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BULGA COAL

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BULGA OPTIMISATION PROJECT MODIFICATION 3 AND BULGA UNDERGROUND MODIFICATION 7

Response to Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development Advice

FINAL

April 2020

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FINAL

Prepared by

Umwelt (Australia) Pty Limited

on behalf of

Bulga Coal Management Pty Ltd

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	Name	Date	Name	Date
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1.0 Introduction

The Statement of Environmental Effects (SEE) for the Bulga Optimisation Project Modification 3 (MOD 3) and Bulga Underground Modification 7 (MOD 7) (Umwelt, 2019) was placed on public exhibition from 8 October to 4 November 2019. During the public exhibition period 17 submissions were made on SSD 4960 MOD 3 and DA 376-8-2003 MOD 7. This included 15 government agency submissions and two community submissions. None of the government agencies indicated that they oppose SSD 4960 MOD 3 or DA 376-8-2003 MOD 7, rather they made submissions seeking further clarification regarding aspects of the assessment.

A Submissions Report was prepared to address the issues raised in the submissions received during the public exhibition period and was submitted to the NSW Department of Planning, Industry and Environment (DPIE) on 20 December 2019.

A submission from the Commonwealth Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) was received on 18 December 2019.

This document has been prepared by Umwelt (Australia) Pty Limited (Umwelt) on behalf of Bulga Coal Management Pty Ltd (BCM) and seeks to address the comments raised in the IESC advice. This document has also been prepared with the assistance of:

- Klohn Crippen Berger Ltd (KCB) on groundwater related issues
- Engeny Water Management (Engeny) on surface water related issues
- Hydro Engineering & Consulting Pty Ltd (HEC) on water balance and final void related issues.

1.1 Overview of Existing Operations and the Proposed Modification

The following sections outline the current operations and the context within the Proposed Modification will occur.

1.1.1 Existing Operations

The Bulga Coal Complex (BCC) is an existing operating coal mining operation located approximately 12 kilometres (km) south west of Singleton in the Hunter Valley, of New South Wales (NSW) (refer to **Figure 1.1**). BCM operates the BCC on behalf of the Bulga Joint Venture, with mining operations occurring at the site for over 35 years.

The BCC consists of open cut operations (Bulga Surface Operations) and underground operations (Bulga Underground Operations) that use shared coal washing and rail loading infrastructure as well as having an integrated water management system (WMS). The Bulga Surface Operations are adjacent to the Mount Thorley open cut mine to the north, which in-turn adjoins the Warkworth open cut mine further to the north.

The existing open cut operations are approved to mine down to and including the Piercefield Seam. These operations are approved to 31 December 2035.

Underground operations commenced at BCC at South Bulga Colliery using longwall extraction methods in 1994. In 2004, the current Bulga Underground Mine Consent was granted (DA 376-8-2003), authorising ongoing underground longwall mining in the Whybrow, Blakefield, Glen Munro and Woodlands Hill seams.

Mining has already taken place in the Whybrow and Blakefield seams. The Underground Operations are currently on care and maintenance with mining yet to commence in the Glen Munro and Woodlands Hill seams.

1.1.2 Proposed Modification

BCM is seeking to modify both the Bulga Surface Operations (SSD 4960 MOD 3) and the Bulga Underground Operations (DA 376-8-2003 MOD 7) through a modification application under section 4.55 (2) of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for both these planning approvals.

The Proposed Modification includes an extension to the open cut operations with a number of consequential changes to the underground operations. The key changes associated with the Proposed Modification are:

- extension of approved open cut operations to the east of existing approved operations (including below areas previously extracted)
- changes to the rehabilitated landform and deeper final void depth
- enlargement of existing approved in-pit tailings facility and the transfer of tailings from the current Deep Pit tailings facility to the enlarged facility.

The Proposed Modification will also require the upgrade, relocation or removal of some components of the infrastructure servicing the Bulga Surface Operations as well as removal of components of the Bulga Underground Operations infrastructure, through DA 376-8-2003 MOD 7, including workshops, gas-fired power generation plant and associated gas infrastructure, electrical substation, fuel and oil storage.

The Proposed Modification will maintain the current approved open cut coal extraction rate of up to 12.2 Million tonnes per annum (Mtpa) of run of mine (ROM) coal while enabling the extraction of an additional approximately 63 Mt of ROM coal. SSD 4960 MOD 3 will extend the life of the development consent by approximately four years until 2039.

The Proposed Modification will maximise resource recovery within the approved Project Area through the extension of the open cut operations. The proposed extension of the open cut pit to the south-east also enables extraction of additional deeper resources below parts of the currently approved Bulga Surface Operations.

An additional disturbance of 20.2 hectares (ha) is required to accommodate the proposed extension of the mining areas. Approximately 200 ha of mine rehabilitation will also be re-disturbed and re-established as a result of the Proposed Modification.

The Bulga Surface Operations will continue to use the BCC shared infrastructure approved to service both the open cut and the underground mining operations including the Coal Handling and Preparation Plant (CHPP), raw coal stockpiles and conveyors, train loading facilities, workshops, stores, offices and deployment areas, water management system, etc.

Figure 1.2 shows the Proposed Modification in relation to the currently approved open cut mining operations at BCC. **Figure 1.3** and **Figure 1.4** show cross sections of approved and proposed mining operations.

FIGURE 1.1

Locality Plan

File Name (A4): R14/4100_225.dgn
20200401 12.25

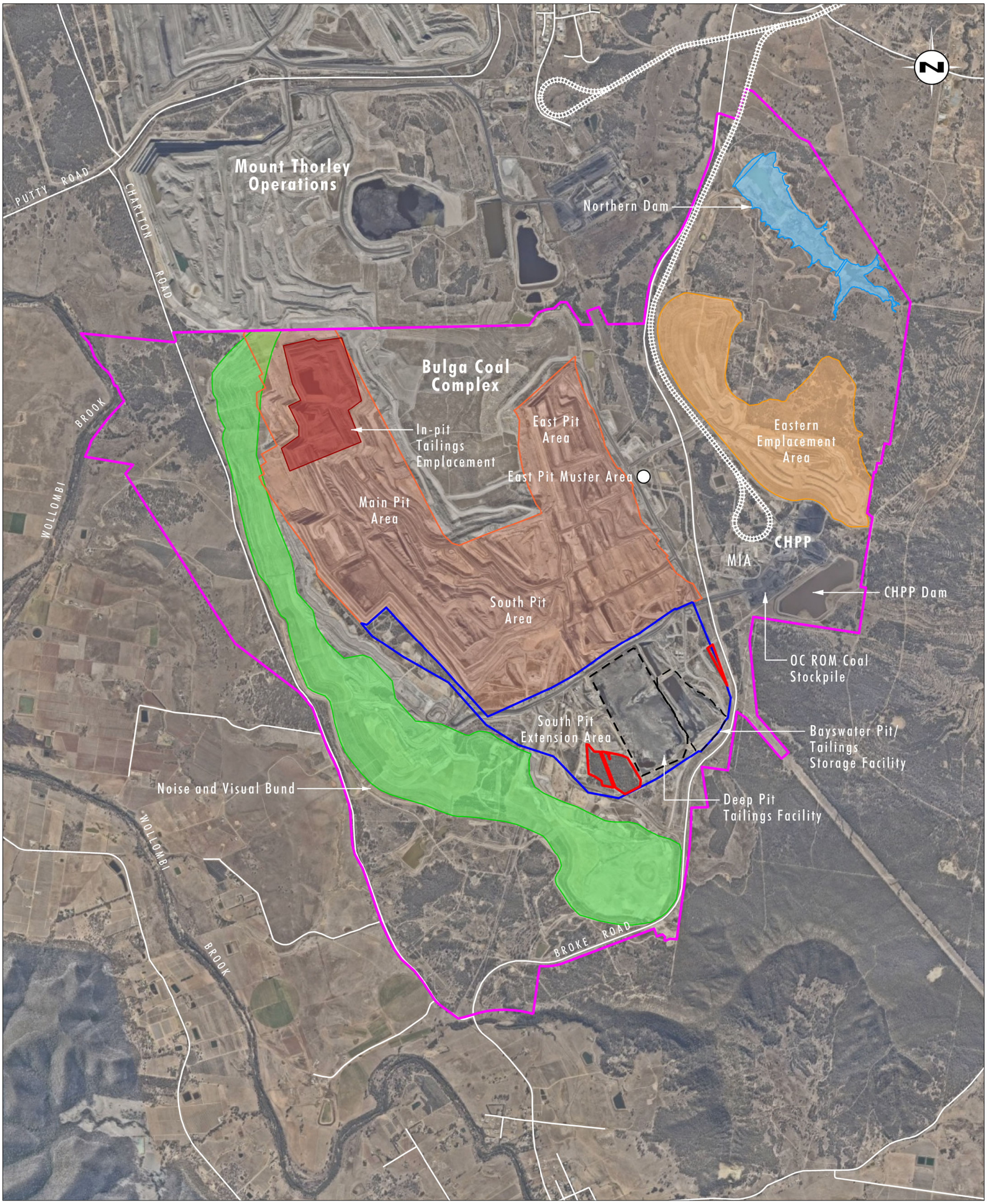


Image Source: Nearmap (Dec 2019)
Data Source: Bulga (2019)

0 1 2 3km
1:60 000

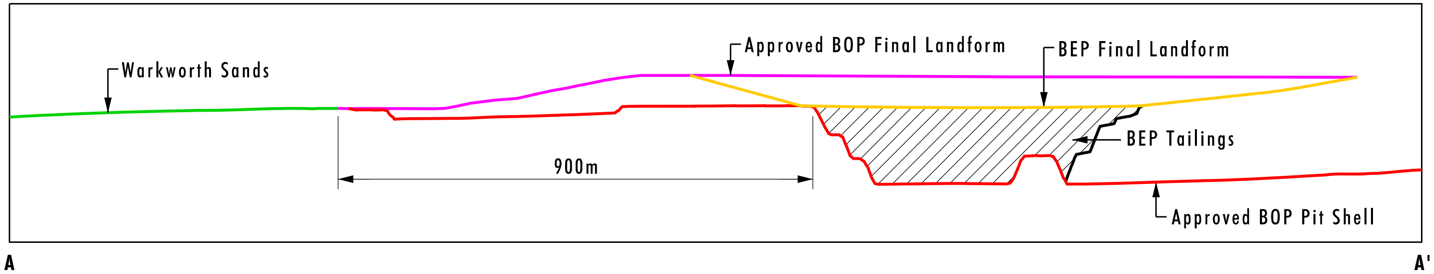
Legend

- Project Area
- Additional Disturbance Area
- South Pit Extension Area
- Approved Mining Area
- Noise and Visual Bund
- Eastern Emplacement Area
- In-pit Tailings Emplacement
- Northern Dam
- Rail Line

FIGURE 1.2

SSD 4960 Modification 3 and DA 376-8-2003 Modification 7 Key Mining Features

File Name (A4): R14/4100_226.dgn
20200401 14.11



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INSET: 1:60 000

0 250 500 750m
1:15 000

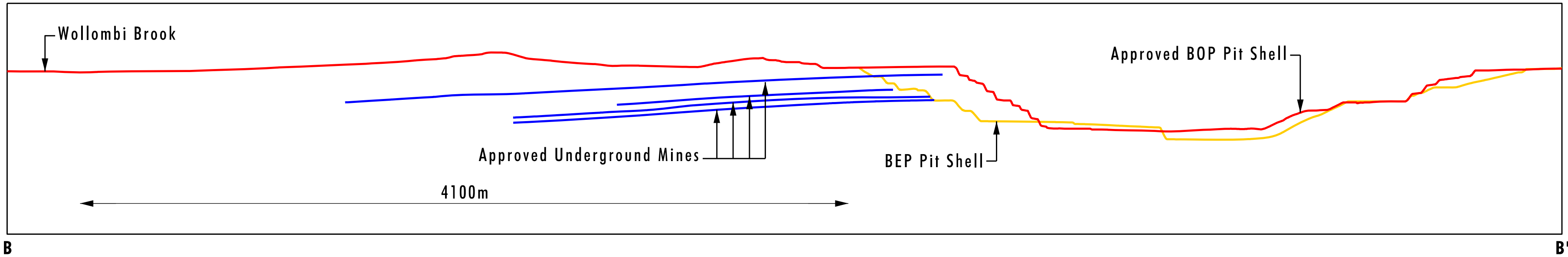
Image Source: Nearmap (Dec 2019)
Data Source: Glencore (2020)

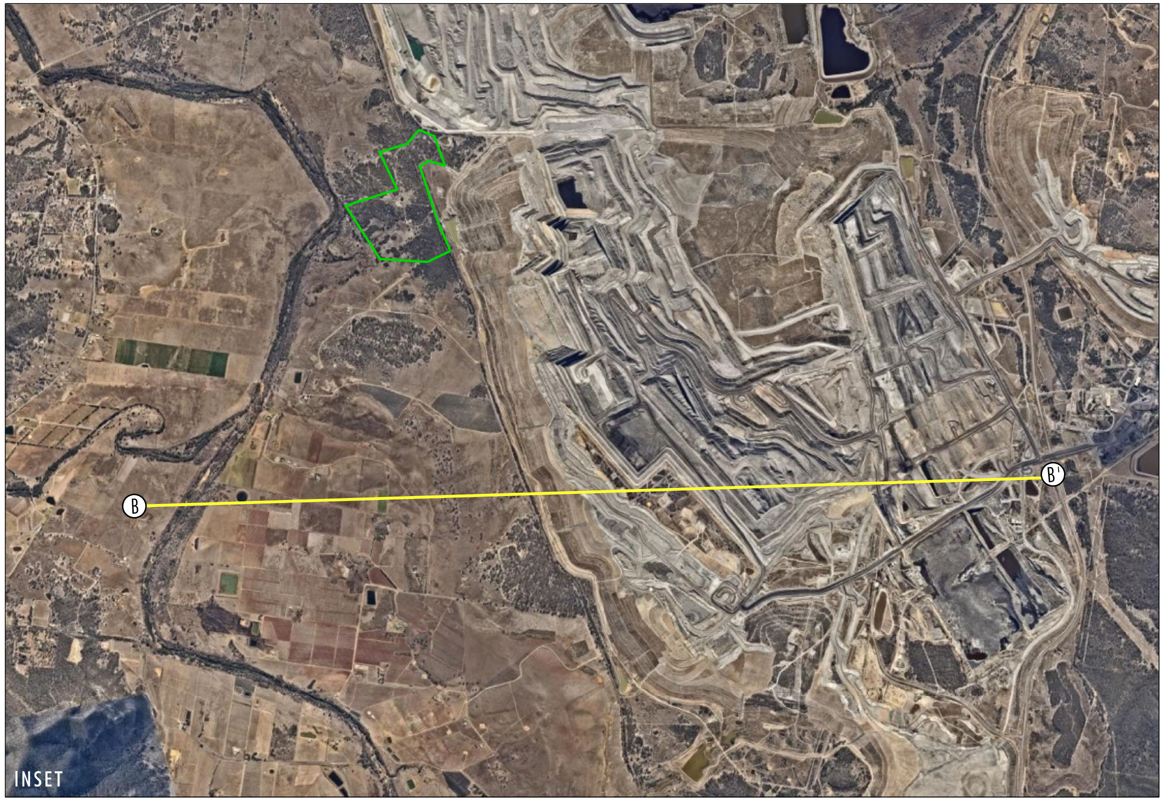
Legend

Transect Line
Warkworth Sands

FIGURE 1.3

Approved v Proposed Cross-section A





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INSET: 1:70 000

0 0.5 1.0 1.5km
1:35 000

Image Source: Nearmap (Dec 2019)
Data Source: Glencore (2020)

Legend
Transect Line
Warkworth Sands

FIGURE 1.4

Approved v Proposed Cross-section B

File Name (A4): R14/4100_224.dgn
20200401 16.02

1.2 Hydrogeological Context

The BCC lies in the Upper Hunter Coalfields and straddles a gentle topographic high between Wollombi Brook and Loders Creek. This feature strikes roughly south-east to north-west, coincident with the Jerrys Plain Subgroup outcrop. Underground mine development is to the west and south of the open cut mine.

