential for impacts is affected by the differential horizontal movements (i.e. strain) rather than the absolute movements. At the distances of the Avon and Cordeaux Dam Walls from the proposed mining areas, the strains are predicted to be in the order of survey tolerance, i.e. not measurable.

Future mining will also be carried out in the already approved Area 3C, to the south of the Cordeaux Dam wall, which will be the subject of a separate Subsidence Management Plan process. The secondary extraction will also be located at a minimum distance of 1000 m from the dam wall. The mining in Area 3C will result in far-field horizontal movements towards this mining area. However, these absolute movements are not additive to the absolute far-field horizontal movements due to mining in Area 6, as described further below. The mining sequence in the EIS is Area 5, Area 3C and then Area 6.

Mining in Area 3C will result in absolute movements towards the south and the subsequent mining in Area 6 will result in absolute movements back towards the north, i.e. reducing the net absolute horizontal movement. In both cases, the far-field effects are expected to be global (i.e. en-masse) movements towards each of the mining areas, where the strains are predicted to be less than the nominal survey tolerance, i.e. not measurable. The potential for impacts on the dam wall is affected by the strains (i.e. unlikely to be measurable) rather than the absolute horizontal movements.

The Avon Dam and Cordeaux Dam walls are located within river valleys and, therefore, could experience low level valley closure effects. The measured total valley closure movements due to the extraction of longwalls at Dendrobium Mine and elsewhere in the Southern Coalfield are illustrated in Fig. 6.17 of the subsidence report (MSEC, 2019) and it has been reproduced in Figure 2.

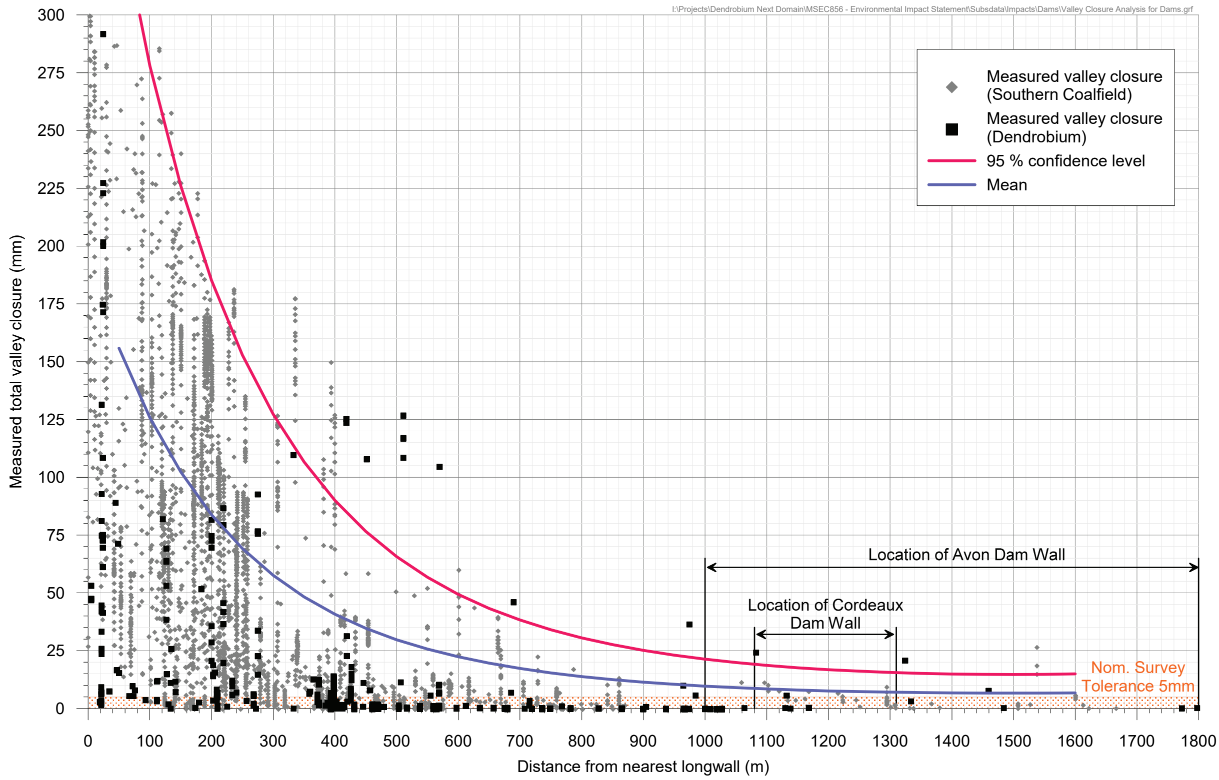

Figure 2 Measured total valley closure versus distance from nearest longwall (Source: Fig. 6.17 from MSEC, 2019)

The valley closure movements measured at Dendrobium Mine are shown as the black squares in Figure 2. At distances of 1000 m or greater from the extracted longwalls at the mine, the majority of the measured valley closure movements (i.e. 93 % of cases) are less than the nominal survey tolerance of 3 mm to 5 mm. Valley closures of 20 mm to 35 mm have been measured at the Wongawilli Creek C-Line after the mining of LW9 to LW11 in Area 3B; however, these values include the measured movements due to previous mining in Area 3A at a minimum distance 370 m. Excluding this monitoring line, the maximum valley closure movement measured at distances of 1000 m or greater at Dendrobium Mine is 8 mm.

The valley closure movements measured elsewhere in the Southern Coalfield are shown as the grey squares in Figure 2 for comparison. At distances of 1000 m or greater from the extracted longwalls, the majority of the measured valley closure movements (i.e. 89 % of cases) are less than the historic survey tolerance of 5 mm to 10 mm. The historic survey tolerance is greater as the monitoring data from the Southern Coalfield includes older surveying techniques. Some data also appear to include results where survey prisms have been disturbed.

At the distances of the Avon and Cordeaux Dam Walls from the proposed mining areas, the valley closures are predicted to be in the order of the survey tolerance of 3 mm to 10 mm. The actual movements are expected to be towards the lower end of the range; however, the older monitoring data from the Southern Coalfield could not measure valley closure less than the upper value.

Modern surveying techniques can measure valley closure to much higher accuracy. For example, the high resolution monitoring for Sandy Creek Waterfall and Harris Creek Cliff Line have accuracies in the order of 1 mm. It is likely therefore that these more accurate surveying methods could measure valley closure movements at distances of 1000 m from longwall mining.

Low level opening movements have been measured outside of mining due to conventional subsidence effects. This occurs when longwall mining occurs directly beneath the valley side causing it to move in the direction of extraction. For example, the mining of Longwalls 12 to 15 in Area 3B, on the eastern side of Avon Reservoir, have resulted in measurable net openings across the reservoir. These longwalls mined beneath the valley side and at a minimum distance of 300 m of the Full Supply Level (FSL) of the reservoir. The movements measured at the Avon Dam closure lines are shown in Fig. 2.3 of the LW15 End of Panel Report (MSEC, 2020) and it has been reproduced in Figure 3.

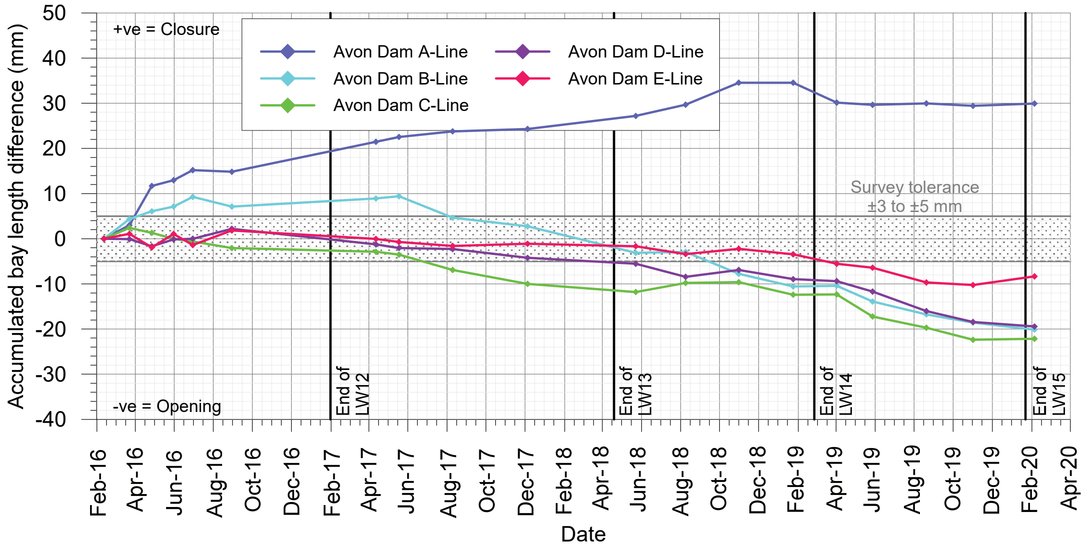

Figure 3 Measured accumulated opening and closure for the Avon Dam closure lines (Source Fig. 2.3 of MSEC, 2020)

Valley closure of 20 mm was initially measured along the Avon Dam A-Line during the mining of LW12 and increasing to 35 mm during the mining of subsequent longwalls. The northern end of this monitoring line is located 330 m from the commencing end of LW12. Closure was also initially measured along the Avon Dam B-Line during the mining of LW12, with its eastern end located 520 m from this longwall.

Valley opening was measured at the Avon Dam C-Line during LW13, the Avon Dam B-Line and D-Line during LW14 and the Avon Dam E-Line during LW15, at distances ranging between 250 m and 850 m from the mining area. These longwalls mined beneath the valley side at a minimum distance of 300 m of the FSL of the reservoir.

The proposed longwalls in Areas 5 and 6 are located at minimum distances of 1000 m from the Avon Dam and Cordeaux Dam walls and, therefore, the potential for valley opening is considerably reduced. The potential net opening movements at the dam walls, due to the proposed mining, are
predicted to be less than the nominal survey tolerance of 3 mm to 5 mm. It is possible; however, that high resolution monitoring techniques (with accuracies in the order of 1 mm) could measure low level opening movements.

The potential impacts on the Avon Dam and Cordeaux Dam walls could be managed with the implementation of monitoring and an adaptive management approach. The individual longwalls in Area 5 will be mined in sequence from south to north (i.e. towards the Avon Dam wall) and the individual longwalls in Area 6 will be mined in sequence from west to east (i.e. towards the Cordeaux Dam wall), allowing for an adaptive management approach.

The subsidence assessment (MSEC, 2019) recommended that the appropriate monitoring and management strategies be developed, in consultation with WaterNSW and DSN, including a Trigger Action Response Plan (TARP). This would include a detailed assessment of the dam walls by a suitably qualified Dams Engineer to establish the appropriate monitoring, triggers and action responses. It is considered appropriate that the detailed assessment and development of the monitoring and management plans are developed as part of the Extraction Plan applications.