There are three general hydrogeological systems across the Project Area:

- alluvial aquifers associated with the Monkey Place Creek and Wollombi Brook which overlie Permian strata and wrap around the south and west of the main mining area. Based on monitoring data, this system has poor connectivity with the underlying Permian strata.
- aquifers within Aeolian sand deposits associated with the Warkworth Sands Woodlands, adjacent to the west of the existing Bulga open cut operations and the Mount Thorley mine. This system is interpreted as having a perched water table, positioned over lower permeable Permian and not in hydraulic connectivity with the underlying groundwater system
- the Permian coal measures of the Singleton Super Group which host the mined coal resource and represent outcrop in all areas where regionally mapped alluvium is absent (low yielding, confined aquifers).

Loders Creek and its tributary (Nine Mile Creek), northeast and north of the open cut operations drain to the Hunter River approximately 5.5 km north of the BCM operations. This system is ephemeral and known for increased salinity as flow recedes (Mackie, 2013), and does not include regionally mapped alluvium.

The Jurassic basalt has in some instance provided localised low yielding good quality water supplies but like the Triassic sandstones of the Narrabeen Group and the Hawkesbury Sandstone are not aquifers of relevance to local mining conditions.

The Permian groundwater systems in the local area are already significantly impacted by past and approved mining operations, including the separately approved adjoining Mount Thorley and Warkworth mining operations. Consistent with predictions from past groundwater impact assessments for the currently approved mining operations, a decline in groundwater levels has been observed within Permian coal measures, as a consequence of mining related depressurisation of the coal measure aquifers. The approved underground operations are yet to mine the deeper seams at depth however these seams, including the deeper seams to be mined by the Proposed Modification, have previously been mined as part of the mining of the monocline in the approved East Pit, Bayswater Pit and Deep Pit.

Approved underground operations and mining to the base of the Broonie series will result in further depressurisation of aquifers in coal seams down to the Broonie Series. These underground operations are located between the current and approved open cut operations and the Wollombi Brook and Monkey Place Creek alluvial systems. The predicted (but unrealised) impacts on the Wollombi Brook Alluvial aquifers from approved operations is predominately caused by the depressurisation associated with existing and approved underground operations rather than open cut operations. Modelling indicated no observable difference in predicted impacts on this aquifer system between the operations approved prior to the approval of the Bulga Optimisation Project in 2014 and the currently approved operations (Mackie 2013, David 2016).

As noted above, monitoring indicates extensive depressurisation of Permian aquifer systems in the immediate vicinity of historical and existing underground operations however no impacts on alluvial groundwater systems (within natural variability) have been observed. These monitoring results are consistent with both modelling predictions for approved operations and the conceptual model of the area.

The Proposed Modification will result in further extraction of the steeply dipping seams further to the east and south or what is presently approved, however these seams have already been significantly depressurised as a result of the existing approved operations. The Proposed Modification does not result in any progression of open cut operations to the west or south (i.e. towards the Monkey Place Creek and Wollombi Brook alluvial systems) beyond currently approved underground operations.

Figure 1.5 shows a conceptual hydrological model of the maximum extent of approved operations and the post closure landform.

Surface Hydrology

Previous mining operations have modified local catchments through the capture of runoff from mining areas within the integrated water management system (WMS) and diversion of upslope runoff around the mining operations.

The additional mining area is located within the Wollombi Brook and Loders Creek catchments. These catchments are well understood as a result of the studies undertaken in relation to past approvals for open cut and underground operations at the BCC. The Proposed Modification will result in 20.2 ha of additional disturbance. The additional disturbance area is relatively minor, in the context of the currently approved BCC disturbance area of 3,786 ha.

The three main sub-catchments of Wollombi Brook within the additional mining area are:

- Monkey Place Creek
- Southern Drainage Line
- Northern Drainage Line.

The Proposed Modification will not involve any additional works relative to the approved development in Monkey Place Creek. Similarly, the Southern Drainage Line and Northern Drainage Line catchments will be largely unchanged relative to the approved operations.

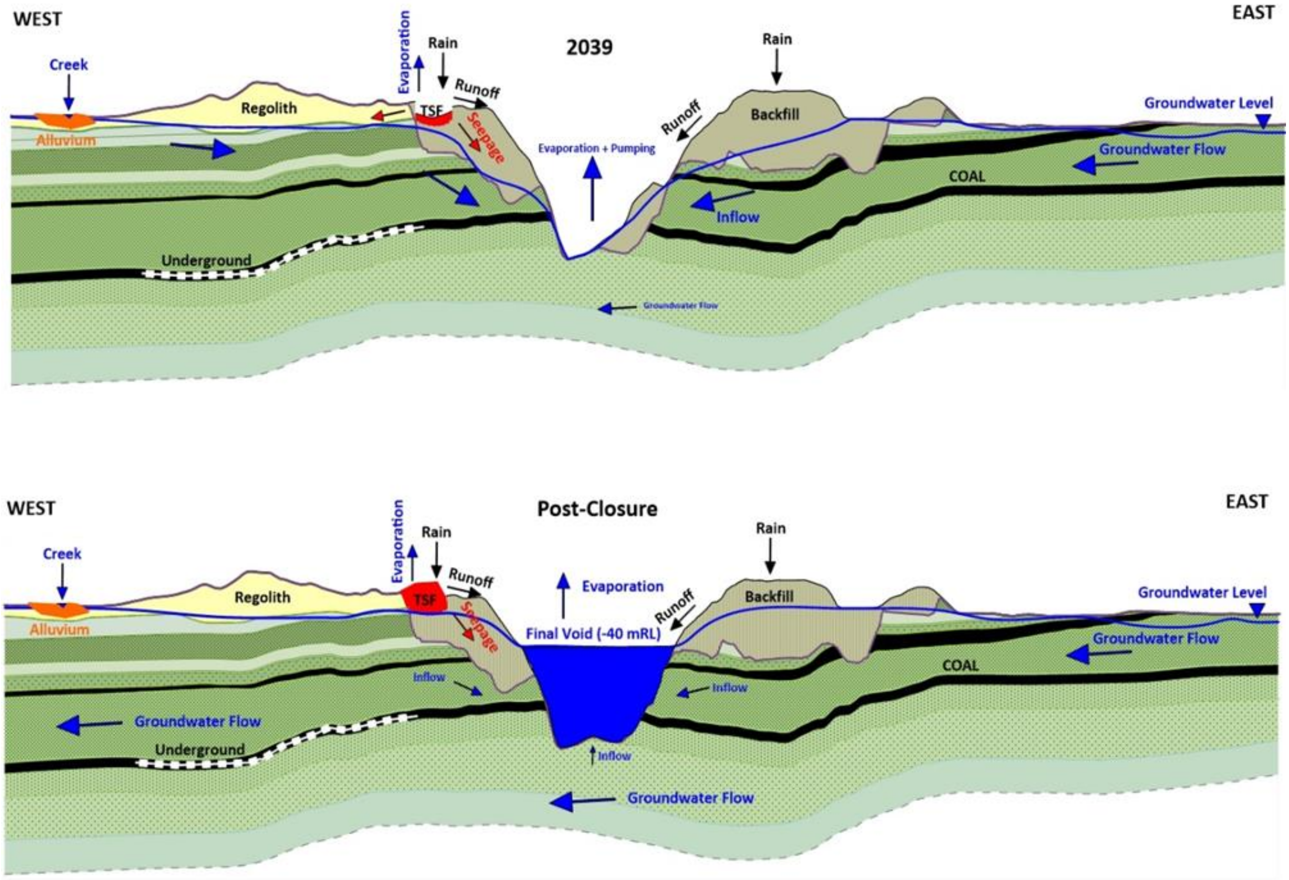

Figure 1.5 **Conceptual Hydrogeological Model for 2039 (maximum extent of mining) and post-closure conditions**

2.0 Responses to IESC Submission

The initial questions raised in the IESC advice, including the recommendations are identified in the following sections in text boxes, with the response provided following each text box.

2.1 General

Question 1: Do the groundwater and surface water assessments within the Statement of Environmental Effects (SEE) provide adequate mapping and delineation of surface and groundwater resources?

1. The assessment documentation generally provides adequate mapping and delineation of water resources within the project area. Some additional work is required to increase understanding of potential impacts and includes:

- **a. mapping of the current groundwater levels and flow directions**
- **b. improved spatial resolution of the extent of the alluvium in areas of current uncertainty such as Loders Creek, Nine Mile Creek and the Beltana Reach of Wollombi Brook**
- **c. improved characterisation of areas where the alluvium occurs and could be in hydraulic connection with Permian aquifers and the time scales of these connections**
- **d. identification of stream reaches where the Permian aquifers are connected, and potentially providing baseflow to, the surface water systems, either directly or via alluvial aquifers**
- **e. mapping of the occurrence of potential GDEs, including stygofauna and riparian vegetation**
- **f. identification of the source of groundwater potentially used by the EPBC-Act listed Warkworth Sands Woodland and whether it is connected to any other groundwater or surface water sources, and,**
- **g. g. groundwater quality data for potential contaminants (other than salinity) particularly in the Wollombi Brook alluvium.**

a. mapping of the current groundwater levels and flow directions

Using groundwater monitoring data from late 2019, the current groundwater contours and inferred flow directions for the shallow aquifer are provided in Section 4.1 of **Appendix A**.

Figure 1 of **Appendix A** indicates that the influence of mining is almost indiscernible when only monitoring locations that are further afield are considered, suggesting that the drawdown impacts associated with mining activities are largely restricted to a zone surrounding the operations.

Figure 2 of **Appendix A** presents the same data but includes consideration of piezometer data and the current mining depths. The inferred late 2019 contours when the mining data is included provides a more complete understanding of the groundwater conditions in the Project Area. Inferred flow directions are toward the mining operations, with steep groundwater gradients towards the mining area near the operations, becoming progressively less pronounced further afield.

b. improved spatial resolution of the extent of the alluvium in areas of current uncertainty such as Loders Creek, Nine Mile Creek and the Beltana Reach of Wollombi Brook

The mapped areas of the alluvium and the associated monitoring points are provided in Figure 3 of **Appendix A**. Alluvium exhibits a small seasonal vertical variability (generally sub-metre scale) and a strong relationship to large flow events in the creeks.

c. improved characterisation of areas where the alluvium occurs and could be in hydraulic connection with Permian aquifers and the time scales of these connections

d. identification of stream reaches where the Permian aquifers are connected, and potentially providing baseflow to, the surface water systems, either directly or via alluvial aquifers

As outlined in the GWIA, interpretation of the available groundwater monitoring data strongly indicates poor hydraulic connection between the Permian and alluvial units in the Project Area. More recent monitoring data up to the end of 2019 has been analysed in **Appendix A** further confirms this interpretation. Examples are provided in a series of hydrographs presented in **Appendix A**.

e. mapping of the occurrence of potential GDEs, including stygofauna and riparian vegetation

Figure 2.1 shows the Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology 2020) (GDE Atlas) mapping of terrestrial and aquatic GDEs in the vicinity of the Project Area. Riparian vegetation along Wollombi Brook and the ephemeral systems of Nine Mile Creek, Loders Creek and the lower reaches of Monkey Place Creek are mapped as being High potential GDEs while the area where the Warkworth Sands Woodlands Ecological Community (WSWEC) is located is mapped as being a moderate potential GDE. Other vegetation is mapped as being a low potential GDE and this typically aligns with eucalypt woodlands which are not typically considered to rely on groundwater. Wollombi Brook (but not Loders Creek or Monkey Place Creek) are mapped as being Aquatic GDEs.

The GDE Atlas does not include mapping of Subterranean GDEs in NSW. However, consistent with other studies in the Hunter Valley, stygofauna and hyporheic may be present in the alluvium but are not typically found in Permian aquifer systems.

f. identification of the source of groundwater potentially used by the EPBC-Act listed Warkworth Sands Woodland and whether it is connected to any other groundwater or surface water sources

The Warkworth Sands soils which support the WSWEC are thin deposits of Aeolian sands lying predominantly over low permeability Permian and weathered Permian rock. The groundwater systems within the Warkworth Sands are a perched groundwater system overlying low permeable weathered Permian strata. These groundwater systems and recharged almost entirely through rainfall with poor to no connectivity with the underlying Permian systems.