The recommendations would not change if the minimum distance of the proposed secondary extraction from the Avon Dam and Cordeaux Dam walls was increased to 1500 m. While the predicted differential horizontal movements at the dam walls would not be expected to be measurable, it would still be recommended that a monitoring and adaptive management approach be adopted. It is expected that the appropriate monitoring, trigger levels and action responses would be similar to those based on a minimum distance of 1000 m.

I trust that this letter is of assistance. Please let me know if you have any questions or require further information.

Yours sincerely,

James Barbato

Dr James Barbato
Mine Subsidence Engineering Consultants

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MSEC (2020). *Dendrobium - Area 3B - Longwall 15 – End of Panel Subsidence Monitoring Review Report for Dendrobium Longwall 15*. Mine Subsidence Engineering Consultants. Report No. MSEC1101 (Rev. A), dated 1 May 2020.

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ENCLOSURE 4

DENDROBIUM SUBMISSIONS REPORT (SECTION 6.3.4)

6.3.4 Responses

1. ***Accuracy of the prediction of surface water losses.***

    a. ***Groundwater model development.***

Potential surface water losses as a result of the Project have been predicted by HydroSimulations (2019), using the groundwater model developed for the Project.

The groundwater model developed for the Project builds on previous groundwater modelling efforts over the last decade in the development of best practice modelling methods, as acknowledged by the IEP (2019a, 2019b), and is an extension of previous groundwater models developed for the Dendrobium Mine.

The Project model domain accounts for historic stresses in the groundwater system by incorporating historical, active and proposed mining operations in the Sydney Drinking Water Catchment.

The model grid or mesh has been refined to incorporate detail in areas where groundwater stresses could occur, such as around longwall panels, or where sensitive natural and built receptors are located (such as reservoirs, along watercourses, Upland Swamps and registered groundwater bores).

    b. ***Conservatism of groundwater model assumptions.***

Hydrogeological parameters incorporated into the groundwater model for the Project are well informed by extensive site-specific dataset of hydraulic conductivity and porosity or storage estimates. This includes the consideration of pre- and post-mining observations to constrain parameters such as horizontal and vertical permeability.

The model also has the benefit of over a decade of data measuring the effect of historic mining operations to the groundwater system. The calibration statistics for the model demonstrate that these historic effects (e.g. drawdown and mine inflows) are adequately replicated (refer below for further detail of the model calibration performance).

Some parameters in the groundwater model are unable to be directly measured (e.g. height of fracturing) or are variable (e.g. flows in ephemeral streams and regulated watercourses). In such cases, the groundwater modelling incorporates a range of **conservative assumptions** in consideration of expert reviews of groundwater modelling in the Southern Coalfield and the recommendations of the IEP (2019a, 2019b), including:

- **Height of sub-surface connective fracturing** – conservatively assumed to extend from the seam to the surface and interact with the surface fracture network for the Project longwall panels with void width of 305 m.

  If other recognised methodologies were used to estimate the height of sub-surface connective fracturing, in particular the 'Tammetta Equation', the majority of the Project underground mining area would not be modelled as having a fracture network that extends from the seam to the surface or extend to the surface fracture network (Appendix B of the EIS) (Figure 6-3B).

- **Depth of surface cracking** – the depth of surface cracking is assumed to be 10 times the maximum longwall cutting height, which is greater than modelled depths of surface cracking simulated in other groundwater studies (e.g. 20 – 30 metres [m] for Springvale Mine).

- **Surface water loss from ephemeral tributaries** – all surface water is modelled as 'lost' from the ephemeral drainage lines that overlie the Project areas, as it is assumed to be permanently lost. In reality, a portion is likely to re-emerge downstream. In addition, the ephemeral tributaries overlying the longwall panels are assumed to have water available to be lost at all times (despite these tributaries experiencing no to low flow during dry periods).

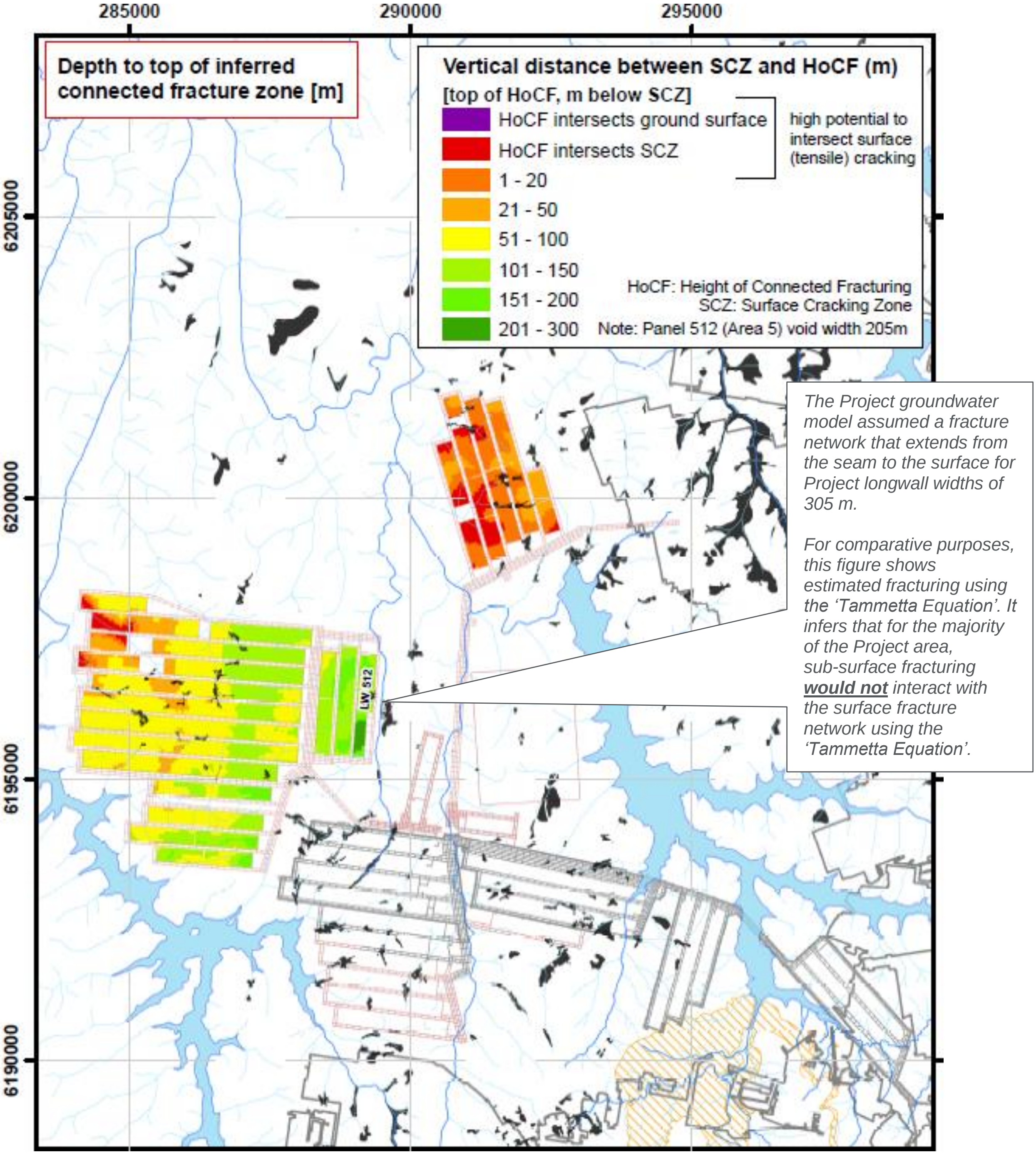


Figure 6-3B – Variation in Inferred Height of Fracturing using the Tammetta Equation

The conservative nature of these assumptions is supported by observed effects. For example:

- Loss of surface flow has been observable and discernible at stream flow gauges located immediately downstream of Area 3B (e.g. WC21, DC13S1 and DCS2). Losses at these sites can be significant, with reductions in median flow being approximately 50-80% of pre-mining median flow. However, corresponding changes in surface water flow at gauges further downstream were not discernible (i.e. DCU and WWL) (Figure 6-3C). This indicates that some portion of localised losses at WC21, DC13S1 and DCS2 re-emerged downstream and/or the volume of water lost was insignificant compared to the total flow at the downstream gauging stations (see Appendix B of the EIS as well as recent analysis in Watershed HydroGeo, 2019b).
- The model simulates drawdown at a similar magnitude and rate near to and above longwalls (e.g. Figures 7-5 and 7-16 of the Groundwater Assessment [Appendix B of the EIS] and reproduced below in Figure 6-3D) when compared to piezometer data, e.g. with significant drawdown at depth (e.g. ~150 m drawdown in Wongawilli Seam at bore S1992) and less drawdown higher above the seam (e.g. S1992 exhibits 80 m drawdown in the Scarborough Sandstone, <40 m drawdown in Bulgo Sandstone and less than 10 m drawdown in the upper Hawkesbury Sandstone). Within the model, most of this drawdown is associated with simulated drainage of groundwater into the mine workings via the ‘stacked drains’ mechanism, whereas in reality more drawdown might be associated with lateral drainage away from the mine footprint.
- The model has a tendency to overpredict total historic mine inflows to Areas 1-3B by approximately 20%, in comparison to the 30-day average observed inflows (Figure 6-3E).

As the model assumes water is always available to be lost from ephemeral streams in the predictive period, modelled losses exceed total stream flow during no to low flow periods.

On the basis of the above, the risk of actual impacts (i.e. surface water losses) being significantly greater than those predicted from the groundwater model can be considered low. This conclusion was supported by Dr Frans Kalf in the peer review of the Groundwater Assessment for the Project:

> *KA has no objection to the use of this ‘Stacked Drain’ method as it has been used by MER* [Mackie Environmental Research Pty Ltd] *for a number of years and has proved to be suitable. In addition it has been found on some projects by MER to overestimate the mining effects such as drawdown and overall inflow and therefore can be considered to be a conservative overall methodology for determining fracture propagation and associated draining in the geological profile.*
>
> …
>
> *… the ‘stacked drains’ approach by HS would very likely capture most flow and therefore would indeed be conservative with respect to mine inflow.*

Dam Seepage Model

South32 has previously been requested to provide estimates of seepage from the Avon Dam (i.e. Mechanism 3 losses) as part of its secondary approval processes for the approved Dendrobium Mine longwalls in Area 3B.

HGEO (2018) prepared a local-scale model for the section of the Avon Dam shoreline proximal to approved Longwalls 12 to 16. As any seepage from the Avon Dam cannot be measured directly, the modelling was based on calculations using Darcy’s Law. Key inputs to the modelling were informed by measured groundwater levels and permeabilities (based on post-mining packer tests).

It is noted that groundwater levels in the section of sandstone between the Avon Dam shoreline and the longwalls vary, with no apparent relationship between groundwater levels (or depressurisation) and distance from the Avon Dam shoreline (Chart 6-3A).

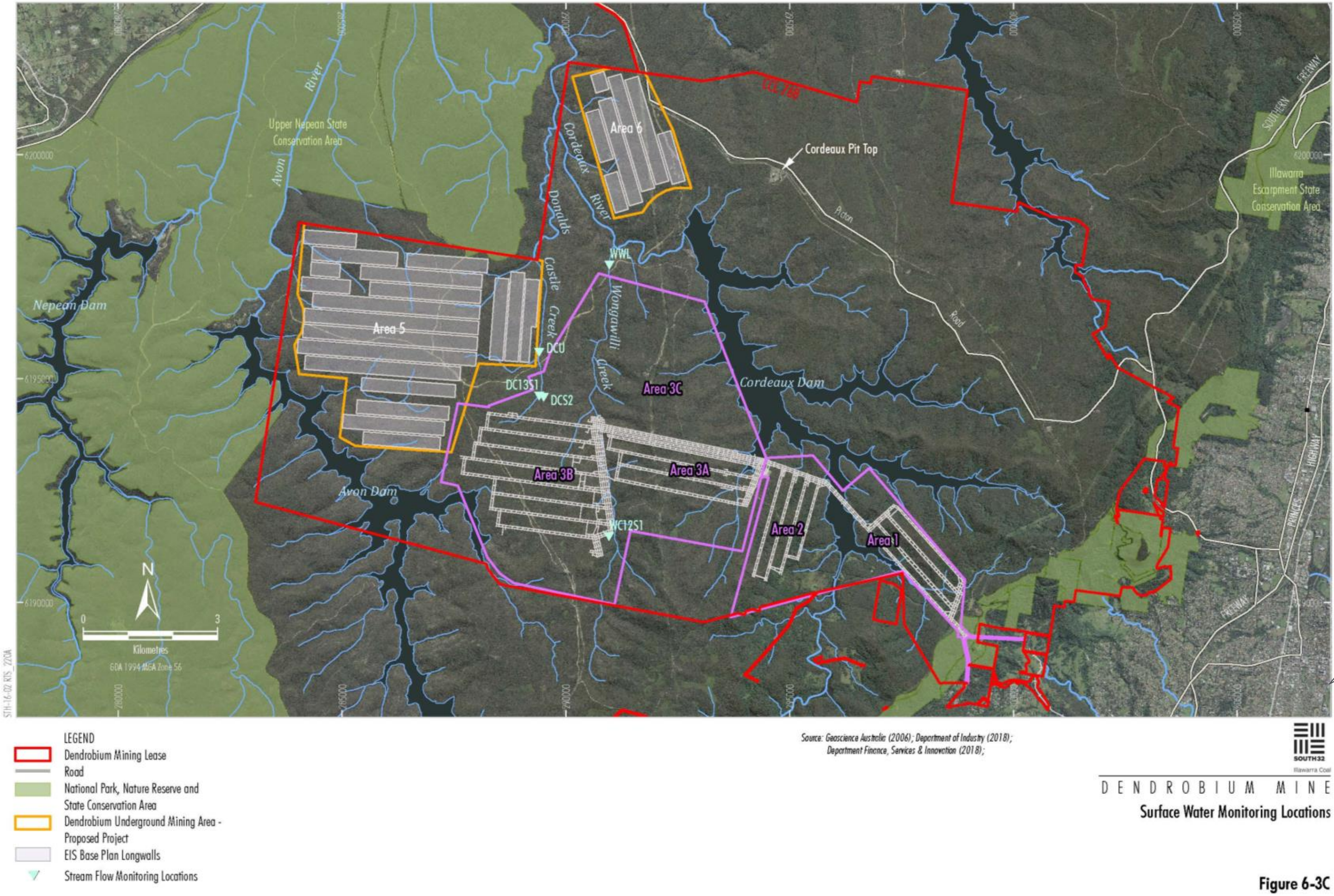


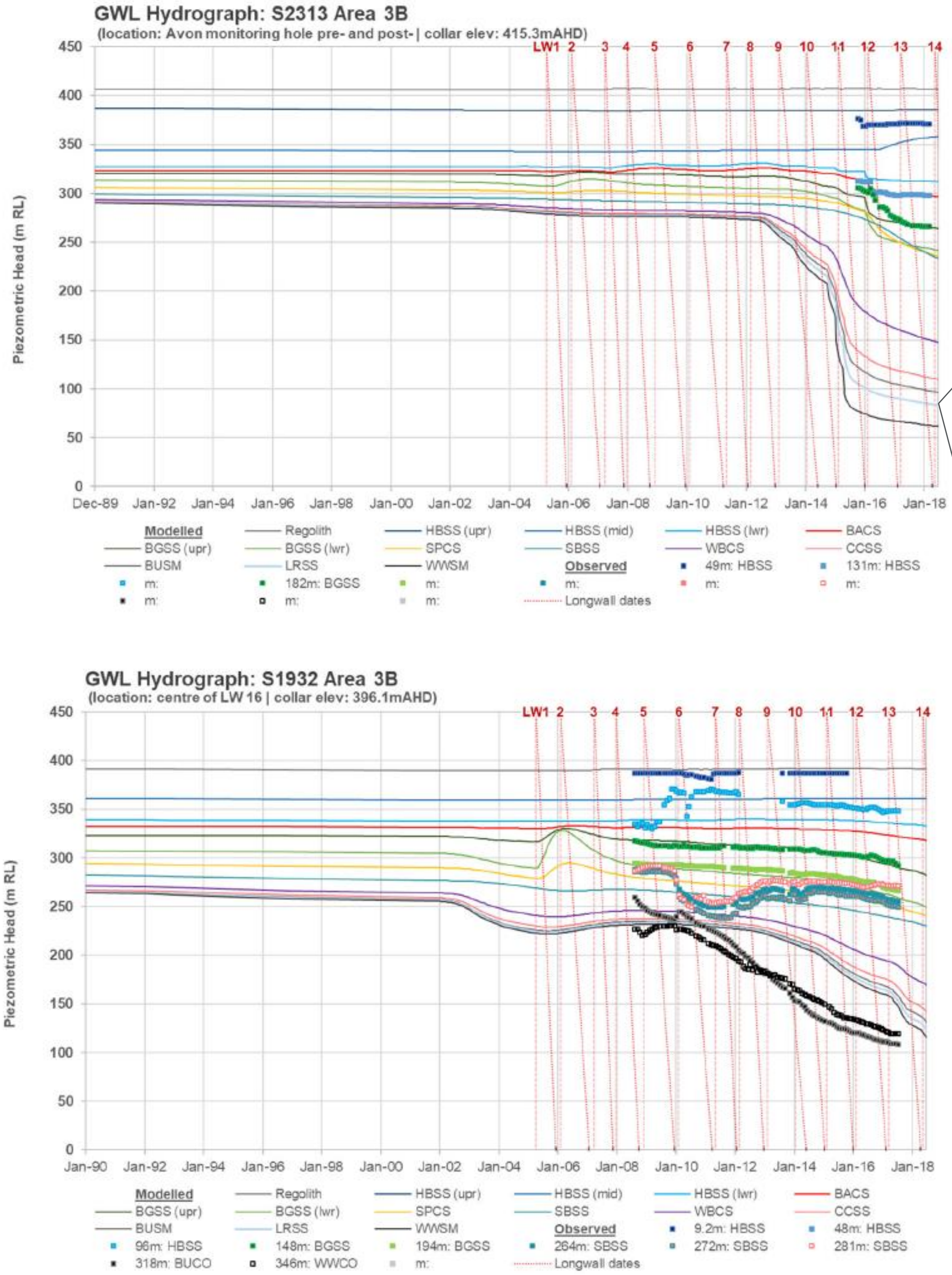
Figure 6-3C

The Project assumed that stream flow diversions would be permanently lost (i.e. Mechanism 2).

Although loss of surface flow has been observed at stream flow gauges located immediately downstream of Area 3B (WC21S1, DCS2 and DC13S1), corresponding changes in surface water flow at gauges further downstream (DCU and WWL) ***were not discernible.***

This indicates that some portion of localised losses re-emerged downstream and/or the volume of water lost was insignificant compared to the total flow at the downstream gauging stations.

Therefore, the model assumption that stream flow diversion is permanently lost is likely conservative.



These graphs compare simulated and measured drawdown of Bores S2313 and S1932 located between Area 3B and Avon Dam.

As can be seen, the model simulates drawdown at similar magnitudes and rates to the measured data, with significant drawdown at depth (~150 m) and less than 10 m drawdown in the Upper Hawkesbury Sandstone.

Figure 6-3D – Modelled vs Observed Groundwater Level Hydrographs – Bores S2313 and S1932