While the Warkworth Sands are assessed as disconnected from the modelled Permian layers, model results for the Proposed Modification suggest that no additional drawdown will occur in the Permian units immediately underlying these sands, as a result of the Proposed Modification. The model results, as well as the probable long-term presence of perched conditions, suggest that ongoing mining under the Proposed Modification scenario will not impact on groundwater conditions in the Warkworth Sands.

umwelt

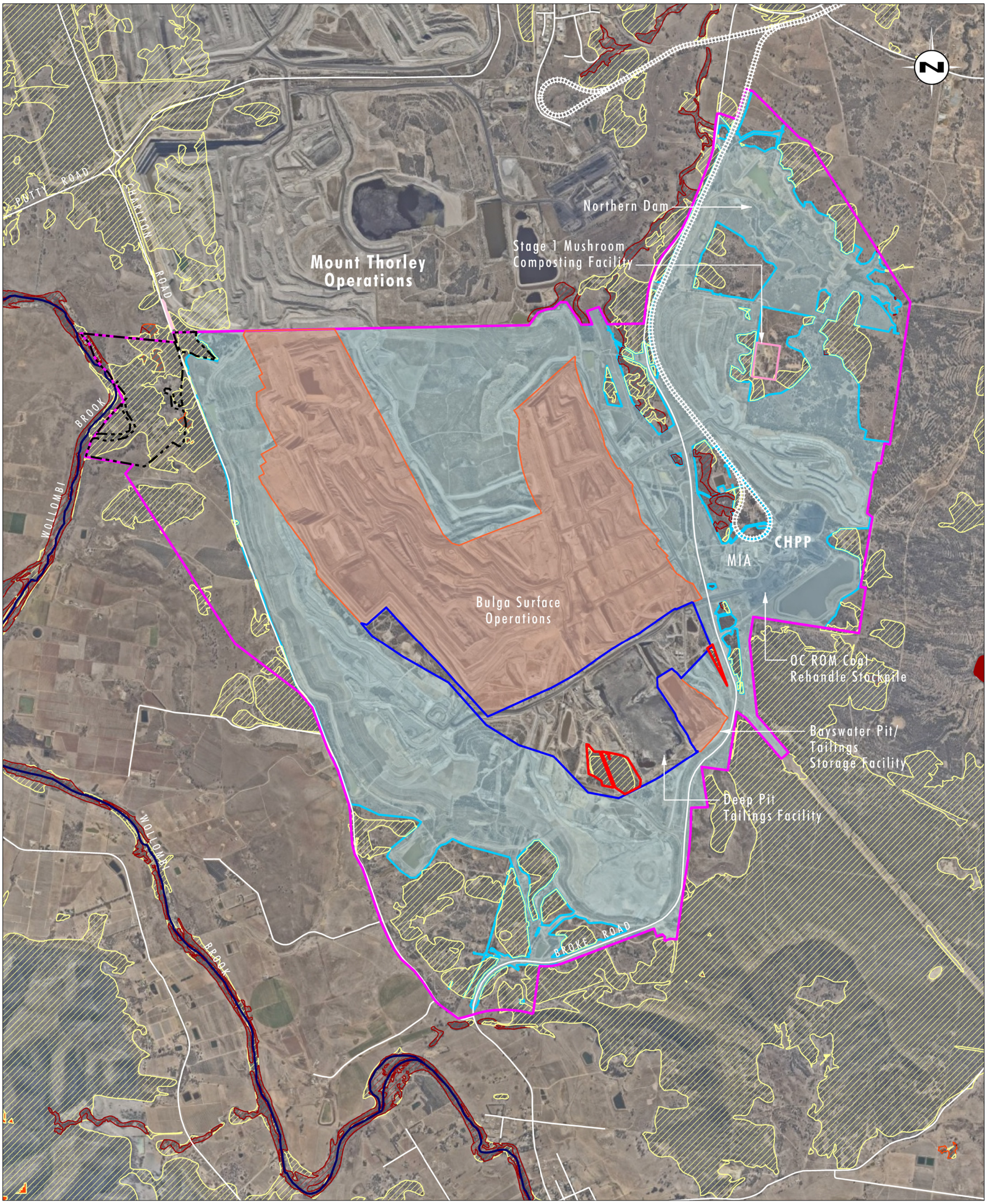

Image Source: Nearmap (Dec 2019)
Data Source: Bulga (2019), OEH (2018), BOM (2020)

0 1 2 3km
1:60 000

Legend

- Project Area
- Modification Additional Disturbance Area
- Current Disturbance Area
- Modification Additional Coal Extraction Area
- BOP Approved Mining Area
- Rail Line
- Wollombi Brook Conservation Area

Groundwater Dependent Ecosystems Atlas Mapping

Terrestrial GDE Mapping:

- High Probability Groundwater Dependent Ecosystem
- Medium Probability Groundwater Dependent Ecosystem
- Low Probability Groundwater Dependent Ecosystem

Aquatic GDE Mapping:

- Known GDE (Regional Study)

FIGURE 2.1

Mapped Groundwater Dependent Ecosystems Proximate to the Project Area

20200401 14.25R14/4100_227.dgn
20200408 12.56

g. groundwater quality data for potential contaminants (other than salinity) particularly in the Wollombi Brook alluvium

As outlined in **Appendix A**, the monitoring data up to the end of 2019 shows that the Wollombi Brook alluvial bores have a relatively stable water quality, largely driven by the surface water flows rather than by the adjacent Permian water quality. The monitoring data shows no trends of persistent increasing concentrations in measured water quality parameters (including salinity and sulfate).

This aspect is also discussed in more detail in **Section 2.3.5**.

2. In addition to the above, specific details of the changes in the proposed depth of mining and what coal seams will be mined as a result of the proposed deepening of the open cut pit are needed so the extent of the project is clear.

Cross-sections of the open cut pit are presented in **Figure 1.3** and **Figure 1.4** demonstrate the proposed deeper mining within the approved open cut pit and proposed extension.

Mining is approved to a depth of approximately 200 m below the original topography in the Main and East Pit Areas and approximately 350 m below the original topography in the South Pit Area to the base of the Broonie series (to approximately RL -270 mAHD).

The Proposed Modification aims to extract an additional coal seam down to the Bayswater seam. The maximum extraction depth will be approximately 400 m below the original topography in the South Pit Area (to approximately RL –320 mAHD).

2.2 Surface Water

Question 2: Are the assumptions used in the modelling reasonable and is there sufficient data within the model to provide meaningful predictions, including worst-case impacts on surface water?

3. The proponent states that the project will impact Wollombi Brook and Loders Creek through changes to catchment areas, and because of reductions in baseflow due to increased groundwater drawdown. The main changes include a reduction of the Loders Creek catchment by 397 ha and an increase in the Wollombi Brook catchment of 354 ha. Baseflow in Wollombi Brook is predicted to decrease by up to 1.38 ML/day (Engeny 2019, pp. 28-29). The proponent states that the assumptions used to assess baseflow impacts were conservatively high as all leakage from Wollombi Brook was assumed to be lost from the surface water system. However, this analysis does not consider the large uncertainty in the groundwater modelling relevant to baseflow impacts, nor the evident bias associated with under-prediction of Layer 1 groundwater levels (as discussed in Paragraphs 18, 19, 22 and 31).

It should be noted that the Surface Water Impact Assessment (Engeny, 2019) indicated that the 1.392 ML per day and 1.380 ML per day were predicted cumulative baseflow losses for the Approved Operations and Proposed Modification (respectively). These baseflow losses values reported have since been clarified by Umwelt and KCB as modelled flows within the alluvial aquifers.

The GIA (KCB, 2019) predicts that the leakage from the alluvial aquifers to the underlying Permian strata with the Proposed Modification are similar to the predictions for the Approved Operations. The groundwater model predicted slight decreases in discharge to natural drainages with the Proposed Modification. **Table 2.1** summarises the modelled groundwater contribution to creek flows in the drainage systems in the vicinity of the Project Area and summarises the modelled differences.

Table 2.1 Cumulative and incremental Impacts to Baseflow

Natural Drainage	Existing Conditions 1995-2018			Future Conditions 2039			
	10th Percentile Groundwater Contribution to Creek from Model Results (m^3/d)	Average Groundwater Contribution to Creek from Model Results (m^3/d)	90th Percentile Groundwater Contribution to Creek from Model Results (m^3/d)	Approved Project – Groundwater Contribution to Creek in 2039 (m^3/d)	Proposed Modification – Groundwater Contribution to Creek in 2039 (m^3/d)	Incremental Impact of Proposed Modification (m^3/d)	Cumulative Impact Relative to Existing Average (m^3/d)
Wollombi Brook (Beltana Reach)	1041	1616	2133	1392	1380	12	236
Wollombi Brook (Bulga Reach)	396	604	803	528	528	0	76
Lower Monkey Place Reach	335	457	590	389	382	7	75
Upper Monkey Place Reach	314	502	699	450	449	1	53
Loders Creek	30	34	37	31	31	0	3
Nine Mile Creek	32	45	54	14	9	5	36

With the exception of the predicted cumulative impacts on Nine Mile Creek, all modelled flows in 2039 are within the modelled variability over the calibration period. The existing modelled baseflows within both Loders Creek and Nine Mile Creek are extremely low and reflective of the ephemeral nature of these systems and limited alluvial/colluvial aquifer systems.

The upper Loders Creek catchment has been significantly impacted by mining over the past 30 years with much of the catchment above the confluence with Nine Mile Creek either removed or approved to be removed by approved mining. The Nine Mile Creek catchment also includes approved areas of disturbance associated with the BCC.

The lack of any cumulative additional impact on baseflows in Loders Creek is largely a reflection of this approved disturbance. The reduction in baseflows in Nine Mile Creek between the 1995 -2018 period and the predictive modelling phase is associated with predicted impacts from the Approved Operations mining the deeply dipping seams in the eastern areas of the approved mining operations. The Proposed Modification's small incremental impact on baseflows in Nine-Mile Creek (approximately 5ML/year) is associated with the continued mining of these seams further to the south.

While the cumulative impact on Nine Mile Creek represents a large percentage decline in baseflows, the overall reductions are small in the context of runoff related streamflow. This is discussed further in **Appendix B**.

Table 2.2 summarises the Proposed Modification's modelled incremental impact on baseflows relative to existing approved operations.

Table 2.2 Modelled incremental impact to baseflows

Natural Drainage	Future Conditions 2019 - 2039 10th Percentile Groundwater Contribution to Creek from Model Results (m^3/d)	Average Groundwater Contribution to Creek from Model Results (m^3/d)	90th Percentile Groundwater Contribution to Creek from Model Results (m^3/d)	Comment
Wollombi Brook (Beltana Reach)	12	19	26	Average incremental impact is <2% of modelled baseflows
Wollombi Brook (Bulga Reach)	0	0	0	No impact predicted
Lower Monkey Place Reach	-1	2	7	Average incremental impact is <2% of modelled baseflows
Upper Monkey Place Reach	0	0	2	Negligible impact
Loders Creek	0	1	1	Negligible impact
Nine Mile Creek	-4	2	6	Small impact predicted but significant variability in modelled impact from small increase to small reduction.

Modelling indicates that the Proposed Modification will decrease the rate of groundwater flow within Wollombi Brook by up to 0.012 ML/day (i.e. a <1% flow reduction) relative to the approved operations (i.e. 1,392 m^3/d to 1,380 m^3/d).

Appendix B includes an assessment of the cumulative and incremental impacts of mining and the Proposed Modification specifically on streamflow within Wollombi Brook and Monkey Place Creek. Cumulative impacts from mining are predicted to result in no additional days of no-flow within Wollombi Brook (Bulga Reach) and 4 additional no-flow days in Loders Creek. In practice, the predicted incremental impacts to baseflows associated with groundwater changes, even based on the 90th percentile predictions, will not be measurable and are likely to be within the modelling accuracy of the groundwater model.

As outlined in **Appendix B**, any material impacts to stream flows will be due to changes in catchment areas, as the groundwater model does not indicate any appreciable difference between the Proposed and Approved Operations over the modelling period. The modelled reductions in baseflows associated with the Proposed Modification relative to Approved Operations are considered unlikely to have any observable effect on refuge pools or aquatic flora or fauna that may rely on persistent pools or low stream flow. It is also noted that historically, Loders Creek is naturally saline (Heron et. al, 2018, Umwelt, 2013), and has few persistent pools within the channel. Loders Creek is also considered to offer low aquatic habitat quality. As was recognised in the *Impact and risk analysis for the Hunter subregion. Product 3-4 for the Hunter subregion from the Northern Sydney Basin Bioregional Assessment* (Heron et. al, 2018), the reduction in baseflow contribution from the Permian is likely to result in a slight improvement in water quality within Loders Creek due to reduced saline contribution from the Permian.

The changes to stream flows associated with catchment areas changes are described in Item 4 below.

4. The surface water assessment modelling concluded that the impacts on baseflows were negligible as they represent a reduction in flows of less than 1%. However, reporting baseflow decreases as a volumetric proportion of the average fails to recognise the potential impacts on ecologically important aspects of the flow regime (e.g. impacts on the frequency, duration and timing of low- and zero-flow periods). Analysis of the groundwater drawdown impacts indicates that baseflow decreases of 1.38 ML/day will increase the number of zero-flow days by around 50%. The timing and duration of these impacts is illustrated in Figure 1 (Attachment A of this advice), where it is seen that the nature of these impacts on the flow regime are of material concern. For example, longer periods of zero- and low-flows will affect the completion of life cycles by aquatic stages of stream biota and maintenance of refugial pools. Evapoconcentration due to reduced flows may further increase salinity.

As discussed above and in **Appendix B**, modelling indicates that the Proposed Modification will decrease the rate of groundwater discharges to Wollombi Brook by up to 0.012 ML/day (i.e. a <1% flow reduction). This is a change from the Approved Project impact rate of 1.392 ML/day to 1.380 ML/day with the Proposed Modification.

To provide further information on the potential nature that incremental and cumulative groundwater and catchment change impacts may have on the flow regime, an analysis of streamflow sequencing for Wollombi Brook and Loders Creek has been undertaken to identify potential impacts on the flow regimes, including low- and zero-flow periods (refer to **Appendix B**).

As discussed in **Appendix B**, the streamflow analysis and flow sequencing assessment for Wollombi Brook used flow data recorded at the Bulga gauge (210028) located adjacent to the BCC on Wollombi Brook. The analysis is presented in **Appendix B** and predicts negligible change in flows in Wollombi Brook as a result of catchment and baseflow changes associated with Proposed Modification. Modelling indicates that the predicted average annual dry days in Wollombi Brook (identified as days with flows less than 0.1 ML/day) is 85 days per year for both the Approved Operations and the Proposed Modification (refer to **Appendix B**).

The analysis indicates that there will be no change in streamflows or dry days with the Proposed Modification when compared to the Approved Operations. As such it is considered that there would be negligible impact on stream biota or water quality with the Proposed Modification.

Potential flow sequencing impacts of the Proposed Modification on streamflows in Loders Creek were analysed using a calibrated Australian Water Balance Model (AWBM) hydrologic model (refer to **Appendix B**). The flow sequencing analysis identifies that Loders Creek will likely be dry (i.e. flows less than 0.1 ML/day) on average four days more per year with the Proposed Modification (moving from 169 days per year to 173 days per year), however this represents a decrease relative to existing conditions under which it is calculated that there are approximately 184 dry days on average. The net impact on streamflow as a result of the Proposed Modification is observed in changes to the predicted average annual flow volumes in Loders Creek with a reduction from 3,606 ML/yr with the Approved Operations to 3,324 ML/yr with the Proposed Modification (refer to **Appendix B**). This reduction in flows is related to landform changes associated with the Proposed Modification rather than any increase in disturbance area within this catchment. The decline in flows in Loders Creek is similar to the modelled increase in annual flows to Wollombi Brook (also a result of landform changes).

As noted in the response above, the Nine Mile Creek/ Loders Creek catchments are already significantly impacted by approved mining operations at the BCC. Downstream areas of the Loders Creek catchment are also impacted by approved operations at the Mt Thorley Mine. Accordingly, the changes in impacts associated with flow changes are within the context of an already heavily disturbed system.