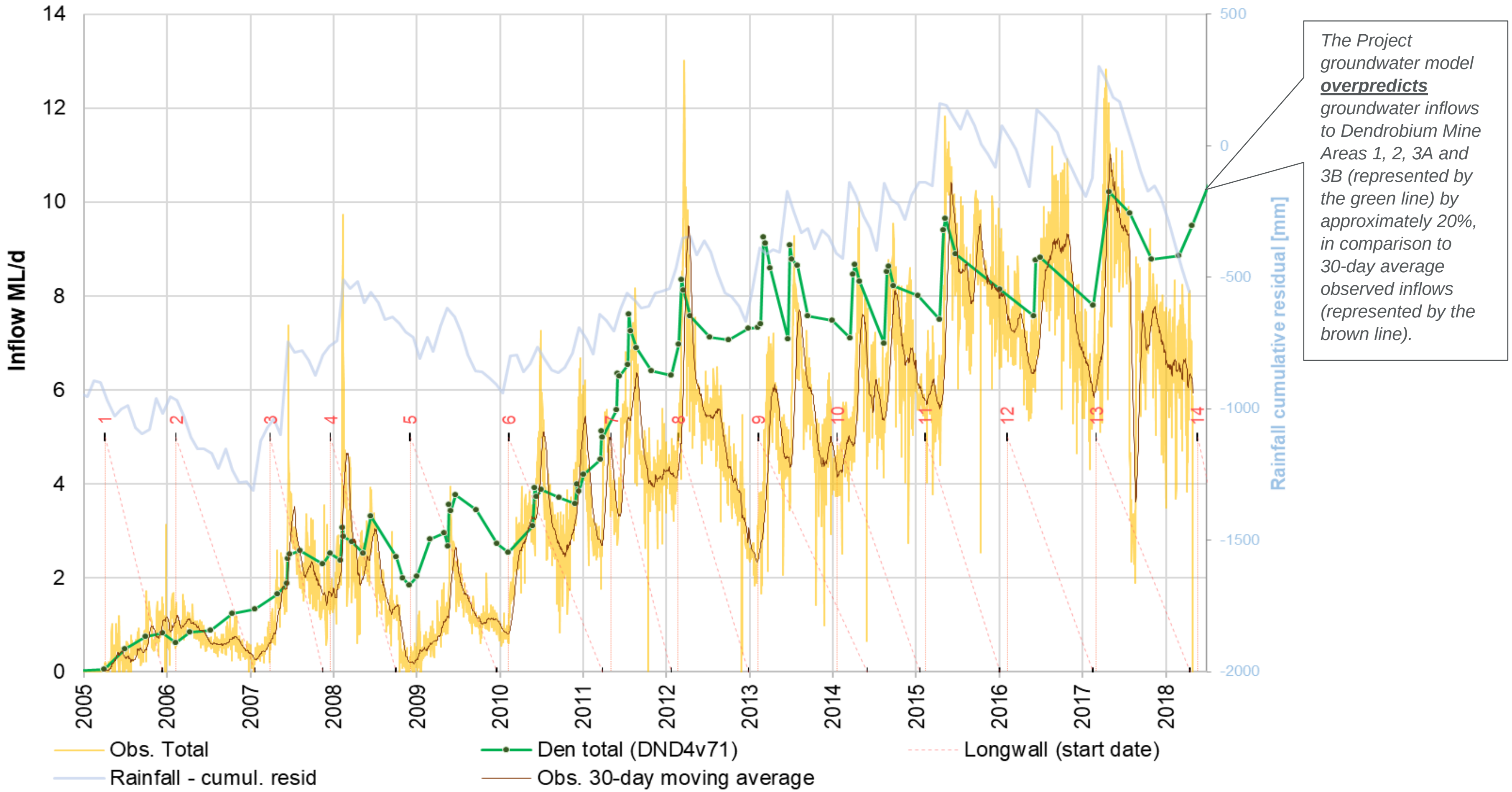
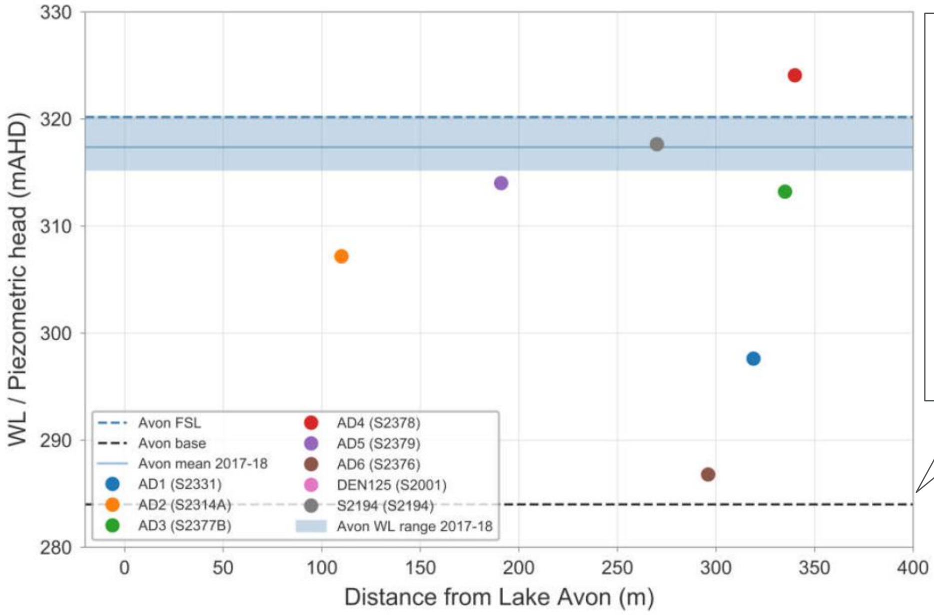


Figure 6-3E – Predicted vs Observed Mine Water Inflow at the Dendrobium Mine

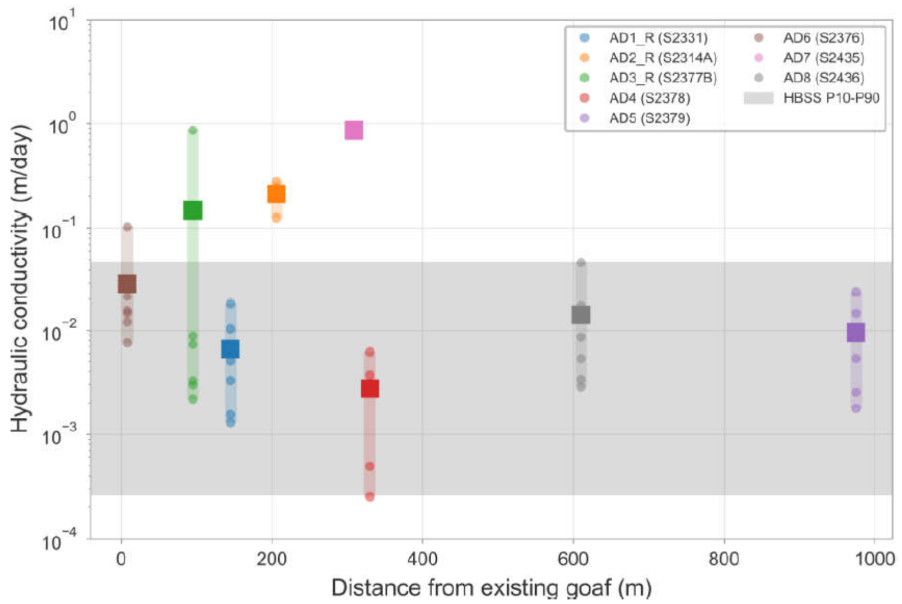


This graph shows measured groundwater levels in the sandstone between the Avon Dam shoreline and approved Area 3B longwalls.

As can be seen, there is no apparent relationship between groundwater levels and distance from the Avon Dam shoreline.

Chart 6-3A – Measured Groundwater Level on Avon Dam Shoreline (After: HGEO [2018])

Similarly, horizontal hydraulic conductivity (measured using packer tests) varies significantly (i.e. orders of magnitude) with no clear trend with distance from the goaf (Chart 6-3B).



This graph shows measured permeabilities (packer tests) in the sandstone between the Avon Dam shoreline and approval Area 3B longwalls.

As can be seen, there is significant variation in the measured permeabilities, and no clear trend with distance from the goaf of the existing longwalls.

Chart 6-3B – Measured Permeability of Sandstone on Avon Dam Shoreline

The local-scale model estimated losses of 0.44 megalitres per day per kilometre (ML/day/km) (HGEO, 2018), or 0.7 ML/day for the 1.6 km of shoreline proximal to the end of Longwall 16 (located in Dendrobium Mine Area 3B). Previous estimates of seepage for this section of shoreline, based on the post-mining permeability measurements, by SCT (2018) were 0.01 to 1 ML/day/km (i.e. a range of two orders of magnitude).

By comparison, the regional groundwater model developed for the EIS (HydroSimulations, 2019) estimates a maximum loss from Avon Dam (i.e. Mechanism 3 losses) of 0.48 ML/day cumulatively from the Project and the Dendrobium Mine. The estimate from the regional model as presented in the EIS is lower than the estimate of HGEO (2018) using the local-scale model.

It is noted that, unlike the regional model, the local-scale model is not constrained by, or calibrated to, measured mine inflows.

If the regional model was revised to incorporate the seepage estimates from the local-scale model, this would reduce calibration performance against mine inflows (i.e. it would result in greater mine inflows when compared to what has been observed in Area 3B, noting that the regional model already overpredicts these inflows).

On the basis of the above, the calibrated regional groundwater model used for the EIS is considered to be a more robust and appropriate tool to predict the total surface water losses from the catchment from the Project. The local-scale model developed by HGEO is aimed specifically at one particular prediction, and is unconstrained by other data (i.e. is not calibrated to mine inflow or groundwater levels).

Stream Flow Loss from Ephemeral Streams

The Project groundwater model adopts assumptions that mean that most surface water modelled as 'lost' from the ephemeral drainage lines that overlie the Project areas is permanently lost.

The IEP Part 2 Report (2019b) states:

> *The Panel's view is that the depressurisation and loss of baseflow observed further upstream will most likely result in baseflow loss at the WWL gauge and, therefore, the apparent absence of baseflow loss at that gauge is likely due to uncertainty in the surface flow measurement and modelling at WWL.*

South32 does not agree with this view.

Gauging stations DC13S1 and DCS2 are located immediately downstream of mined panels in Area 3B. Flow monitoring at DC13S1 and DCS2 clearly shows a reduction in flow following mining (Figures 6-3F to 6-3I).

The reduction in median flow at DC13S1 and DCS2 represents approximately 45 to 60% of median flow at the downstream gauge DCU. If the losses at DC13S1 and DCS2 were permanently lost from the catchment, then this should be apparent at DCU (which is not the case). This indicates the diverted stream flow does re-emerge downstream.

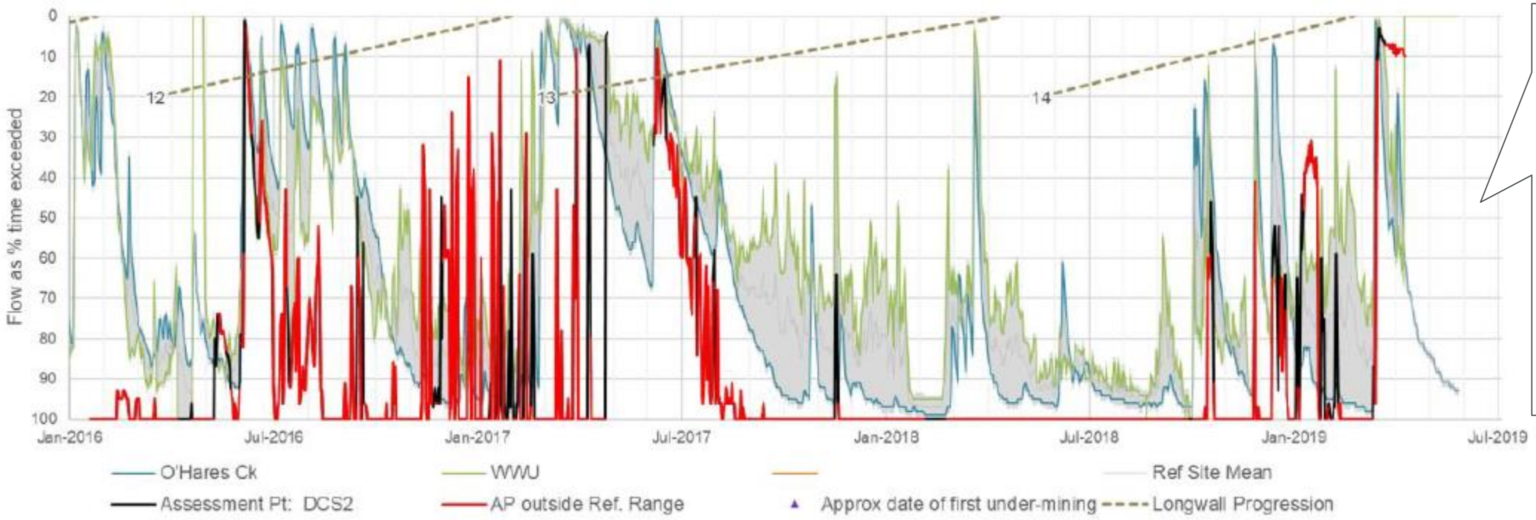
Various analysis methods support this position for both downstream gauges DCU and WWL.

One such method, used in support of analysis for TARPs for the Area 3 SMPs, is comparison of flows to reference sites (i.e. sites unaffected by mining). To account for differences in catchment size (and therefore volume of flow), the analysis compares 'flow percentile' for the various catchments. This is because, while absolute flow values will vary between catchments, it would be expected that median flows (i.e. 50th percentile) would occur at similar times, 95th percentile low flows would occur at similar times during dry periods, 5th percentile wet flows would occur at similar times during wet periods, and so forth.

It can be seen from the graphs below (Figures 6-3F and 6-3G) that changes in flow (as 'flow percentile') at DCS2 clearly differs from the reference sites at WWU (Wongawilli Creek upstream of mining), O'Hares Creek and Bomaderry Creek. This is indicative of mining having impacted flows this site.

By comparison, flow percentiles further downstream at site DCU clearly follows the references sites.

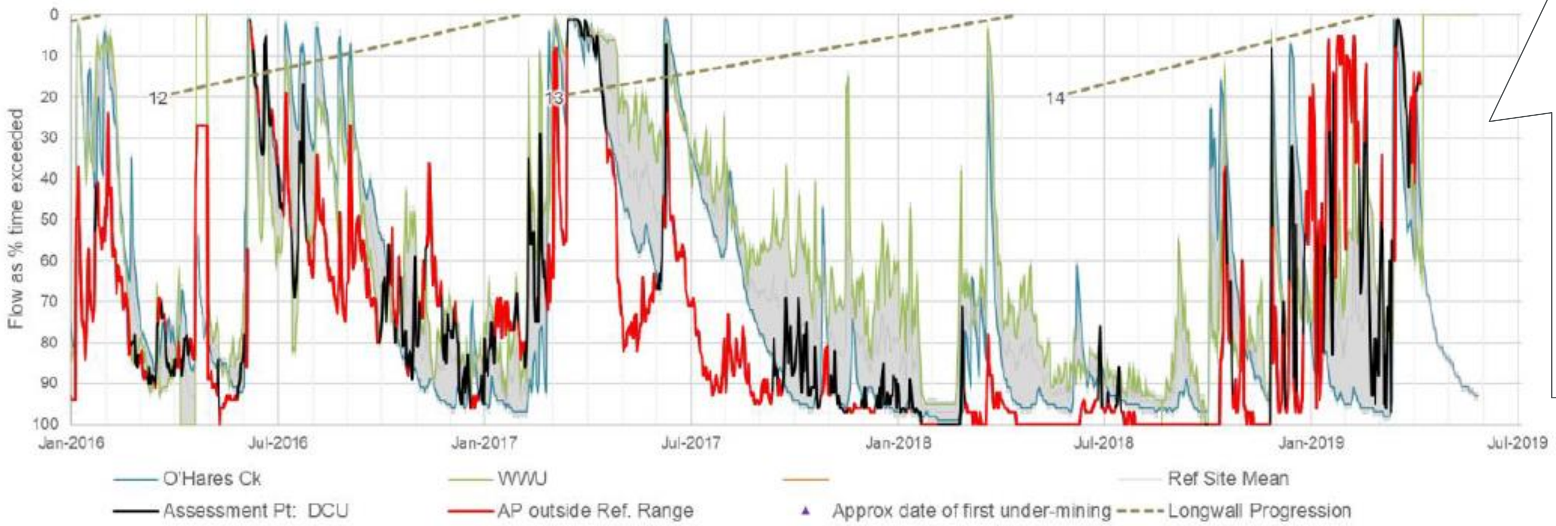
Similarly, flow at WC21S1 (located immediately downstream of the Area 3B longwalls) (Figures 6-3H and 6-3I) clearly differs from the reference sites (indicative of mining having impacted this site), whereas flow at WWL does not.



This figure shows flow (as 'percentile flow') at the DCS2 'assessment site', represented by the red and black lines, in comparison to reference flow gauge sites unaffected by mining (the blue and green lines).

As can be seen, the red/black clearly differs from the reference sites – indicating flow at this stream gauge, located immediately downstream of Area 3B, has been affected by mining.

Figure 6-3F – Flow Monitoring at Gauge Station DCS2



By comparison, this figure shows flow at DCU over the same time period, which is further downstream from DCS2 (above). For the same time period, it shows that flow percentile (red/black line) more closely follows the reference sites. Indicating the flow has not been affected significantly beyond natural variability.

These results indicate that a portion of flow diverted from streams above the longwalls is likely to re-emerge downstream.

Figure 6-3G – Flow Monitoring at Gauge Station DCU

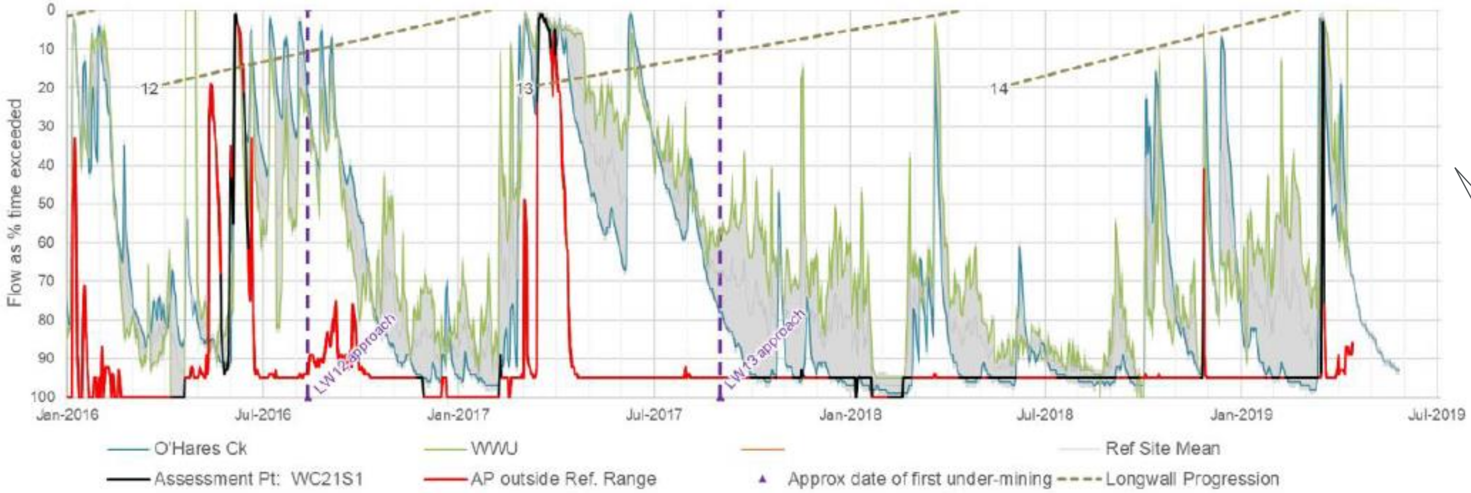


Figure 6-3H – Flow Monitoring at Gauge Station WC21S1

Similar to the above, flow at WC21S1 (located immediately downstream of the Area 3B longwalls) clearly differs from the reference sites, whereas flow at WWL over the same time period, (graph below) (located further downstream from WC21S1) does not.

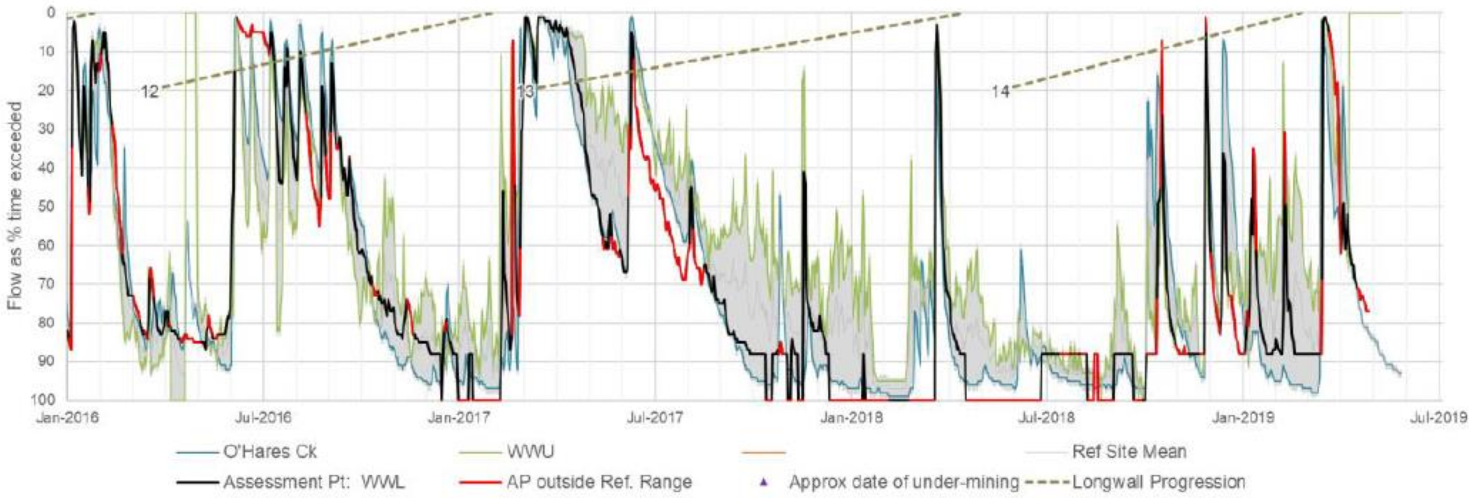


Figure 6-3I – Flow Monitoring at Gauge Station WWL

Similar analysis was presented in Watershed HydroGeo (2019a) for other flow parameters, being median flow and a measure of the number of cease-to-flow days at gauging stations around Area 3B. These showed a consistent pattern – clearly discernible mining effects in headwater catchments overlying or near to extracted panels, but little effect observed downstream.

For example, the reduction in median flow at DC13S1 and DCS2 represents approximately 45 to 60% of median flow at the downstream gauge DCU. If the losses at DC13S1 and DCS2 were permanently lost from the catchment, then this should be apparent at DCU (which is not the case). This indicates the diverted stream flow does re-emerge downstream. This does not equate to a finding that there is no change in the pattern of flow at DCU, because some changes to very low flows are likely, however the consistency of median flow is an indicator that the overall volume of flow is the same.

Therefore, in reality, a significant portion of surface water is likely to re-emerge downstream of the mine footprint as shown by the Area 3B gauging stations.

c. Groundwater model calibration performance.

The conceptual model of the groundwater system has been developed over time in consideration of one of the largest databases of groundwater-related data for a mine in NSW and considering the findings made in external studies (e.g. Advisian *et al,* 2016; PSM, 2017; IEPMC, 2018). The conceptualisation has been translated into a groundwater model with the inclusion of a number of conservative assumptions around the depth of surface cracking, the development of permeability beyond the longwall footprint, and, most importantly, the height and degree of vertical fracturing above the goaf.

The numerical model has been calibrated against a significant database of groundwater levels and to fluxes (mine inflow and baseflow) and for unstressed and stressed conditions, which being constrained by considerable amount of pre- and post-mining permeability data and independently determined recharge estimates.

The conceptualisation and numerical modelling have been reviewed by an independent and experienced peer-reviewer considering the Australian Groundwater Modelling Guidelines.