The analysis undertaken by Engeny indicates that there will be minor impacts on streamflows and dry days with the Proposed Modification when compared to the Approved Operations. As such, combined with the ephemeral nature of Loders Creek (i.e. the creek being dry on average nearly half the year), it is considered that the Proposed Modification would have only a negligible impact on any stream biota that may be present or water quality within Loders Creek.

5. The proponent presented flood modelling which suggests that there will be lower peak flows and reduced flood levels in Loders Creek due to the landform modifications over the life of the project (Engeny 2019, p. 36). The modelling is based on an approach and assumptions sometimes adopted for urban environments but which are not consistent with national flood guidance provided for rural catchments (Hill and Thomson, 2019). No attempt was made to relate flood estimates to nearby gauged catchments or other regional information. It is noted that the 1% Annual Exceedance Probability (AEP) flood estimate is around half the magnitude of the flood estimate based on regional flood information and only slightly higher than the corresponding lower 5% confidence limit (http://rffe.arr-software.org/). While the use of ARR87 procedures is reasonable for the purposes of assessing impacts *relative* to previously provided estimates, it does not provide a suitable basis for assessing *current* flood risks.

Other than some minor catchment changes, the Proposed Modification does not involve any changes that are likely to significantly increase flooding risks.

As discussed in **Appendix B**, the ARR 1987 Intensity-Frequency-Duration (IFD) data was used in the assessment of the Proposed Modification to enable comparison to previous models, as has been the accepted process for the approval of modifications for surrounding mines in the Hunter Valley. The purpose of the flood modelling undertaken in the *Surface Water Impact Assessment* (Engeny, 2019) was to assess the potential relative changes in flood risks of the Proposed Modification relative to existing Approved Operations. The flood modelling undertaken was based on the previously approved flood modelling, including the general modelling approach, assumptions, and parameterisation.

A comparison of the adopted ARR 1987 rainfall depths with the updated ARR 2019 rainfall depths is presented in **Table 2.3**.

Table 2.3 Comparison of ARR 1987 and ARR 2019 Rainfall Depths

Annual Exceedance Probability	AR&R 1987 Rainfall Depth (mm)	AR&R 2019 Rainfall Depth (mm)
39% AEP	59.76 (39% AEP/2 yr ARI)	57.5 (39% AEP/2 yr ARI)
5% AEP	103.68	97.9
1% AEP	139.2	134

The comparison identifies that the ARR1987 IFD provides greater rainfall depths and associated average rainfall intensities than the ARR2019 IFD for the modelled events. Accordingly, the flood modelling use of the ARR1987 data provides a conservative assessment for the Proposed Modification in regard to current flood risk and allows for comparison to previous assessments at the Bulga Coal Complex.

6. The sensitivity of flood impacts to climate change was assessed by reference to the difference between 0.5% and 0.2% AEP flood events, although the rationale and nature of the inferences to be drawn from this assessment are not explained. No consideration was given to assessing the impacts of climate change on rainfall intensity as discussed in national flood guidelines (Bates et al. 2019).

The use of the 0.5% AEP and 0.2% AEP storm events is identified by the NSW Government as a proxy for assessing climate variability. The assessment used ARR2016 IFD data, as these events are not published for ARR1987. This approach was undertaken to meet the NSW state government requirements.

The ARR1987 and ARR2019 design rainfalls do not include potential climate change effects. The recommended process for assessing the impacts of climate change in accordance with the ARR2019 Guidelines (Book 6, Bates et al. 2019) is to increase the rainfall (intensity or depth) by 5% per °C of predicted local warming (i.e. a temperature-scaling approach).

The adjusted climate change scenario rainfall depths (refer to **Appendix B**) for ARR2019 are smaller than the ARR1987 1% AEP base case. The base case modelling in the Surface Water Impact Assessment is therefore conservative in the prediction of climate change impacts, as the IFDs are higher than the design storm intensity under future climate change for ARR2019.

7. The flood modelling also did not consider potential impacts on the downstream environment from spills from the Northern and Surge Dams during high rainfall events (HEC 2019, Figures 31-33, p. 39). The IESC recommends a sensitivity analysis should be undertaken to assess the likely impacts of a range of rainfall events (including extreme events), and the potential for spillage post-mining by considering climate change. The influence of climate change on expected storage levels in these dams could be informed through the use of the Climate Futures Framework and Tools (Whetton et al. 2012) (https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/projections/) which allows for various climate regimes to be simulated.

The Proposed Modification will not change the Northern Dam, Surge Dam or their catchments or the design measures adopted for their operation. These storages have limited inflow catchment areas which are controlled through interception channels designed to divert storm runoff around the storages. These storages are operated as pumped storages, and as such maintain sufficient freeboard at all times to prevent over-topping. The storages may not exist post-mining unless alternate uses are approved, otherwise they will be decommissioned. There is very little influence of climate change on the storage levels in these dams as they are pumped storages, apart from potential changes to the frequency of their filling, which has been considered in the water balance modelling (HEC, 2019 & 2020).

In order to meet the pollution requirements of the *Protection of the Environment Operations Act 1997* (POEO Act), NSW Government approved water containment and design mechanisms are put in place at the BCC. As discussed in **Appendix B**, to meet the mine water design requirements, mine water dams, such as the Northern and Surge Dams, are maintained at operating water levels such that there is sufficient freeboard to contain the 1% AEP 24 hour storm event. Both dams have limited catchment areas and the dams can only discharge from the controlled release points (i.e. under the EPL and HRSTS).

Pumping to and from these storages can be managed to ensure sufficient freeboard is maintained ahead of any significant forecast rainfall events. Additionally, runoff can be stored within the mining voids if necessary, to avoid any discharges.

Over time, the operational rules applicable to these dams will have regard to the climate change associated changes in rainfall to ensure the general design criteria principles can be met. It is noted however that, with their limited catchments, climate change associated variability in rainfall is likely to only have a minimum influence on any changes to operational rules.

This is discussed further in **Appendix B**.

8. The site water balance modelling was based on the use of a well-accepted rainfall-runoff model (AWBM), and a reasonable level of agreement was obtained between model simulations and monitored storage levels. The site water balance considered three scenarios relating to underground operations: existing approved underground operations, delaying restart of underground operations until 2029 and no further underground operations. These scenarios considered climate variability through the use of 121 "climate realisations" which were based on 20-year periods that were successively shifted forward one year at a time over the full historic period. This approach to investigating the impacts of climate variability does not allow for projected changes in rainfall and temperature associated with climate change (Whetton et al. 2012).

Model predicted average inflows and outflows for the three modelled scenarios relating to underground operations with climate change factors applied, averaged over all 121 realizations and the 21 year simulation period, are shown in **Appendix C**. The methodology used for the assessment is set out in **Appendix C**.

The relative proportions of inflows and outflows shown in **Appendix C** are similar to those originally predicted (HEC, 2019). As outlined in **Appendix C** modelled climate change results in a forecast average reduction of approximately 300 ML/year in site runoff with a small increase of between 30 and 70 ML/year in the volume of water sourced from Hunter River Supply (WALs). Overall, this results in less water stored on site and, even with the increased evapotranspiration factors, this results in a decrease in average annual evaporation of between 20 to 30 ML/year. Lower site water inventory also results in approximately 150 to 200 ML/year less licensed HRSTS discharge. A slight increase in the average annual volume supplied for haul road dust suppression is predicted (approximately 30 ML/year) which is due to increased haul road demand associated with the use of the evapotranspiration factors.

Appendix C demonstrates that there is a 0.8% reduction in the forecast lowest CHPP supply reliability for the approved underground case but no discernible change in the forecast high average reliability of supply for the CHPP when RCP factors were applied. There is a 1.4% reduction in the forecast lowest haul road dust suppression reliability for the approved underground case and a 0.9% reduction in the forecast average reliability of supply for haul road dust suppression. Modelling with climate change continues to indicate an overall high predicted water supply reliability.

As concluded in **Appendix C**, the application of climate change factors to the calculation of site rainfall runoff in the operational water balance model results in a reduction in forecast site runoff volumes. This results in a predicted reduction in stored water inventory, supply reliability, licensed release and a slight increase in dust suppression demand and volumes sourced from Hunter River WALs. In the overall context of the water balance volumes, the forecast changes are small and within the bounds of historical climatic variability. Model forecasts continue to indicate a high predicted water supply reliability.

9. The proponent states that discharges from the Northern Dam and Surge Dam into the Hunter River may occur in accordance with their existing environment protection licence (EPL). However, the modelling predicts zero median discharge volumes until well after the end of tailings relocation, with up to approximately 2,000 ML/year median discharge in the last eight years of the proposed project (HEC 2019, p. 43). The proponent has stated that licensed discharges via the Hunter River Salinity Trading Scheme (HRSTS) may be required at times of higher rainfall to mitigate spill risk and control high water inventories. The IESC notes that the downstream impacts on aquatic and riparian ecosystems and impacts on water quality and flow as a consequence of the increase in discharge have not been fully considered by the proponent (discussed further in Paragraphs 10, 12 and 15).

10. The IESC considers that the proponent has not fully assessed the additive effects of altered water quality (caused by sporadic and uncontrolled discharges) and increased water take on aquatic, riparian and floodplain biota and ecological processes downstream. A comprehensive risk assessment of these impacts (including cumulative ones) is needed, along with reliable baseline data against which to judge the effectiveness of proposed mitigation and management plans.

Discharge to the Hunter River under the provisions of the HRSTS is currently permitted as part of the existing approved operations and no changes to this approved discharge facility are proposed as part of the Proposed Modification. The Proposed Modification will continue to discharge under the same arrangements using the already approved facilities, and will not result in sporadic or uncontrolled discharges from the major storages.

The HRSTS is designed for the effective protection of waterways. In maintaining discharges in accordance with the HRSTS and EPL, there will be no additional downstream impacts on aquatic and riparian ecosystems or impacts on water quality and flow as a consequence of the Proposed Modification. Potential impacts on stream bank stability associated with approved discharges was assessed as part of the approval process for the existing approved operations.

The Proposed Modification is not predicted to result in any change in water quality in terms of TSS, salinity or metals and anions relative to existing approved operations.

The *Surface Water Impact Assessment* (Engeny, 2019) for the Proposed Modification predicted changes to flow regimes both during and following the mining operations associated with the Proposed Modification to be negligible on Wollombi Brook and also on a regional scale, i.e. Wollombi Brook and Loders Creek flows into the Hunter River regulated river system.

The Water Balance Assessment (HEC, 2019) undertaken for the Proposed Modification was informed by both the Groundwater Impact Assessment (KCB, 2019) and the Surface Water Impact Assessment (Engeny, 2019) and has not identified an increase in sporadic or uncontrolled discharges from sediment control dams. These dams will continue to operate as currently designed and approved, and will only discharge water under conditions that exceed their specific design criteria, at which time there will be significant other runoff occurring in the receiving catchments, as per current approvals. The Proposed Modification is not predicted to result in any measurable change to the currently approved surface water management system outcomes.

Further discussion on this issue is set out in **Appendix C**.

11. The proponent has not adequately modelled potential impacts of the final void in the rehabilitated landscape, including worse-case impacts on surface water. These include long-term impacts on surface water and groundwater quality (particularly salinity). More detail is needed on the range of possible rates of water level recovery (cf. KCB 2019, Figure 4-12, p. 71) to improve assessment of legacy impacts. Further information on the salt balance of the site and salt sources and stores within the final landform should be provided by the proponent (discussed further in Paragraphs 16 and 25).

A final void water and salinity balance model was prepared for the Proposed Modification and included as Appendix 11 of the SEE.

Model results indicate that the final void water body would reach an equilibrium level approximately 120 m below spill level. The equilibrium level would be reached very slowly over a period of several hundred years. Groundwater outflow would occur in the longer term at a rate of up to 0.3 ML/d. Final void salinity levels would increase slowly as a result of evapo-concentration, however are expected to be approximately 6,000 uS/cm after 200 years of recovery and approximately 13,000 µS/cm after 1,000 years.

The final void will not spill, therefore no impacts to surface water are predicted in the rehabilitated landscape.

Question 3: To what extent can decision makers have confidence in the predictions of potential impacts on surface water resources provided in the SEE, including in regard to potential stream flow losses, water quality, discharges and flooding?

12. The proponent considers that the changes to flow regimes associated with the proposed project will be negligible in Wollombi Brook as well as at a regional scale in relation to flows from Wollombi Brook and Loders Creek into the Hunter River (Engeny 2019, p. 36). As noted in Paragraph 3, the proponent has not considered changes to ecologically important flow components, and thus it is not possible to fully assess the potential impact of this on GDEs and aquatic biota and ecological processes in Wollombi Brook, Loders Creek and Nine Mile Creek. In particular, the proponent has highlighted potential changes to baseflow and reduced saline Permian groundwater leakage into the alluvium in Wollombi Brook. Further analysis is needed as to how changes in surface water regimes and groundwater availability could affect the presence of the following EPBC Act-listed communities: Coastal Swamp Oak (*Casuarina glauca*) Forest (endangered), White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (critically endangered) and the Central Hunter Valley Eucalypt Forest and Woodland (critically endangered).

As discussed for comment 3 above, the groundwater model does not indicate any significant difference in impact on base flows between the Proposed Modification and Approved Operations over the modelling period. An analysis of 10^{th} and 90^{th} percentile predicted impacts on baseflows attributable to the Proposed Modification (i.e. relative to Approved Operations) (refer to **Table 2.2**) indicates a tight range within the model variability. This is not unexpected given the long history of monitoring which indicates poor connectivity between Permian and Alluvial aquifer systems.

Predicted impacts on refugia, low flow conditions and riparian vegetation associated with groundwater impacts are considered to be unlikely and not observable within the context of natural variability.

Accordingly, any impacts to predicted streamflows (and associated) baseflows are effectively limited to runoff changes associated with changes in catchment areas.

To provide further information on the potential nature that incremental and cumulative groundwater and catchment change impacts may have on the flow regime, an analysis of streamflow sequencing for Wollombi Brook and Loders Creek has been undertaken to identify potential impacts on the flow regimes, including low- and zero-flow periods (refer to **Appendix B**). The analysis indicates that there will be no discernible impacts on streamflows or dry days with the Proposed Modification when compared to the Approved Operations. As such it is considered that there would be negligible impact on stream biota or water quality with the Proposed Modification.

As discussed in **Section 2.0**, the Project Area has a long history of coal mining. The additional disturbance area includes an area of 16.4 ha of *Central Hunter Valley Eucalypt Forest and Woodland* listed under the EPBC Act which will be directly impacted by the Proposed Modification. This community, which occurs more broadly around the Project Area, is not considered to be a GDE, and is unlikely to be significantly affected by changes in groundwater.