This model has then been used to provide forecasts considering the results of a set of deterministic scenarios to inform uncertainty of key predictions.

- **The groundwater model builds on previous groundwater modelling efforts over the last decade in the development of best practice modelling methods acknowledged by the IEP.**
- **The model is informed and constrained by measured data, and is calibrated to historic mining stresses to the groundwater system.**
- **The groundwater model incorporates a range of conservative assumptions in the prediction of surface water losses.**
- **The prediction of surface water losses from the catchment is, therefore, inherently conservative, with the risk of actual impacts to surface water losses being significantly greater than those predicted from the groundwater model considered to be very low.**

2. Impacts to Sydney Drinking Water Catchment water supply.

a. Mechanisms resulting in surface water loss.

Part 2 of the IEP Report (2019b) identifies mechanisms via which surface water can be lost from the catchment. Three mechanisms relevant to the Project are summarised below and in Table 6-3A:

- **Mechanism 1 – Surface Water Diversion (within the mine footprint)**. Localised surface water losses due to subsidence-related impacts such as cracking of stream beds. Where localised surface water losses re-emerge downstream (i.e. the surface fracture network does not interact with sub-surface fracturing) there is no net loss to catchment surface water supplies.

- **Mechanism 2 – Permanent Surface Water Diversion (within the mine footprint)**. As per Mechanism 1, however, this mechanism relates to situations where the surface fracture network interacts with sub-surface fracturing, and surface water does not re-emerge downstream (i.e. it is transferred to the groundwater system or mine workings) and therefore is no longer available as surface water supply in the catchment.
- **Mechanism 3 – Groundwater Depressurisation (beyond the mine footprint)**. Beyond the extent of the area potentially affected by subsidence, groundwater drawdown can increase leakage from (or reduce baseflow to) surface water. That is, this mechanism is not necessarily associated with subsidence (or other physical) impacts to the beds of the surface water bodies, rather, losses are a result of changes in the gradient of surface water and groundwater interactions.

A breakdown of the modelled surface water losses by mechanism is provided in Table 6-3A. The majority of the predicted losses are associated with Mechanism 2. If realistic, but less conservative, assumptions were adopted for groundwater modelling some of the Mechanism 2 losses would actually be Mechanism 1 losses, and therefore, would not be permanently lost from the catchment.

b. Predictions for the catchments of the Avon and Cordeaux Reservoirs.

The Project underground mining area is wholly located within the Metropolitan Special Area (Figure 6-3J).

As shown in Table 6-3B and Figure 6-3J, only a small portion of the Project underground mining area is located within the catchments of the storages within the Metropolitan Special Area (i.e. the Avon and Cordeaux Dams) (Figure 6-3J). The majority of the Project underground mining area is located in the catchment downstream of the dam (Figure 6-3J).

As noted above, the majority of Project surface water losses are associated with permanent surface water diversion due to subsidence-related impacts (i.e. Mechanism 2).

The majority of predicted Mechanism 2 losses would not affect surface water supply to the Avon and Cordeaux Dams, as only 34% of Area 5 is located within the Avon Dam catchment area and 4% of Area 6 is located within the Cordeaux Dam catchment area (Figure 6-3J).

A breakdown of predicted losses per catchment area is provided in Tables 6-3C and 6-3D. As shown, only approximately 709 ML/annum of the 1,935 ML/annum (i.e. 35%) of total predicted surface water losses would potentially affect water supply and security of the Avon and Cordeaux Dams.

c. Significance of predicted surface water losses

Water Storage Security Yield

Part 2 of the IEP Report (2019b) notes that consideration of the significance and tolerability of predicted surface water losses should primarily be based on impacts to 'security yield':

> *Assessment of the significance and tolerability of cumulative water supply losses due to mining should be based primarily on the degree to which they reduce security yield, including consideration of whether the reduction would require compensatory investments or other management actions. WaterNSW presented to the Panel the initial stages of work towards a framework that will support this assessment. Predicted water losses used in this assessment should be conservatively high, ideally with stated probabilities of non-exceedance, to allow for prediction uncertainty.*

'Security yield' is described by the IEP (2019b) as follows (emphasis added):

> *The security criterion is the most relevant in the context of assessing the potential consequences of mining for water supply. It is that **storage** should not fall below 5% of **storage** capacity in more than one in every 100,000 months (WaterNSW, 2018).*

Table 6-3A
Summary of Total Project Surface Water Losses

Mechanism	Description	Examples for Project	Maximum Predicted Surface Water Loss for the Project (ML/annum)	Implication of Conservative Model Assumptions
Mechanism 1	Surface Water Diversion (that re-emerges downstream)	N/A	N/A	Most surface water from headwater streams above workings is assumed to be permanently lost
Mechanism 2	Surface Water Diversion (that does not re-emerge downstream)	Losses from ephemeral streams overlying Project longwalls	~ 1,070 – 1,500	Conservative estimate of surface water losses as surface water assumed to be available to be lost at all times from streams
Mechanism 3	Groundwater Depressurisation	Modelled increases in leakages from dams and named watercourses	~ 435 - 865	Model is likely to simulate more leakage from watercourses than would occur in reality, and more water within shallow strata entering the conservatively-represented fracture network and being lost from the catchment
		Total	***1,935***	

Table 6-3B
Summary of Catchment Areas

Catchment		Catchment Area	Project	
			Area of Project Longwall Footprint Located within Catchment	Project as a Portion of Catchment
Storages	Avon Reservoir	143 km^2	6.9 km^2 (34% of Area 5)	4.8%
	Cordeaux Reservoir	86 km^2	0.2 km^2 (4% of Area 6)	0.2%
	Nepean Reservoir	320 km^2	~ 0 km^2	-
	Cataract Reservoir	130 km^2	~ 0 km^2	-
Downstream of Storages	Pheasants Nest Weir (Downstream of Nepean, Avon and Cordeaux Reservoirs)	137 km^2	18 km^2 (66% of Area 5 and 96% of Area 6)	13.1%
	Broughtons Pass Weir (Downstream of Cataract Reservoir)	86 km^2	-	-
	Total – Metropolitan Special Area	***902 km^2***	***25.1 km^2***	***2.8%***

Table 6-3C
Breakdown of Total Maximum Predicted Surface Water Losses from the Metropolitan Special Area – Project-only (ML/annum)

Mechanism	Storages				Downstream of Storages	
	Avon Reservoir	Cordeaux Reservoir	Nepean Reservoir	Cataract Reservoir	Pheasants Nest Weir	Broughtons Pass Weir
Mechanism 1	0	0	0	0	0	0
Mechanism 2 (% of total)	19-25%	1-3%	0%	0%	35-50%	0%
Mechanism 3 (% of total)	6-12%	1-3%	1%	0%	13-28%	1%
Sub-total [ML/annum]	630	79	27	0	1,172	28
Total	1,935 ML/annum (max)					

Mechanism 1 = Surface water diversion that re-emerges downstream

Mechanism 2 = Surface water diversion that does not re-emerge downstream

Mechanism 3 = Groundwater depressurisation (e.g. modelled increases in leakages from dams and named watercourses)

Note: Figures 6-3K and 6-3L show the maximum predicted surface water losses in Project year 30

Note: estimates of losses due to Mechanisms 2 and 3 are based on modelled losses occurring directly above the longwalls (Mechanism 2) and >300 m from the longwalls (Mechanism 3). Losses within 0-300 m of the longwalls could be attributed to either mechanism, hence the range in estimates

Table 6-3D
Breakdown of Total Maximum Predicted Surface Water Losses from the Metropolitan Special Area – Cumulative Dendrobium Mine Areas 1 – 6 (ML/annum)

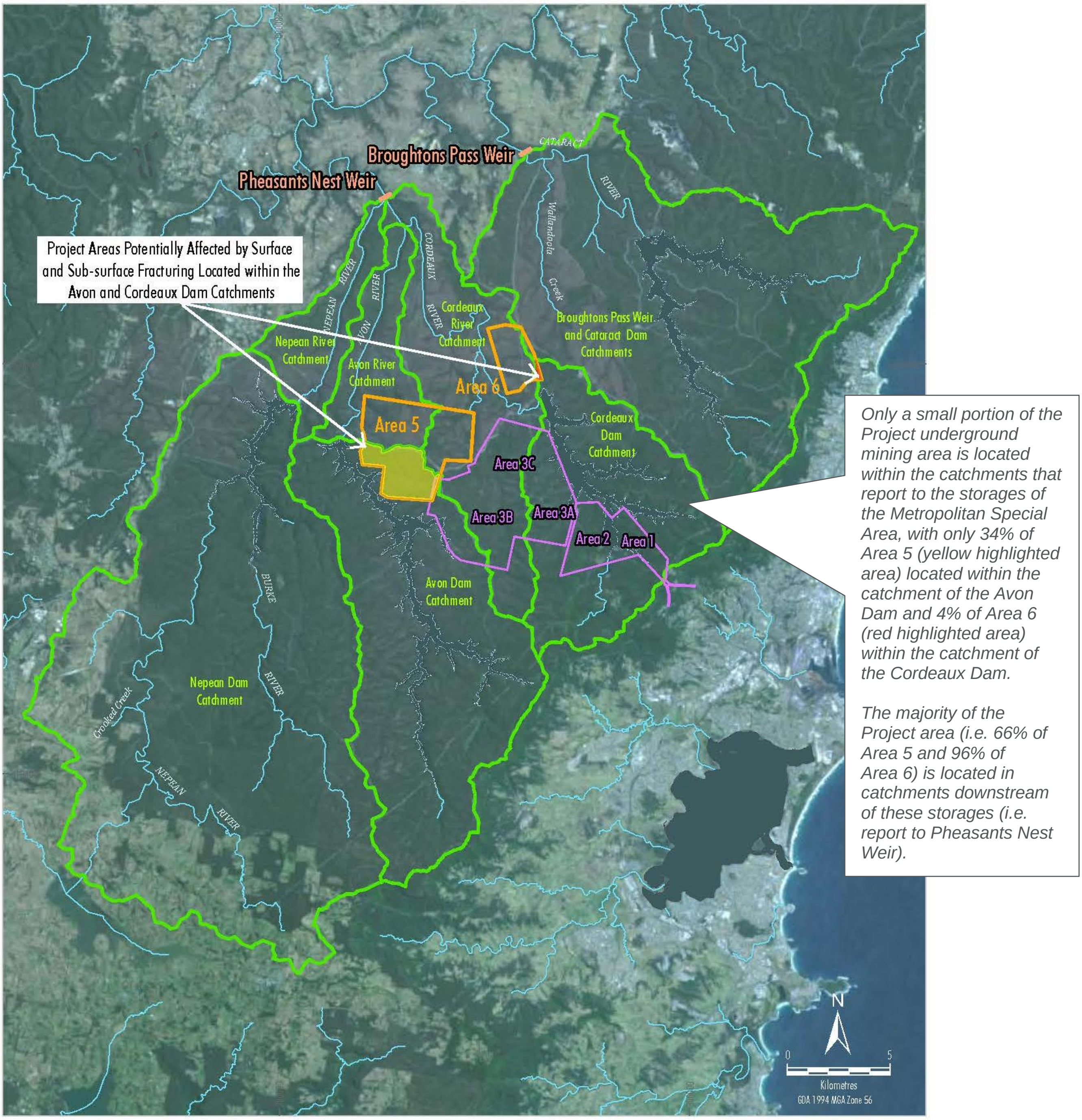
Mechanism	Storages				Downstream of Storages	
	Avon Reservoir	Cordeaux Reservoir	Nepean Reservoir	Cataract Reservoir	Pheasants Nest Weir	Broughtons Pass Weir
Mechanism 1	0	0	0	0	0	0
Mechanism 2 (% of total)	16-21%	4-8%	0%	0%	39-53%	0%
Mechanism 3 (% of total)	5-10%	3-7%	0%	0%	10-24%	0%
Total	3,330 ML/annum					

Mechanism 1 = Surface water diversion that re-emerges downstream

Mechanism 2 = Surface water diversion that does not re-emerge downstream

Mechanism 3 = Groundwater depressurisation

Note: estimates of losses due to Mechanisms 2 and 3 are based on modelled losses occurring directly above the longwalls (Mechanism 2) and >300 m from the longwalls (Mechanism 3). Losses within 0-300 m of the longwalls could be attributed to either mechanism, hence the range in estimates



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LEGEND

- Dendrobium Underground Mining Area - Proposed Project
- Dendrobium Underground Mining Area - Existing Mine (DA 60-03-2001)
- Catchment Boundaries of the Metropolitan Special Area
- Project Area Located within Avon Dam Catchment
- Project Area Located within Cordeaux Dam Catchment

Source: Geoscience Australia (2006); Department of Industry (2018); Department Finance, Services & Innovation (2018);

SOUTH32
Illawarra Coal

DENDROBIUM MINE

Portions of Project Area Located within Catchment Areas Reporting to Reservoirs

Figure 6-3J

WaterNSW has previously outlined to South32 that project-induced water losses of a volume greater than 20% of the security yield of a downstream storage would significantly hamper its ability to maintain Greater Sydney's water supply system (WaterNSW, 2018a).

The loss that would equate to a greater than 20% loss of the security yields is 4,200 ML/annum for Avon Dam and 2,800 ML/annum for Cordeaux Dam (WaterNSW, 2018a) (Table 6-3E). By comparison, the security yield of the Sydney water supply system in 2018 was approximately 570,000 ML/annum (WaterNSW, 2018b).

Pheasants Nest Weir and Broughtons Pass Weir are small storages that function as water supply diversion weirs, unlike the upstream storages (e.g. Avon and Cordeaux Dams), WaterNSW does not report these weirs as having a 'security yield'.

Table 6-3E
Security Yield and Storage Capacity of Reservoirs Within the Metropolitan Special Area

Storage	Total Operating Capacity (ML)	Security Yield (ML/annum)	>20% Security Yield (ML/annum)
Cataract Reservoir	97,190	20,000	4,000
Cordeaux Reservoir	93,460	14,000	2,800
Avon Reservoir	146,700	20,800	4,200
Nepean Reservoir	67,730	19,000	3,800
Broughtons Pass Weir	50	N/A	N/A
Pheasants Nest Weir	25	N/A	N/A

Source: (WaterNSW, 2018a).

The maximum volume of surface water predicted to be diverted from the Avon and Cordeaux Dams (630 ML/annum and 79 ML/annum) is less than the 20% threshold values due to the Project and cumulatively (Figure 6-3K).

Significance of Predicted Surface Water Losses to Catchment Yields

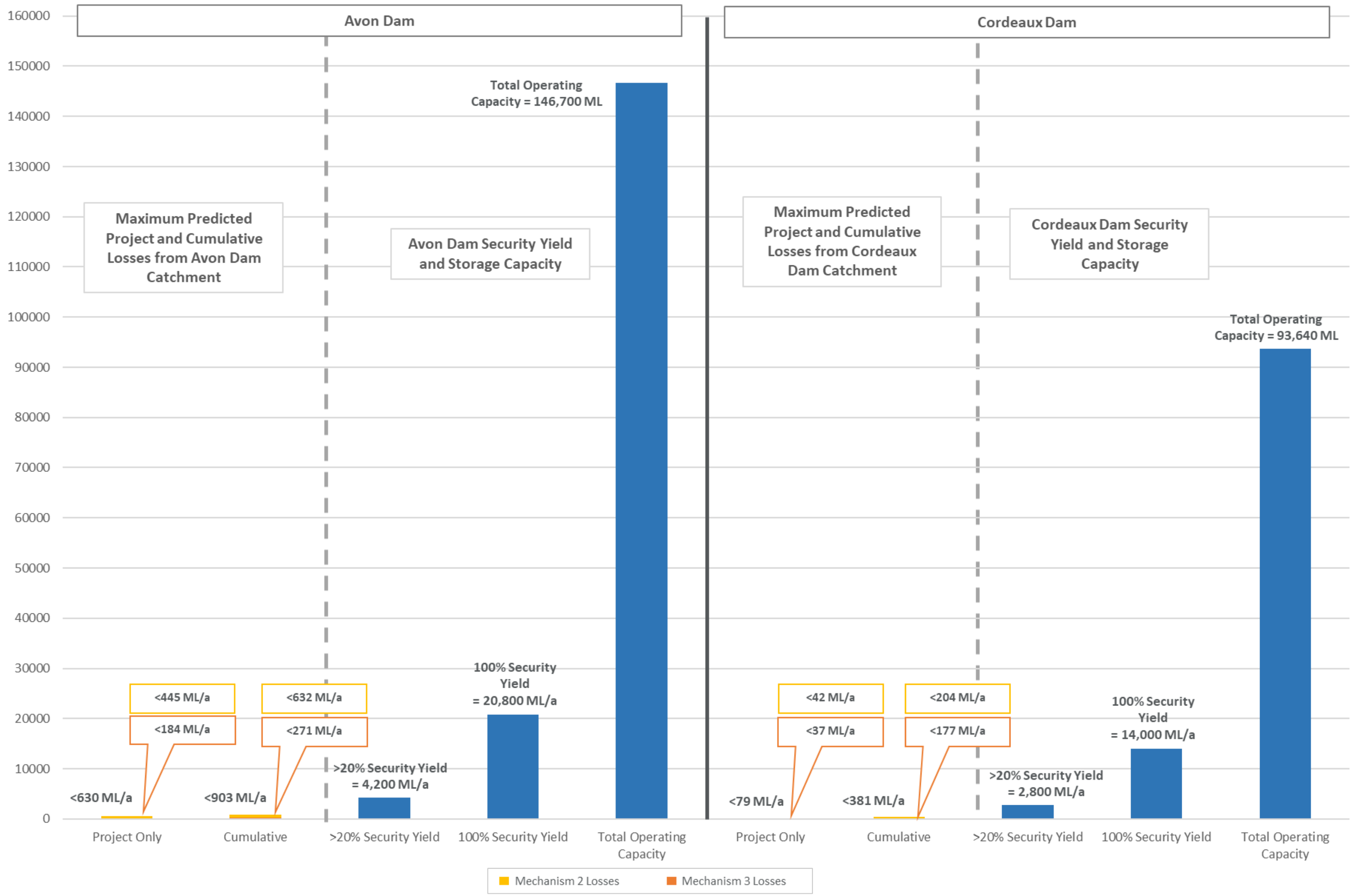
The predicted surface water losses due to the Project are estimated to reduce total yields of the Metropolitan Special Area by less than 1% under median climate conditions. Figure 6-3L compares the predicted surface water losses to catchment rainfall, rainfall net evaporation and yields (i.e. estimated runoff).

The IESC (2019) states in its advice in regard to the Project EIS (emphasis added):

> *The IESC notes that **reductions to Sydney's drinking water supply is predicted to be relatively small**, where yields to Lake Avon and Pheasants Nest Weir are predicted to be reduced by 0.55% and 0.39% respectively in median years. These impacts are **unlikely to be of material concern even in drought years or under expected future climate projections**.*

Comparison of Predicted Surface Water Losses to Drinking Water Network Losses and Components

The predicted maximum losses are insignificant when compared to other losses from the drinking water network. For example, by comparison to the maximum predicted Project losses of 1,935 ML/annum for wet climatic conditions, estimated water losses from the Sydney drinking water pipe network were reported to increase by approximately 5,500 ML in a single year (i.e. Sydney Water estimated losses increased from 41,610 ML to 47,268 ML between financial years 16-17 and 17-18).

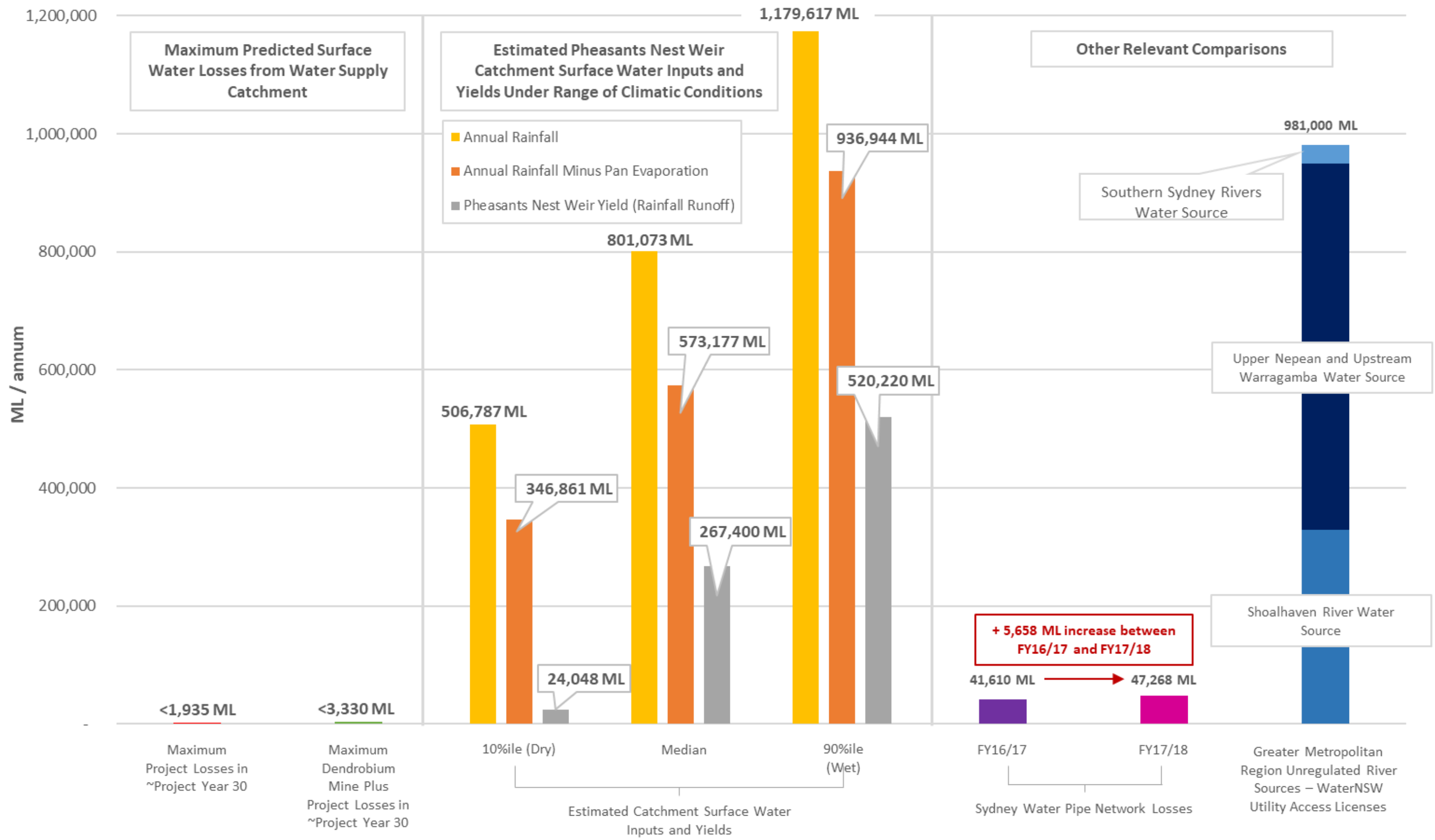


Only a small portion of the Project underground mining area is located within the catchments of the Avon and Cordeaux Dams.