The Central Hunter Swamp Oak Community within areas of Loders Creek below 50 m ASL may conform with the Coastal Swamp Oak Forest EEC. As identified in **Appendix A** and **Appendix B**, the Proposed Modification is not predicted to have any incremental groundwater related impacts on baseflows within Loders Creek itself. All potential areas of this community within Wollombi Brook are limited to a small section of the Brook within 1.5 km of the Hunter River (up to 50 m ASL) and well outside the area of predicted impacts on groundwater associated with the Proposed Modification.

The analysis of stream flows within Loders Creek (refer to **Appendix B**) indicates the Proposed Modification will have only minor impacts on stream flows and dry days in Loders Creek. These impacts are considered unlikely to have a significant effect on the Hunter Swamp Oak Community due to its ability exist in ephemeral creek systems with substantially lower flow conditions than are modelled for Loders Creek.

The White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland CEEC is not present within the area of predicted groundwater or surface flow impacts (Umwelt 2013).

Potential impacts on the WSW CEEC are discussed further in response to Comment 29.

The predicted impacts associated with the Proposed Modification are negligible in terms of the existing and approved impacts from a groundwater and surface water perspective. As such, the Proposed Modification is not anticipated to significantly impact on the surface water regimes and groundwater availability of EPBC Act listed communities.

13. The proponent has presented monitoring data for pH, EC (electrical conductivity) and TSS (total suspended solids) which are monitored under their EPL. Future monitoring should include a broader suite of analytes such as sulfate, metals and metalloids for all current surface water monitoring sites, and should include new sites in Loders Creek, downstream from licenced discharge points. Discharges are likely to contain a number of metals and metalloids which have the potential to adversely affect biota. The proponent should also provide water quality data for water used in dust suppression.

BCM monitor surface water quality in accordance with the NSW Government and EPBC approved Bulga Coal Water Management Plan (WMP) (Approved 2017). As discussed in the Surface Water Impact Assessment (Engeny, 2019), this program includes monthly monitoring of pH, TSS, EC and flow conditions, at various upstream and downstream locations on the creeks affected by BCC operations. This includes future monitoring of additional locations on Loders Creeks downstream of the HRSTS discharge point. Historical monitoring indicates licensed discharges are generally neutral to slightly alkaline which limits the mobilisation of metals. The Geochemical analysis undertaken for the Bulga Optimisation Project (EGi 2012) indicates a high degree of confidence that runoff from overburden will remain neutral given the high presence of buffering material present in overburden material. This assessment remains relevant to the extension of mining contemplated in the Proposed Modification.

Monitoring at EPL licensed discharge points (LDP) is summarised in **Appendix B**. Monitoring is undertaken in accordance with the EPL and meets the requirements of the NSW EPA under the *Protection of the Environment Operations Act 1997* (POEO Act). BCM is committed to continue meeting these monitoring requirements.

The WMP does not currently commit BCC to monitoring of a broader set of analytes including sulfate, metals and metalloids. In addition to the existing monthly monitoring program, BCC will implement further speciation analysis at existing and future monitoring locations on a 6 monthly basis. The speciation analysis will include the following:

- pH, TSS, EC in accordance with monthly monitoring
- Total Metal/Metalloids: Aluminium (Al), Arsenic (As), Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Selenium (Se), Zinc (Zn), Mercury (Hg), Lead (Pb), Potassium (K), Silver (Ag), Fluoride (Fl), Boron (B), Calcium (Ca), Barium (Ba), Magnesium (Mg), Cadmium (Cd), Sodium (Na)
- Nutrients: Total phosphorous (P), Nitrite, Nitrate, Total Kjeldahl Nitrogen (TKN), Total Nitrogen (Total N)
- Ions: Chloride (Cl), Bicarbonate (CaCO3), Sulphate (SO4).

More frequent sampling of analytes other than pH, TSS and EC is not considered warranted based on the geochemical assessment of material being mining and handled at the BCC unless significant variations in pH levels are observed in intervening sampling periods.

14. The proponent has stated that there is the potential for mining to be disrupted over time due to excessive volumes of water stored in the open cut voids (HEC 2019, p. 37). Consequently, the proponent has outlined a site water storage strategy which includes discharging excess water to underground goafs and the Hunter River through the HRSTS. Limited information has been provided on the volumes, quality and timing of releases of this excess water. Further information on the quality of the water and potential for interactions with the goaf material should be provided. Monitoring of the water quality of all water subject to controlled discharge should occur prior to discharge.

As discussed in **Appendix B** and the Surface Water Impact Assessment (Engeny, 2019), the Approved Operations and the Proposed Modification exist within a well-regulated system that has been designed to provide for the sustainable management of the State's water resources. This includes licensing of allowable water take with consideration of environmental flow requirements of watercourses and the needs of other water users. It also includes control of water pollution, incorporating management of sustainable salt loads associated with all water sources, including mine water discharges; and guidelines that govern the appropriate design of water management systems for mines to provide for appropriate water quality in accordance with EPL requirements.

The ability to discharge from the Northern Dam and the Surge Dam to the Hunter River is already part of the existing Project Approval, licensed under EPL 563 and managed in accordance with the HRSTS. The Proposed Modification will continue to discharge under the same arrangement in accordance with the HRSTS rules.

The volumes of water proposed to be released in accordance with the HRSTS and the provisions of EPL 563 are summarised in the SEE and in **Appendix C**. Timing of releases would be in accordance with high or flood flow events in the Hunter River as prescribed by the HRSTS as well as the need to discharge from the site water management system (refer to **Appendix C**).

The Proposed Modification will not require any alteration to the existing regulatory or licensing arrangements for discharges under the EPL or the HRSTS. All discharges are monitored and must meet the relevant EPL criteria including HRSTS requirements in relation to salinity.

Storage of water within underground goafs is in line with the existing Project Approval. Water pumped into the goafs will only occur in areas where these former workings will eventually flood through groundwater inflows. The storage of water in these workings will therefore enhance recovery of the groundwater systems in these areas. The storage of water in the goafs is not expected to result in any adverse impacts on water quality relative to groundwater inflows to these workings which is occurring as a result of existing approved underground operations. No releases are proposed from the underground goaf water storages directly to water courses. Releases would predominantly occur from the Northern Dam.

Forecast salinity in the Northern Dam for the mine case of no further underground operations is shown in **Appendix C**.

15. The proponent has highlighted that, under the new water management system, there will be discharges from the Northern Dam and Surge Dam (HEC 2019, pp. 12-14). As noted in Paragraph 7, the potential impacts from controlled and uncontrolled discharges (spills from dams overtopping during high rainfall events) are not discussed. Any impacts from discharge into the Hunter River will be cumulative with existing impacts from agriculture and mining, and these potential impacts should be assessed in the context of current and future monitoring. The IESC notes that the HRSTS is intended to manage impacts from salinity but not other contaminants. The proponent should provide a detailed assessment of all potential impacts from discharges, including from metal contaminants and cumulative impacts. This assessment should include expected quantity, quality, frequency and timing of discharges, together with assessment of the likely impacts and any proposed mitigation measures (such as water treatment). As discharges may present an ongoing local erosion risk, the potential impacts of this on downstream water quality also require consideration.

As noted above in relation to Comment 10, the Project does not involve any change to the operation of the Northern Dam or Surge Dam in terms of their operations or allowable discharge volumes. These controlled discharges from the Northern Dam and Surge Dam have previously been approved, are licensed under EPL 563 and managed in accordance with the HRSTS. The Proposed Modification will continue to discharge under EPL 563 and in accordance with the HRSTS. The Proposed Modification will not present any additional erosion risk relative to existing approved operations.

Controlled discharge from the Northern Dam and Surge Dam via the HRSTS will comprise a very small component of the flow in the Hunter River (as governed by the discharge rules of the HRSTS) and dilution will be substantial. As discussed in **Appendix C**, water balance model results (HEC, 2019) and Figure 11 to Figure 13 in **Appendix C** provide forecast annual release volumes. The forecast median annual controlled discharge volume varies from zero to 2,003 ML. This compares with a median annual flow recorded in the Hunter River at Singleton of 419,616 ML, meaning the forecast maximum median discharge represents less than 0.5% of the recorded median annual river flow. Similarly, **Appendix C** indicates a 90th percentile annual controlled discharge volume of between 257 and 6,614 ML. This compares with a 90th percentile annual flow recorded in the Hunter River at Singleton of 1,653,443 ML, meaning the forecast 90th percentile discharge represents between 0.02 and 0.4% of the recorded 90th percentile annual river flow.

The above illustrates that any contaminants present in the Northern Dam and Surge Dam at the time of controlled discharge would be highly diluted by flow in the Hunter River.

As discussed in **Appendix C**, the risk of uncontrolled discharge from the Northern Dam and Surge dam is extremely low. Both have limited catchments and receive water primarily through pumping from the pit or sediment dams. These dams are operated with significant freeboard volume (more than 500 ML for the Northern Dam and 200 ML for the Surge Dam). In the event of significant rainfall events water would be retained in the in the open cut pits rather than being pumped to these storages where there is a risk of uncontrolled discharges. If, however, an uncontrolled discharge was to occur, modelling indicates that only small volumes of spill from these two dams would occur during rainfall events which exceed the 1% AEP design criteria (e.g. an event similar to the June 2007 recorded high rainfall event (the 'Pasha Bulker' event)); the volume of uncontrolled discharge during this event was modelled as 71 and 4 ML from the Northern and Surge Dams respectively. These discharges are effectively caused by direct rainfall into the storages exceeding the freeboard volume. In the context of flow in the Hunter River during such a flood (e.g. approximately 563,000 ML recorded at the Singleton gauge in June 2007) such small volumes of discharge are trivial and would have no discernible impact on water quality in the Hunter River.

16. The proponent needs to include analysis of the evolution of salinity and water level in the final void. This information is key for understanding the potential risks posed by the void should it spill or leach. The analysis should use relevant predictions from the project's surface water and groundwater modelling.

A final void water and salinity balance model was prepared for the Proposed Modification and included as Appendix 11 of the SEE.

Modelling indicates that the water level rising slowly to equilibrium over several hundred years but remaining well below the void spill level at equilibrium. The salinity is forecast to slowly rise with time, reaching an EC value of approximately 13,000 µS/cm after 1,000 years.

2.3 Groundwater

Question 4: To what extent can decision makers have confidence in the prediction of potential impacts on groundwater resources provided in the SEE, including in regard to groundwater inflows, potential impacts on private bores, change in flux to the Hunter River, Monkey Place Creek and Wollombi Brook Alluvium and salt balance?

17. Confidence in the predictions of potential impacts on groundwater resources relies entirely on the adequacy of the groundwater model design, history-matching and uncertainty quantification. The paragraphs below describe the IESC's concern about the groundwater model and outlines work that should be undertaken to improve confidence in the predictions of potential impacts.

Noted.

2.3.1 Limitations of the groundwater model

18. The proponent notes that currently the alluvium is not represented in detail in the groundwater model because the model is intended to predict impacts on Permian aquifers (KCB 2019, p. 68). The IESC considers this to be a significant limitation severely reducing confidence in the predicted impacts of groundwater drawdown within the alluvial aquifers. The history-matching hydrographs provided for Layer 1 of the groundwater model, which include the alluvial aquifers, indicate bias as the modelled hydrographs are unable to replicate the observed variability and systematically under-predict groundwater levels. As a result, the current groundwater model has limited application for predicting impacts to the alluvial aquifer, GDEs and baseflow changes. The groundwater model requires further work including improved representation of the alluvial aquifer and should be history-matched with field data to provide confidence in predicted impacts.

There are three general hydrogeological systems across the BCC Project Area:

- alluvial aquifers associated with the Monkey Place Creek and Wollombi Brook which overlie Permian strata and wrap around the south and west of the main mining area
- Warkworth Sands Woodlands (WSW), adjacent to the west of the existing operations and the Mount Thorley open cut mines. This system is interpreted as perched, positioned over lower permeable Permian and not in hydraulic connectivity with the underlying groundwater system
- the Permian coal measures of the Singleton Super Group which host the mined resource and represent outcrop in all areas where regionally mapped alluvium is absent (low yielding, confined aquifers).

As outlined in **Appendix A**, the alluvium of the Wollombi Brook and Monkey Place Creek are well instrumented, with 11 and 5 piezometers in each aquifer respectively, all with relatively intact records showing good correlation to the Wollombi Brook flow elevation. In the Beltana mining area, coverage is relatively dense along the western margin of the mine footprint where it spatially approaches the edge of the alluvium. The distribution of monitoring in the area of drainage from Monkey Place Creek to Wollombi Brook also indicates that this is portion is well-instrumented.

This network is extensive and is considered adequate for verification of hydrogeological concepts and model calibration purposes (KCB, 2020). Depending on the location and depth of monitoring, and the timing of data collection, Permian strata have observed significant response to mining development, of the scale of 10's to 100's of metres. This is in contrast to the response of the alluvium which is more strongly aligned with creek flow (and possibly local alluvial abstraction), which only observe metre to sub-metre scale vertical variations of groundwater level.

The two systems are therefore assessed as having poor connectivity and are effectively hydrogeologically disconnected.

Appendix A concludes that the consistency between the conceptual understanding and model representation suggest that the numerical model is appropriate and fit for purpose to assess the incremental impact on the groundwater environment from the Proposed Modification (in comparison to the Approved Operations).

Mining impacts, which are predicted to continue to be small consistent with the current monitoring data, appear in localised areas of the alluvium and are the consequence of the Approved Mining activities. The Proposed Modification does not appreciably change groundwater conditions in the mapped alluvial areas, compared to the Approved Mining scenario.

19. The history-matched hydrographs provided by the proponent highlight that in many layers simulated and observed heads vary considerably (sometimes by greater than 50 m). Discussion of the history-matching results was limited and focused primarily on the improvement between model versions rather than providing an analysis of potential causes for the observed mismatches. Additionally it was stated that there were limited data available for history-matching (KCB 2019, p. 53) though this was not explained. It also appears that not all available data were used for history-matching, for example, groundwater inflows to the mine do not appear to have been used as a direct history-matching target in the groundwater model. The proponent compared predicted mine inflows from the current model with those calculated in a previous version of the groundwater model (KCB 2019, p. 54) rather than providing a comparison to measured inflows. Further discussion and analysis is required of the data used for history-matching and how groundwater model predictions compare to observations to provide confidence in the ability of the groundwater model to predict impacts to important environmental assets such as the Wollombi Brook alluvium, surface waterways and GDEs. Further monitoring of the groundwater levels in the alluvium is recommended to provide more relevant data for history-matching.

Matching of the modelled predicted levels to available observed data has been provided in **Appendix A** as a summary of the model calibration (KCB August 2019). The anomalies between observed and simulated heads is considered to be largely a function of a difference in timing between simulation time steps and mining operations and is limited to the Permian. Examples of other potential causes for these inconsistencies include dewatering activities or underground roadway construction occurring ahead of modelled mining activities. The impact on the alluvial predictions is not significant.

KCB extracted transient monitoring points across all bores in the calibration period (up to 2018); and achieved a normalised RMS error of 10% focussed on the Permian mining sequence. This suggests that the model better replicates late-time observations; that is observations that are not as influenced by mining stress mis-timings; and represents a considerable improvement on previously reported values, used for the Approved Operations (refer to **Appendix A**).

Appendix A provides a visual comparison of modelled versus observed data for the entire transient data set used. A comparison is also shown that provides a subset of this information focussed on late calibration period (2018 data). This improvement supports the use of the "end of calibration period" modelled state for use as the initial state groundwater environment for use during predictive simulations.

As discussed in **Appendix A**, since the modelling was focussed on the potential incremental change to the groundwater regime (i.e. additional changes to the groundwater system in addition to the already-approved case), the focus for calibration remained on obtaining a good match to observed groundwater responses in the Permian layers, aligning measured mining flows to the modelled values and improving the calibration of the model when compared to the approved case.

20. The IESC considers confidence in impact predictions could be further increased by undertaking additional sensitivity and uncertainty analyses (Middlemis and Peeters 2018). The reported sensitivity analysis only varied specific yield. It is unclear which parameters were varied in the uncertainty analysis, whether the model used in the uncertainty analysis was constrained by history-matching (noting it was not the current model) and what prior parameter distributions were used. The additional analyses should be used to identify which parameters have the greatest influence on impact predictions under a range of plausible parameterisations and rainfall scenarios. These analyses are needed to assist understanding of how the groundwater model limitations affect impact predictions. Once the likely range of potential impacts is established, the proponent should undertake further work to identify any additional management measures required to address the range of impacts.

As part of the model construction, and calibration process, sensitivity and uncertainty analyses were completed for the model (refer to **Appendix A**).

As discussed in **Appendix A**, the uncertainty analysis approach broadly followed the Explanatory Note, Uncertainty Analysis in Groundwater Modelling from the IESC (Middelmis and Peeters 2018), with the approach used for the BCC consistent with the more advanced “stochastic modelling with Bayesian probability” approach outlined by the IESC note. The modelling also considered uncertainty as an integral part of the model development and assessment of results; and included the input of the external model peer-reviewer to assist in framing the approach.

A suite of sensitivity analysis was completed for three specific runs, being variants of spoil recharge and spoil hydrogeological conditions, aimed at understanding the potential changes these may have on prediction of interactions between alluvium and Permian strata; and on potential groundwater derived baseflow discharge in mine proximal creeks. The three scenarios were:

- SA1 - Spoil Kh = 1 m/day; Spoil Kv = 0.1 m/day; Recharge factor = 1% of daily rainfall
- SA2 - Spoil Kh = 0.05 m/d; Spoil Kv = 0.05 m/d; Recharge factor = 5% of daily rainfall
- SA3 - Spoil Kh = 0.1 m/d; Spoil Kv = 0.01 m/d; Recharge factor = 2% of daily rainfall.

In addition, a non-linear, Monte-Carlo methodology was applied for the uncertainty analysis (refer to **Appendix A**). This methodology allows a suite of models, which collectively include the plausible range in key input parameters, to be run so that the range of outcomes can be obtained from the suite of models. A total of 360 model runs were completed.

KCB indicate that, in general, the uncertainty analysis has shown that there is the potential for slight groundwater level drawdowns in the alluvium segments of the Wollombi Brook (Bulga Reach) (refer to **Appendix A**). The range of predicted drawdowns in these segments is localised and indicates a relatively high level of confidence with similar predictions made by the cumulative case predictive model.

In the case of Nine Mile and Loders Creeks, uncertainty analysis shows that there is generally potential for groundwater levels to decrease or rise at nearby points that potentially translate as decreased or increased baseflows.

A total of 96 parameters were adjusted during calibration and include Kh, Kv, Ss, Sy and Recharge factors (refer to **Appendix A**).

The process of automated calibration has resulted in the estimation of all parameters in an unbiased sense, importantly this includes storage parameters. Visual comparison of previous models can be used as a general indicator of the changes made to the simulation. These show:

- improved root mean square (RMS) of the KCB model over that of the previous models
- similar overall mine production rates
- head predictions are similar for the calibration period for the models used for previous approvals
- late calibration time (2018) which represents starting conditions for the transient model observed improved calibration performance statistics of less than 23.5 m RMS error and 8.7% normalised RMS.

BCM will include additional groundwater monitoring as part of future environmental management plans for the sites and in the north/northwest associated with the TSF. Data collected from these additional points (including assessments of aquifer parameters and vertical gradients/separation between units) will be used to update the model once these are in place. To confirm the current conceptual understanding and to further bolster the data set used for modelling to date.

KCB indicate that these future model updates will include further assessment of uncertainty, however based on the site monitoring and the small incremental impact predicted to arise (from the comparison of the Approved Operations and Proposed Modification cases), this uncertainty assessment is expected to refine the understanding rather than indicate a large-scale impacts. Should the approved underground areas go ahead, additional monitoring around these is expected to provide data to further refine the understanding around the mining area.

2.3.2 Bores

21. The proponent has identified that there are no privately owned registered bores located within the predicted 2-m drawdown contour. The IESC notes that the range of uncertainty in drawdown has not been clearly presented in the assessment documentation. The results of the uncertainty analysis should be presented as drawdown contours at a range of likelihoods (Middlemis and Peeters 2018) so that decision-makers can have confidence that no privately owned bores are likely to be impacted by the project.

As discussed in **Appendix A**, Montel Carlo analysis on 360 model cases was undertaken. The results of the uncertainty analysis previously provided in the GIA are presented in **Appendix A** as histograms, using common scale axes, and presented as a percentage of successful runs versus drawdown variance at the eight locations (refer to Figure 18 in **Appendix A**) and the summary of results is provided in Figure 19 of **Appendix A**.

In general, the uncertainty analysis has shown that there is the potential for slight groundwater level drawdowns in the alluvium segments of the Wollombi Brook (Bulga Reach). The range of predicted drawdowns in these segments is localised and indicates a relatively high level of confidence with similar predictions made by the cumulative case predictive model.

2.3.3 Change in flux to surface waters

22. The proponent notes that the groundwater model is intended primarily for impact prediction in the Permian aquifers, and that the alluvium is not included in detail in the groundwater model (KCB 2019, p. 68). Consistent with this, the IESC notes that the shallow groundwater level dynamics were not represented well within the model, which has implications for the reliability of predictions and long-term drawdown impacts on the shallow alluvium. This reduces confidence in predictions of flux to surface waters including the Hunter River, Monkey Place Creek, Wollombi Brook and their associated alluvial aquifers (and GDEs). While some uncertainty analysis has been provided to aid understanding of how the project may change flux to surface waters, further comprehensive uncertainty analysis and presentation of the results incorporating likelihoods are needed (Middlemis and Peeters 2018). These should include a description of the prior parameter distributions used in the uncertainty analysis. Given the known high connectivity between some surface waters and the groundwater, the potential for changes to groundwater levels, flux and quality to impact GDEs and aquatic biota, plus the dependence of agriculture on surface water and alluvial groundwater, it is important to understand variability in flux under a range of plausible hydraulic parameterisations and different climate and rainfall scenarios.

As outlined in the responses to comments 1, 3 and 18, there is a robust data set of monitoring to indicate that the groundwater responses in the alluvial aquifers are strongly tied to the surface water flows and that these alluvial systems have poor hydraulic connectivity to the adjacent Permian units. This is demonstrated in both the regional contours, the difference in hydraulic response for bore pairs located in different units and in the response of individual alluvial bores.

Further examples of these differing responses can be shown by considering the most recent data for the various sets of dual piezometers which confirm this differentiated response.

Assessments of potential worst case changes to surface flows have been provided as part of the groundwater modelling (refer to **Appendix A** and the response to Comment 3 above). Since the focus of the modelling was to provide an assessment of the potential impact of the Proposed Modification relative to existing approved operations, detailed modelling of the surface water/alluvial interactions under variable surface water flow conditions was not considered pertinent to consider for the Proposed Modification. These changes would occur at a temporal scale that is far more rapid than the mining-associated groundwater level changes (refer to Figure 2 in **Appendix A**) and the changes in alluvial conditions would be influenced more strongly by surface flow and climatic influences.

23. To investigate how changes in flux may impact water-dependent ecosystems, the proponent should provide ecohydrological conceptual models. These models should include potential changes to flow regimes (e.g. frequency, duration and timing of low- and zero-flow periods) and how this could impact biota, including through changes in refugial pool persistence. At a minimum, ecohydrological conceptual models should be developed for:

a. the potential impacts to ephemeral streams and Wollombi Brook; and,

b. the Warkworth Sands Woodland CEEC to show how the perched aquifer and associated GDEs may be affected by the project.

Several conceptual sections are provided in **Appendix A** which provide an indication of the relative rates of exchange that may be possible for each of the reaches. For consistency, the same creek reaches as reported on previously (Beltana Reach of Wollombi, Bulga Reach of Wollombi, Lower Monkey Place, Upper Monkey Place, Loders Creek and Nine Mile Creek) have been simplified to conceptual sections that indicate the relative flow exchanges for the Approved Operations case and the comparison to the Proposed Modification case.

Refugial pools within Loders Creek and Mine Mile Creek are almost certainly associated with ephemeral flows collecting within shallow depressions in the channel. These pools have limited persistence and their persistence is considered likely to have little to no association with groundwater systems.

Persistent pools within Wollombi Brook and the lower reaches of Monkey Place Creek are likely to be surface expressions of the water table within the alluvium. Impacts on the persistence of these pools is considered more likely to be associated with changes in groundwater levels around the pools rather than any direct inflows or outflows from the pools themselves. Figure 11 from **Appendix A** is reproduced in **Figure 2.2** and shows the areas and magnitude of predicted maximum drawdown within the alluvium. As can be seen from **Figure 2.2**, there is little to no predicted drawdown below the channel of Wollombi Brook or the lower reaches of Monkey Place Creek indicating that the Proposed Modification is unlikely to have any effect water levels with persistent pools. Similarly, these predicted drawdown impacts are unlikely to have any significant effect on riparian vegetation along Monkey Place Creek.

The response to Comment 1 contains further discussion regarding the Proposed Modifications interactions with any perched aquifers that may be present with the Aeolian sands associated with the Warkworth Sands Woodlands.

The modelled predicted drawdown and reduction in baseflows is considered unlikely to have any observable impact on stygofauna or hyporheic fauna within impacts systems given their existing tolerance to large natural variability within water tables and baseflows. The areas of predicted drawdown within the Wollombi Brook and Monkey Place Creek alluvium do not result in any areas becoming isolated or drying or becoming unsaturated with contiguous saturated areas available for refuge and recolonisation.

The Proposed Modification is not anticipated to have any direct or indirect impact on the WSWEC. Further information on the condition monitoring and the relationship between the Proposed Modification with mapped WSWEC is provided in **Appendix D**.

umwelt

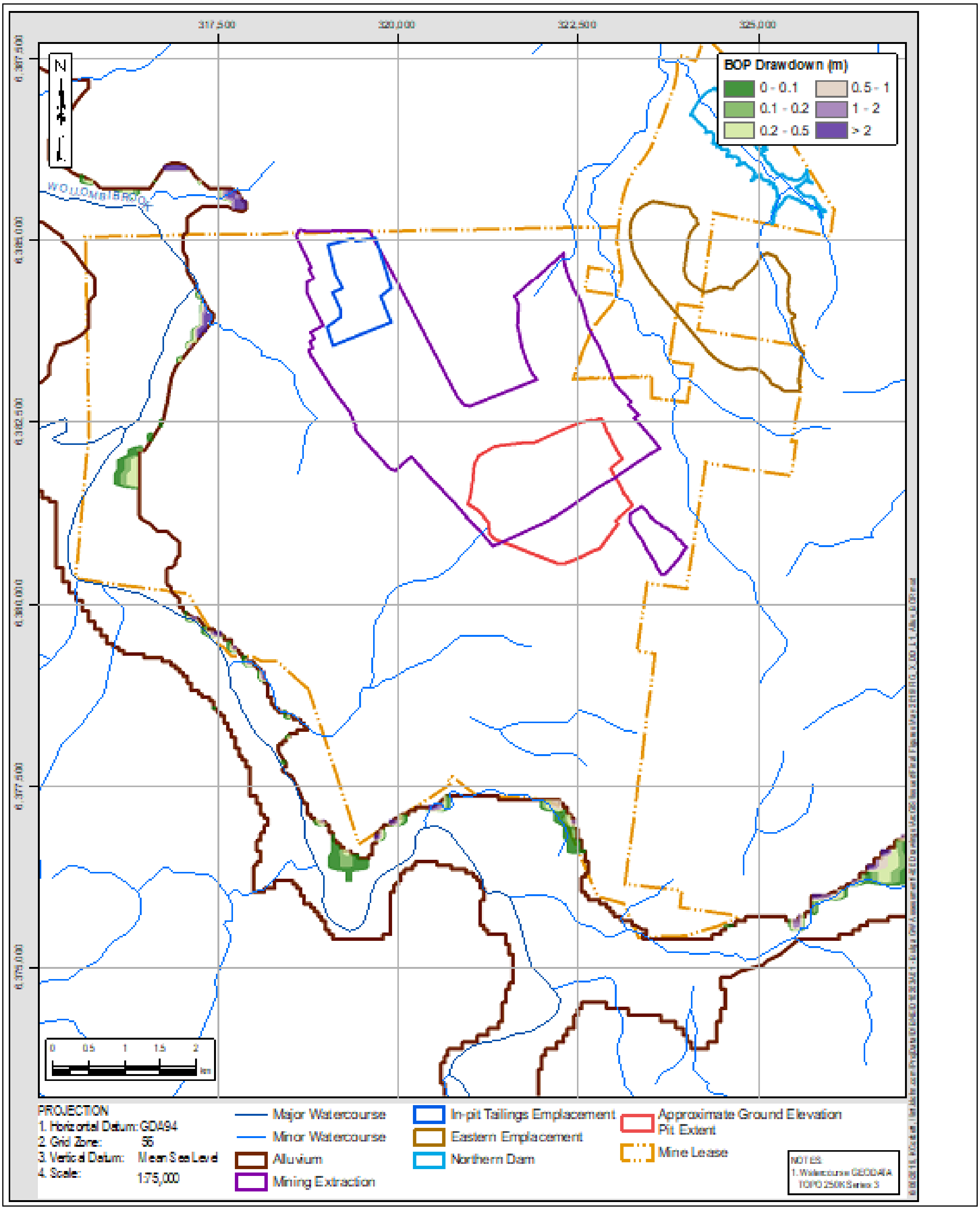

Figure 2.2 Areas of Predicted Maximum Drawdown

2.3.4 Salt balance

24. The proponent has not explicitly modelled changes to the catchment salt balances. This is presumably because they are generally predicting small changes in groundwater discharge to surface waters which are expected to result in no changes to water quality. Planned discharges to surface water are managed under the HRSTS and, as such, are unlikely to have a considerable impact on the catchment salt balance.