This graph shows a comparison of the maximum predicted surface water losses from the Avon and Cordeaux Dam catchments as a result of the Project (the yellow and orange boxes) to the security yields of these storages, consistent with the recommendations of the IEP.

As shown on the graph, the maximum predicted surface water losses from the Avon and Cordeaux Dam catchments as a result of the Project are significantly less than the >20% security yields, and total operating capacities of these storages.

Figure 6-3K – Comparison of Maximum Predicted Surface Water Losses to Dam Operating Capacities and Security Yields



<u>Notes:</u>

a) *Estimated yields based on rainfall runoff do not consider regulated flows downstream of the Nepean, Avon and Cordeaux Dams – as these flows are not dependent on rainfall.*

b) *Project surface water losses would be significantly lower than 1,935 ML/annum (Project) or 3,300 ML/annum (cumulative) during 10%ile dry climatic conditions, as there would be limited water available in the ephemeral tributaries overlying Areas 5 and 6 to be lost during dry periods. The groundwater model conservatively assumes water is always available to be lost from these ephemeral tributaries (up to approximately 1,600 ML/annum).*

Figure 6-3L – Comparison of Predicted Surface Water Losses

The IEP (2019b) notes that its estimates of cumulative losses from Sydney's drinking water catchment from the Dendrobium, Russell Vale and Wongawilli mines of 8 ML/day are "low" when compared to other components of the drinking water network (emphasis added):

> *The* [surface water] *losses referred to in Section 3.2.3* ***are low*** *compared to other components of Sydney's supply and demand, for example recent losses from the Dendrobium, Russell Vale and Wongawilli mines of less than 8 ML/day on average compare to the Sydney Desalination Plant capacity of approximately 250 ML/day (Sydney Desalination Plant, 2019) and estimated leaks from the Sydney Water supply infrastructure of approximately 130 ML/day (Sydney Water, 2018).*

A comparison of the maximum predicted surface water losses as a result of the Project, to these other losses/components is provided in Figure 6-3K.

In summary:

- The IEP identifies impacts of predicted surface water loss to 'security yield' as a component of the assessment of significance and tolerability.
- Predicted maximum surface water losses due to the Project are:
  - Less than 20% of security yields for the Avon and Cordeaux Dams.
  - Negligible compared to the total yields of the Metropolitan Special Area.
  - Insignificant compared to other network losses and demands.
- These conclusions are based on conservative assumptions adopted in the groundwater modelling.
- If more realistic but less conservative assumptions were adopted, predicted surface water losses would be lower than those presented in the EIS.

3. Mitigation and management measures for the Project.

To offset predicted surface water impacts, South32 commits to implement or fund works such that the Project results in net neutral or net beneficial effects to Sydney's drinking water supplies from subsidence-related surface water losses from the Metropolitan Special Area, including:

- beneficial use of mine water to reduce existing demands on the drinking water system, and/or funding or implementing works that reduce existing losses (e.g. pipe losses or evaporation);
- payment to WaterNSW for the maximum predicted take; and
- holding of sufficient licences to account for this take.

This is consistent with the recommendations of the IEP (2019b), who state:

> *Options identified for offsetting water loss from the Special Areas include:*
>
> - *'purchasing' the water lost from the catchment that can be attributed to mining operations, the financial offset could be used to fund make-up water sources, such as through the operation of desalination plants and borefields, or*
> - *treating the water pumped from the mine to a standard that enables it to supplement water that would otherwise be drawn from the Greater Sydney Water Catchment.*

a. Beneficial use of mine water

South32 proposes to implement a beneficial mine water use scheme for excess mine water for industrial and/or other users. The intention of the beneficial mine water use scheme is that the volume used matches or exceeds maximum predicted Project surface water take, therefore, achieving no net reduction (or a net gain) in the total drinking water supply system.

This commitment is also consistent with Condition 11, Schedule 4 included in the Dendrobium Mine Longwall 17 approval, which requires South32 to offset the reduction in surface water reporting to WaterNSW storages as a result of the extraction of Longwall 17.

South32 has investigated options for the beneficial use of excess mine water and undertaken consultation with water infrastructure stakeholders and water users, which indicates that there is demand for excess mine water from the Project (subject to treatment to a comparable quality of raw water from the storages).

The investigation has identified a number of potential mine water use options for Project mine-water and for a variety of use volumes, including:

- direct discharge back into the Sydney Drinking Water Catchment (subject to treatment);
- discharge to the Illawarra Filtration Plant for end-use potable water supply, which would offset the current direct water take from the Avon Dam via the existing raw water supply pipeline; and
- supply for industrial water use which would also offset the existing direct water take from the Avon Dam, including:
  - direct input into the existing raw water supply pipeline from Avon Dam to the Sydney Water-BlueScope Steel recycled water network;
  - discharge to the Berkeley Storage Tanks (which supply the Sydney Water-BlueScope Steel recycled water network); and
  - direct supply to the final industrial end-user(s).

Other options under investigation include the use of the mine water for greenspace irrigation as well as funding works to increase Sydney Water's ability to treat water and meet industrial user demands (e.g. funding of upgrade works at the Wollongong Recycled Water Plant) and funding water works that would reduce losses from the drinking water system (e.g. such as pipe losses and evaporation).

All options being considered would account for predicted losses via either direct offset of treated water or through funding of works to reduce network losses.

In addition, any option that would directly offset existing raw water take from the Avon Reservoir would have a positive effect on storage security yield, consistent with WaterNSW (2018b):

> *Any action which slows the rate of depletion of the dams in the latter stages of a drought will have a positive effect on Security Yield.*

Sydney Water is working collaboratively with South32 to investigate opportunities to beneficially use mine water. While no commitments have been made, and any final proposal would be subject to confirmation by Sydney Water, the implementation of such options to use treated mine water would have a **net positive** effect on the total water budget, as the volume of surface water loss from the Metropolitan Special Area storages would be met, or exceeded by this use.

South32 commits to implement or fund works such that the Project results in net neutral or net beneficial effects to Sydney's drinking water supplies from subsidence-related surface water losses from the Metropolitan Special Area.

This would include beneficial use of mine water to reduce existing demands on the drinking water system, and/or funding or implementing works that reduce existing losses (e.g. pipe losses or evaporation).

b. Payment for predicted surface water take.

In addition to the beneficial use of excess mine water, South32 would pay WaterNSW for the volume of surface water diverted from the Sydney Drinking Water Catchment (i.e. as it would be no longer available for sale to other water users).

It is proposed that payment would be calculated based on the following:

- Price per megalitres ($53.85 per ML) consistent with the Independent Pricing and Regulatory Tribunal (IPART) determination for WaterNSW's prices for bulk water operations in the Greater Sydney area for Council use of bulk water (IPART, 2016).
- To account for climate variability and the progressive stage of longwall mining, actual losses would be quantified annually using a combination of streamflow, mine inflow and climate data, and predictive groundwater and catchment runoff modelling.

It is expected that this would result in payment of approximately $100,000 per annum during peak predicted surface water losses for the Project.

It is noted that some submissions raised that the price per megalitre of payment be independently determined. South32 considers that the price determined by IPART, which by definition is an independent pricing tribunal, is appropriate.

Other submissions raised that WaterNSW has previously stated that the 'replacement' value of water was $2,276/ML. It is unclear how this value has been derived, however, it is more than an order of magnitude higher than the maximum price IPART has determined WaterNSW can sell water to Councils ($53.85/ML) or Sydney Water ($73.77/ML) (IPART, 2016).

The purpose of the commitment to pay WaterNSW for predicted surface water loss is to compensate WaterNSW for lost revenue for water it may otherwise be able to sell. As such, South32 considers the price independently determined by the IPART to be reasonable.

This is in addition to the commitment to beneficially use mine water and/or funding or implementing works that reduce existing losses such that there is no net loss to the drinking water system.

South32 commits to paying WaterNSW for the maximum predicted surface water take at the rate independently determined for bulk water by the Independent Pricing and Regulatory Tribunal.

c. Surface water licensing.

South32 would hold the required surface water licences for the maximum predicted surface water take for the Project.

South32 currently holds sufficient volumetric licences to account for the maximum predicted mine water inflow (i.e. the combined groundwater and surface water take).

Although these licences cover the volumetric take, these licences are not currently distributed to all of the administrative water sources required for the Project.

Due to existing restrictions on the availability of licences, South32 is reliant on the NSW Government creating additional licences/entitlements and/or amending transfer rules to facilitate the development of the Project in the applicable adjoining water sharing plan management areas and zones.

South32 commits to holding sufficient water licences to account for the maximum predicted surface water take of the Project.

Any additional licences required under the NSW *Water Management Act, 2000* would be sought and obtained by South32 in consultation with DPIE-Water. Refer to Section 6.4 for further detail.

4. Surface Water Flow Monitoring.

South32 maintains a surface water monitoring and management program for the approved Dendrobium Mine.

The existing program includes stream flow monitoring of a number of ephemeral drainage lines proximal to Area 5, Area 6 and Donalds Castle Creek.

Consistent with the recommendations of Hydro Engineering & Consulting (HEC) (2019), the existing Area 5 and Area 6 surface water monitoring networks would be expanded and augmented for the Project as follows:

- implementation of additional water level/flow rate monitoring sites at the downstream end of swamps (monitoring locations to be selected during the review and update of the Dendrobium Mine Water Management Plan [WMP] for the Project);
- pool water level monitoring of pools associated with key stream features, including four additional pools as 'control' pools in areas outside of the Project mining area; and
- continuation and further development of existing surface water quality monitoring sites.

TARPs would be developed incorporating baseline data and predicted impacts, and would build on mining experience to date at the Dendrobium Mine. TARPs would be developed during the Extraction Plan stage of the Project and would be outlined in the relevant management plans for the Project.