25. If the additional uncertainty analyses recommended in the response to this question suggest that fluxes to surface waters may be likely to be large enough to impact water quality, then the catchment salt balance should be calculated and discussed to inform potential management.

Salt balance modelling has been included in the water balance model for the Proposed Modification as detailed in Appendix 11 of the SEE. Model forecasts of the salinity within the two dams (from which discharge under the HRSTS can occur) have been undertaken (refer to **Appendix C**), together with discharge volumes. The volume of water discharged will be subject to the provisions of the HRSTS which is designed to control discharges so that the resulting mixture of river and discharge water can be kept fresh to meet water quality standards. The salinity of waters discharged from these two dams will be highly diluted by flow in the Hunter River, as discussed in the response to comment 15. Controlled discharges are currently approved and licensed under EPL 563 and managed in accordance with the HRSTS. The Proposed Modification will continue to discharge under EPL 563 and in accordance with the HRSTS. There is no change to discharge requirements proposed under the Proposed Modification.

The modelling of final void water quality (refer to Appendix 11 of the SEE) has similarly had regard to salt present within groundwater inflows, surface water run-off and infiltration through spoil.

2.3.5 Other potential impacts

26. From the groundwater impact assessment, it is unclear what the likelihood is that groundwater levels will recover to a point at which saturation of the TSF occurs and, if so, how this could impact both groundwater and surface water quality. While the proponent has identified that most discharge from the TSF will ultimately drain to the void lake, they suggest that local flow paths could possibly develop. Information on where these flow paths could discharge is needed to understand and manage the potential impacts on receiving environments.

28. The nature of connectivity between the underground workings and the final void post-mining requires further investigation. It is unclear from the hydrogeological conceptualisation whether this water, which could be contaminated depending on the geochemistry of the target coal seams, will also flow toward the final void lake. Site-specific data should be used to justify the parameter functions applied in the model for hydraulic conductivity and specific storage, particularly between the longwall panels and the open cut pit.

As outlined in **Appendix A**, recovery of the final void water body was an iterative process between the water specialists. Rates of groundwater inflow/outflow at various elevations were assessed in the post-closure scenario and based on the consideration of surface water inflows, groundwater flows and evaporation, the final pit lake elevation has been assessed to be in the range of - 40 m RL. A schematic indication of the groundwater flow and other influences at closure and once the pit lake has recovered is provided in Figure 29 of **Appendix A**.

Appendix A also includes the following comments regarding the post-closure recovery:

- The likely final void recovered water level is at ~- 40mRL. At this elevation, the groundwater gradients remain strongly toward the final void.

- This elevation is significantly below the elevation of the TSF.
- More detailed modelling of the TSF design and flows has also been undertaken by WSP to support the assessment of likely flows toward the void.
- The balance between surface inflow and evaporation (rather than groundwater contributions) will play the most important role in the transient changes to this long-term equilibrium level. Above an elevation of around - 51 mRL some reversal of flow into the workings may occur.
- Further groundwater and surface water monitoring will be put in place to confirm the current understanding and to allow detection of unexpected flows away from the final mine void, especially in the area of the proposed TSF.

27. Groundwater quality data are required that includes monitoring for a range of potential contaminants other than salinity, particularly for the Wollombi Brook Alluvium. This information is needed to understand the current condition of the water resources and for comparison with monitoring data collected during and post-mining to identify whether impacts are occurring. The effectiveness of mitigation strategies can also be assessed using this information.

As outlined in **Appendix A**, the groundwater quality to date indicates that the groundwater in the Permian and the alluvial aquifers is circa-neutral pH with variable salinity. As indicated in previous responses, the alluvial aquifer bore respond far more significantly to surface water flow conditions and the variability in quality does not appear to be associated with groundwater quality changes in the Permian due to mining. Current groundwater gradients are strongly toward mining operations, and a poor hydraulic connection exists between the Permian and alluvial aquifers; under these conditions, no groundwater quality effects are currently expected as a result of mining-influenced groundwater quality changes (if any) in the Permian units.

The near-neutral pH values limit the mobilisations of most common metals and salinity influences are considered to be the most likely influence should any occur.

The long-term trends in salinity in the alluvial and Permian measures can be illustrated by the monitoring record. Neither of these series shows an overall increasing trend but the Wollombi alluvials do show lower salinity, greater variability and a stronger response to surface water flow over the ~20 year period (2000 to 2020) (refer to **Appendix A**).

29. The proponent currently predicts that no impacts will occur to the Warkworth Sands Woodland CEEC. This is based on the assumption that the CEEC accesses groundwater from perched aquifers disconnected from the underlying Permian aquifers and that drawdown of the water table will not extend to the Warkworth Sands Woodland. Confidence in this impact prediction is limited. The measures suggested by the consultants (KCB 2019, pp. 86-87) should be implemented to address and manage the limited confidence. The IESC also suggests the following:

a. undertaking concurrent ecological monitoring of the Warkworth Sands Woodland CEEC, including species recruitment and persistence, to identify potential impacts;

b. instigating a groundwater monitoring program (using nested monitoring bores) which would continue during and after operations to identify potential water table drawdown at the Warkworth Sands Woodland CEEC;

c. undertaking an uncertainty analysis to determine the likelihood and magnitude of water table drawdown in the area of the Warkworth Sands Woodland; and,

d. developing a management plan if the additional measures identify the potential for impact to the Warkworth Sands Woodland CEEC. This plan should utilise the ecohydrological conceptual modelling discussed in Paragraph 23.

The Proposed Modification is not predicted to have a significant impact on the Warkworth Sands Woodland CEEC. As discussed in **Section 1.2**, the groundwater systems in the local area are already significantly impacted by past and approved mining operations. Any impacts to Warkworth Sands Woodland CEEC have either been experienced from previous mining or are approved to occur from existing mining operations.

Regardless, as noted by the IESC, KCB suggested a number of measures to be implemented in relation to the Warkworth Sands Woodland CEEC, including:

- hydrogeological ground-truthing at the Warkworth Sands Woodlands, located to the west, to verify current understanding of perched aquifers of aeolian sand sheet deposits, and assess the suitability of a site for monitoring if warranted
- consideration of establishment of monitoring, or confirmation of assumed conceptualisation, of perched groundwater conditions in the area of the Warkworth Sands Woodlands. In the event such assessment indicates these systems are confirmed to require closer monitoring, establishment of suitable monitoring of creek flows (levels, temperature and quality) should be made.

Ecological monitoring within the area of Warkworth Sands Woodland CEEC is currently undertaken in accordance with the Biodiversity Offset Management Plan (BOMP) for the Wollombi Brook Voluntary Conservation Area. Each monitoring event must include:

- photo-point monitoring – four photographs from each monitoring point at specific bearings (N, S, E, W) to allow annual comparisons
- plot monitoring – floristic data collected from existing locations following the biometric methodology, and compared against the relevant Plant Community Types (PCTs)
- walk through assessment – opportunistic observations should be made on management-related issues, including fire events or the impacts of fire management, weeds, locations or evidence of pest animal species, visitor and vehicle impacts, rubbish dumping, natural regeneration of previously disturbed areas, and sightings of threatened species
- monitoring report – by December each year, a report must be prepared which includes a description of all completed management actions completed in the preceding 12 months, appending monitoring data sheets and photographs, and discussing any changes in floristics and condition evident in quadrat data, and discussion on the effectiveness of management actions and recommendations for the following year.

The most recent ecological monitoring report *Flora and Fauna Monitoring at Wollombi Brook VCA Singleton LGA: 2019 Results* (Bell, Murray and Sims, 2020) indicates that regenerating Warkworth Sands Woodland shows good recruitment of canopy and shrub species, although this has been tempered by recent dry conditions. After five years of monitoring, species diversity is being maintained, or changing in response to varying climatic conditions.

As an additional management measure, the Warkworth Sands Woodland Integrated Management Plan (Rio Tinto, 2017) prepared by Mt Thorley Warkworth mine in consultation with the owners of the Wambo and Bulga mines, outlines the measures that would be implemented to co-ordinate management and recovery efforts for the CEEC. The key action of the Plan has been to establish a Warkworth Sands Woodland Exchange Forum to enable integration of management actions and knowledge exchange between the three landholders.

As detailed in the Groundwater Impact Assessment (KCB 2019), the Bulga Coal Water Management Plan (WMP) is a comprehensive document which addresses all activities associated with the management of water at BCC, with exception of the potable water supply. The monitoring network at BCC is comprehensive as detailed in **Appendix A**, and reporting obligations are met through online posting of routine monitoring reports. While model predictions of incremental impacts from the Proposed Modification do not identify potential impacts that may necessitate further monitoring, the groundwater monitoring program will be reviewed if the Proposed Modification is approved. This will include:

- increased monitoring near the edge of the alluvial in the reach of the northern flow where this thins. This is an area where modelling suggests that an increased level of scrutiny is required to confirm that drawdown does not impact on the alluvial system
- hydrogeological ground-truthing at the Warkworth Sands Woodlands, located to the west, to verify current understanding of perched aquifers of aeolian sand sheet deposits, and assess the suitability of a site for monitoring if warranted
- consideration of establishment of monitoring, or confirmation of assumed conceptualisation, of perched groundwater conditions in the area of the Warkworth Sands Woodlands. In the event such assessment indicates these systems are confirmed to require closer monitoring, establishment of suitable monitoring of Warkworth Sands phreatic water level, water quality and soil moisture should be made.

Question 5: Are the assumptions and the range of scenarios applied in the groundwater modelling reasonable and is there sufficient data within the model to provide meaningful predictions, including worst-case impacts on groundwater resources?

30. The justification in the report (KCB 2019) for the input data used in the model is limited for some parameters and scenarios. Furthermore, there are significant data gaps. Some of the model design assumptions and selected parameterisations do not appear credible as evidenced by the poor history-matching (for example, in many instances the anomalies between simulated and observed heads exceed 50 m). Currently, the modelling does not consider worse-case situations and the uncertainty analysis provided is not consistent with the most recent iteration of the groundwater model (KCB 2019, p. 73). Future uncertainty analyses should use a groundwater model incorporating the current mine plan.

A detailed response to this issue is provided in response to comment 10 and **Appendix A.**

Future updating of the model will incorporate mine plans as updated from time to time.

31. Given the long history of mining at the site, the IESC would expect the proponent to present more data for history-matching, representing the potential impacts of deepening the open cut and for in-pit tailings placement. History-matching targets are not available for all model layers. Where targets are available, history-matching fits are sometimes poor and importantly when simulating impacts on surface waters and existing bores, do not represent the dynamics (or even the median response) of the aquifer within the shallow layers. Uncertainty analysis testing a range of plausible parameterisations is needed to understand how these limitations may affect impact predictions. Reporting of any uncertainty analysis should include a description of the parameters varied and their prior and posterior probability distributions (Middlemis and Peeters 2018).

Refer to the response to Comment 19 and **Appendix A**.

Groundwater contours and groundwater monitoring data provided is also provided for responses to Comments 1 and 3 (and presented in **Appendix A**).

32. Additional limitations of the groundwater model noted by the proponent include the boundary conditions influencing the prediction of creek discharge and that local impacts such as groundwater extraction for irrigation and high rainfall events are not incorporated into the model (KCB 2019, p. 68). These limitations should be considered in the updated version of the model and uncertainty analyses suggested in Paragraphs 20 and 22, and during future model updates.

As discussed in **Appendix A**, BCM has committed to increasing the groundwater and surface water monitoring for the Project Area followed by an update to the groundwater modelling (including further assessment of uncertainty), should the underground mining be undertaken as approved .

Responses provided in **Appendix A** provide the context and intent of the groundwater model for the Proposed Modification, discuss the poor hydraulic connection between the alluvial and Permian units and the consequent focus on the Permian calibration, as well the degree of sensitivity and uncertainty analysis already undertaken.

Question 6: Does the SEE provide an adequate assessment of cumulative impacts to water resources?

33. The current groundwater model is used as the basis for assessing cumulative impacts. However, the groundwater model has a number of limitations as outlined in Paragraphs 18-20. In addition, while the current groundwater modelling provides predictions of cumulative impacts the presentation of these predictions makes it difficult to clearly identify the changes in groundwater levels from current conditions and to determine the contribution of the proposed project to cumulative impacts. These limitations need to be addressed so that the incremental changes of the project and the total cumulative impacts to groundwater can be clearly identified and assessed.

As discussed in **Appendix A**, the modelling has focused on assessing the potential incremental change of the Proposed Modification, compared to the currently approved mining case. The comparison to the approved case is shown on Figure 13 of **Appendix A**, and the magnitude of incremental change is also provided in **Appendix A**. In addition, the areas of potentially greatest drawdown impact in the alluvials have been provided in Figure 11 of **Appendix A**.

Table 2.1 above sets out the modelled cumulative impacts on baseflows relative to existing conditions.

Contextualisation of the potential impact and the monitoring data to support the expected small drawdown impacts on the alluvial aquifers has been discussed in response to a number of comments. The long-term groundwater flow gradients will continue to be toward the final void over the duration of operations and into closure (refer to Figure 29 of **Appendix A**).

34. It is noted by the proponent that irrigation impacts are not incorporated into the groundwater model (KCB 2019, p. 68). Incorporating irrigation water use into groundwater models can be complicated as pumping volumes may not be known and timing is often not at the temporal scale of the modelling. Further discussion of irrigation water extraction and return flows should be provided and incorporated into future groundwater model updates, and their impacts should be considered on alluvial aquifers and their dependent ecosystems along Wollombi Brook.

Understanding the irrigation water use and surface water impacts on the alluvial aquifer was beyond the intended scope of the model. From a catchment management perspective, KCB indicate that irrigation impacts should be considered and may be the dominant groundwater influence on the alluvials. Consequently as indicated by the modelling and available data, the change in groundwater conditions as a result of the Proposed Modification (compared to the approved case) is far smaller than changes to groundwater conditions due to surface flows and/or irrigation.

35. The proponent identifies that flows of approximately 100 m^3/day may occur from the TSF to Mount Thorley, the adjacent mine site (KCB 2019, p. 80). This potential cumulative impact is not fully considered in the groundwater impact assessment. Further information and analysis are needed of where these flows discharge. If they enter the final void of the Mount Thorley Mine (which is likely), consideration is needed of whether these discharges change the predicted water levels in the Mount Thorley final void, increase the chance of spills from the final void and/or change the void's water quality.

Appendix A indicates that modelling results for the Proposed Modification have indicated that a small groundwater mound will develop within the spoil in the Bulga pit shell adjacent to Mount Thorley as a result the head from the TSF and the assumed groundwater elevations to the north in the Mount Thorley workings. As indicated by KCB, the magnitude of this flow will be a function of the head in the TSF and in the adjacent workings and is expected to vary seasonally, averaging at less than 1 L/s over the longer-term. The TSF as a facility has already been approved, with consideration of these minor flows to the north. Depending on timing of water level increases in Mount Thorley this flow will be distributed across a length of around 1 km. These factors suggest that the proposed northward flow is likely a small proportion of the Mount Thorley water balance to be accounted for.

It is noted that the northern end of the adjacent pit area (Loders Pit) at Mount Thorley is also planned for use as a tailings storage facility under the current Mount Thorley Warkworth Mining Operations Plan. The predicted groundwater mound and modelled outflows of up to 15ML/year during operations are unlikely to affect the operations of the Mt Thorley tailings storage facility. It is also noted that the rate of seepage will decline as tailings desiccate and consolidate.

2.4 Water-dependent Ecosystems

Question 7: Have impacts of the Proposed Modification on surface water and groundwater dependent ecosystems been adequately described and assessed?

36. Potential impacts to surface and groundwater resources are discussed in response to Questions 1 to 6 above. Where information is considered inadequate, this is highlighted below.

Noted.

37. Information on riparian and groundwater-dependent vegetation is limited. In particular:

a. McVicar et al. (2016) mapped GDEs in the Hunter sub-region, where KCB (2019, p. 40) acknowledges that riparian zones may be groundwater-dependent. Loss of riparian and groundwater-dependent vegetation has the potential to impact semi-aquatic and terrestrial biota, especially species heavily reliant on remnant woodlands and streamside trees. Baseline information, including verification of groundwater-dependence, is required to predict, monitor and manage potential impacts of the proposal. Doody et al. (2019) provide useful guidance on approaches to assess groundwater dependency and to survey and manage GDEs.

b. the critically endangered Warkworth Sands Woodland is approximately 3.5 km from the project (KCB 2019, p. 40). It is unclear to what spatial and temporal extent this CEEC may utilise groundwater, especially during periods of low rainfall. If drawdown occurs in the Warkworth Sands aquifer, then persistence and recruitment of vegetation in the Warkworth Sands Woodland may be impacted. Confirmation of the groundwater source for this community is required (see Paragraph 29), along with its vulnerability to drawdown due to individual or cumulative impacts associated with the project.

As discussed in the Groundwater Impact Assessment (KCB, 2019), the modelling predicts that the majority of the groundwater drawdown impacts at the BCC arise from the already-approved mining operations. The incremental change in drawdown resulting from the Proposed Modification (compared to the approved case) is small and almost entirely constrained to weathered or deeper Permian strata with poor or no connectivity with the aquifers in alluvial systems or potential perched aquifer systems in the Warkworth Sands. The SEE also contained a detailed assessment of impacts on GDEs, with drawdowns determined to be within levels previously assessed as not being significant as part of the Bulga Optimisation Project (Umwelt 2019). The Proposed Modification's incremental impacts on baseflows are considered unlikely to have any observable effect on refugia within ephemeral system, low flow conditions or riparian vegetation relative to Approved Operations given the very low magnitude of predicted impacts.

As outlined in the Groundwater Impact Assessment (KCB, 2019) and in **Appendix A**, the Warkworth Sands are interpreted to be perched, thin deposits of aeolian sands lying predominantly over low permeability Permian and weathered Permian rock. The model results indicate that the change to Permian groundwater levels as a result of the Proposed Modification in this area is negligible. In addition, the Warkworth Sands are expected to be hydraulically disconnected from the regional saturated groundwater systems and, because of this isolation, are unlikely to be impacted by either the already-approved case or the Proposed Modification case.

While the Warkworth Sands are assessed as disconnected from the modelled Permian layers, model results for the Proposed Modification suggest that no additional drawdown will occur in the Permian units immediately underlying these sands as a result of the Proposed Modification. The model results, as well as the probable long-term presence of perched conditions, suggest that it is unlikely that ongoing mining under the Proposed Modification scenario will negatively impact on groundwater conditions in the Warkworth Sands.

As discussed above for comment 29, there are a number of monitoring and management measures in place for the known areas of Warkworth Sands Woodland CEEC.

38. While targeted surveys of EPBC Act-listed fauna were undertaken, limited aquatic ecology surveys of the project site and downstream environments have been conducted. The IESC notes that frog surveys targeted only the Green and Golden Bell Frog (Litoria aurea) (Umwelt 2019a, p. 29), and were limited to the areas that are proposed to be cleared. However, previous surveys (e.g. targeted Green and Golden Bell Frog surveys and searches for tracks of nocturnal reptiles and amphibians) were undertaken outside of the proposed project area.

a. The survey dates and effort of previous fauna assessment sites noted in Umwelt (2019a, Figure 2.5, p. 38) are unclear. It is therefore not possible to determine their completeness, and their relevance to assessing potential impacts of the current project on water-dependent biota.

b. Although surveys did not detect the Green and Golden Bell Frog (Umwelt 2019a, p. 59), if the proposed project is approved, targeted surveys for the Green and Golden Bell Frog (and other amphibian species) should be undertaken over adequate timeframes to verify their absence from the site and potentially affected areas.

As outlined in the SEE and response above, the Proposed Modification is anticipated to have a similar impact as the approved operations.

The Project does not include any changes to existing approved discharge arrangements. All discharges will be undertaken in accordance with existing guidelines and limits. There is not predicted to be any impacts to baseflows resulting from the Proposed Modification. As such, the key area of additional impact is restricted to the minor additional disturbance areas.

The Biodiversity Assessment Report (BAR) (Umwelt 2019a) included as an Appendix to the SEE for the Proposed Modification, comprehensively assesses the potential ecological impacts of the Proposed Modification.

As discussed in the BAR (Umwelt 2019a), the green and golden bell frog (*Litoria aurea*) was not recorded within the additional disturbance area despite extensive surveys undertaken in the known detection period for the species. The closest record of this species occurs approximately 30 km to the south-east of the additional disturbance area near Paxton, recorded in 1993. Other records to the north-west of the additional disturbance area are associated with the Upper Hunter green and golden bell frog key population. The Upper Hunter green and golden bell frog key population consists of one main diffuse population at, or in the vicinity of, the Ravensworth and Liddell area and bordering areas of the Singleton and Muswellbrook LGA. No records of the population in the Upper Hunter have been found since 2009. Furthermore, there is not suitable habitat within the additional disturbance area that provides potential habitat for the species. The absence of individuals in the locality following annual monitoring surveys indicates that the Development Footprint is unlikely to provide habitat for the species. It is unlikely that this species would be impacted by the Proposed Modification.

Diurnal and nocturnal searches for the green and golden bell frog are currently undertaken as part of monitoring in the BCC annually and will continue.

39. As rates of carbon processing in hyporheic and alluvial sediments of ephemeral streams like Loders and Monkey Place Creeks can be high (e.g. Burrows et al. 2017), it is possible that groundwater drawdown in the alluvial sediments will affect this crucial ecological process. This risk is not addressed by the proponent, nor are the implications for similar ecological processes that may be affected by drawdown in the sediments of Wollombi Creek.

As discussed above in relation to Comment 1 and in **Appendix A**, monitoring of the Wollombi Brook and Monkey Place Creek alluvium support the conceptual model that there is very poor connectivity between the Permian and overlying alluvial aquifer systems. The very low level of incremental impact modelled as being attributable to the Project is considered unlikely to have any observable effect on carbon processing within hyporheic and alluvial sediments in ephemeral creek systems nor the Wollombi Brook or Monkey Place Creek Alluvial systems.

The Surface Water Impact Assessment (Engeny 2019) predicted changes to flow regimes both during and following the mining operations associated with the Proposed Modification to be negligible on Wollombi Brook. The changes to flow regimes associated with catchment changes were also considered to be negligible on a regional scale, i.e. Wollombi Brook and Loders Creek flows into the Hunter River regulated river system. These changes are considered unlikely to have any observable impact on any aquatic or riparian communities present in the creek systems relative to existing approved operations (refer to response to Comment 23).

The Proposed Modification was also predicted to have minor impacts on the annual flow volumes in Loders Creek compared to the Approved Operations landform conditions. The ephemeral nature of this system (dry for approximately half the year) means that the reduction in number of modelled flow days is unlikely to have any observable effect on the persistence of pools within the creek or aquatic ecosystems that may rely on them. Refer also to earlier discussion in relation to Comment 23.

It is therefore considered that further assessment of the risk to the processing of carbon in alluvial sediments of ephemeral streams is unwarranted given the level of predicted impacts.

40. There has been no sampling of stygofauna, an obligate GDE, that has been recorded in other assessments of the alluvial sediments of Wollombi Brook and tributaries of the Hunter River (Eco Logical 2015, p 20; AGE 2016, p.55). As drawdown and/or altered groundwater water quality associated with the project may impact upon this GDE, stygofauna should be sampled and monitored using appropriate methods, potentially including the use of environmental DNA (Doody et al. 2019). Sampling should include, where possible, multiple reference sites upstream of the proposed project and in alluvial aquifers where no drawdown is predicted. These data will provide crucial baseline information for comparison with samples from areas where groundwater drawdown or changes to groundwater quality occur as a result of the project.

The SEE contained a detailed assessment of impacts on GDEs, with drawdowns determined to be within levels previously assessed as not being significant as part of the Bulga Optimisation Project (Umwelt 2019). The majority of the groundwater drawdown impacts arise from the already-approved mining operations. The incremental change in drawdown resulting from the Proposed Modification (compared to the Approved Case) is small and almost entirely constrained to weathered or deeper Permian strata.

The alluvium impacts are consistently small to moderate due to the strong hydrogeological isolation of this system from the Permian. Modelled drawdown within the alluvial systems (refer to **Figure 2.2** and response to Comment 23) does not identify any areas of significant drawdown which would result in isolation or loss of stygofauna communities, particularly given the magnitude of observed head changes in the alluvium due to natural processes.

The model predictions are consistent with current monitoring records and supported by model predictions inclusive of sensitivity and uncertainty analysis results (KCB 2019).

Given the minor impacts predicted, it is considered that sampling of stygofauna is not warranted.

41. Cumulative impacts to water-dependent ecological communities and species have not been adequately assessed. The proponent should discuss the project's likely impacts by providing a summary of historical and current impacts to these ecological receptors and an assessment of how the project would add to the existing cumulative impacts. This work should consider the Hunter sub-region Bioregional Assessment which identified that changes to the hydrological regime from further resource development may result in increases of low-flow days of 3 to 80 days across the 5th to 95th percentile range which was considered potentially likely to impact a number of identified GDEs (Herron et al. 2018).

Biodiversity impacts have been assessed in accordance with the specific requirements of the *Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major* Projects (FBA) (OEH, 2014). The FBA process is a credit driven system where calculators provided by the NSW government are populated with ecological data about the site to generate 'impact credits'. The Proposed Modification is then required to offset these credits through a biodiversity offset strategy.

The BAR includes an assessment of cumulative habitat loss and vegetation clearance impacts, as required by the FBA. It is recognised that the Proposed Modification will remove vegetation and thus contribute to cumulative habitat loss and vegetation clearance in the locality however the proposed areas of additional disturbance are already isolated within existing approved disturbance areas and their removal will not increase fragmentation or isolation. A number of avoidance, mitigation and offset measures have been included to manage the potential impacts from the Proposed Modification.

Cumulative water resource impacts were addressed in Section 5.1 of the Groundwater Impact Assessment (KCB, 2019) and Section 4.9 of the Surface Water Impact Assessment (Engeny, 2019).

The potential impacts on groundwater dependent ecosystems and downstream impacts on hydrology and environmental flows on vegetation are outlined in the main text of the SEE. It was concluded that the Proposed Modification would not result in significant downstream impacts on surface vegetation. The SEE also contained a detailed assessment of impacts on GDEs, with drawdowns determined to be within levels previously assessed as not being significant as part of the Bulga Optimisation Project (Umwelt 2019).

As discussed above, the magnitude of incremental impacts associated solely to the Proposed Modification are considered unlikely to be observable nor have any material impact on water dependent ecosystems.

2.1 Avoidance, Mitigation and Monitoring

Question 8: Are there any additional mitigation, monitoring, management or offsetting measures that should be considered by the decision makers to address the residual impacts of the Proposed Modification on water resources in conditions of consent?

42. Additional monitoring of the Warkworth Sands Woodland CEEC is needed as outlined in Paragraph 29. This would allow potential impacts to be detected and adaptively managed through a trigger-action response plan (TARP). The IESC considers that 'like-for-like' offsetting measures for this CEEC are not feasible because of the extreme rarity of this community and its unique association with perched groundwater and aeolian sands.

As discussed for comment 29, a number of measures will be considered in relation to the Warkworth Sands Woodland CEEC, including:

- hydrogeological ground-truthing at the Warkworth Sands Woodlands, located to the west, to verify current understanding of perched aquifers of aeolian sand sheet deposits, and assess the suitability of a site for monitoring if warranted
- consideration of establishment of monitoring, or confirmation of assumed conceptualisation, of perched groundwater conditions in the area of the Warkworth Sands Woodlands. In the event such assessment indicates these systems are confirmed to require closer monitoring, establishment of suitable monitoring of Warkworth Sands phreatic water level, water quality and soil moisture should be made.

As part of additional monitoring, a TARP will be prepared and included in the relevant management plans to be updated if the Proposed Modification is approved.

43. Additional monitoring of the groundwater in the alluvium is needed to better understand how impacts in the Permian aquifer propagate to the alluvial aquifer and influence surface water flows.

A considerable number of groundwater monitoring points are already in place particularly in the areas where potential impacts may occur in the alluvials. Current monitoring locations are provided on Figure 33 of **Appendix A**.

BCM is in the process of assessing the need for additional groundwater monitoring around the site. The proposed areas targeted are based on the potential areas of interaction with the alluvials, the Permian units between the operations and the alluvials to west and south while to the north these relate to monitoring in the Permian along the northern boundary. The latter monitoring will have two separate objectives since there is a need to understand the potential flows toward Mt Thorley immediately north of the TSF as well as understanding and providing an early warning (if needed) of potential drawdown toward the Warkworth Sand or other alluvials.

44. Baseline ecological surveys targeting aquatic biota, stygofauna and riparian vegetation that may be impacted by the project (for example in the Beltana Reach of Wollombi Brook where drawdown may exceed 2 m) should be undertaken and reported. Aquatic biota should be sampled opportunistically when streams are flowing and from refugial pools. Currently, the only monitoring for "stream health" focuses solely on the riparian zone, using the "Rapid Appraisal of Riparian Conditions" described by Jansen et al. (2005). Jansen et al. (2005) caution that this method is designed for rivers and creeks with "relatively permanent" water. Baseline data of aquatic biota, stygofauna and riparian vegetation are needed to understand the current condition of the systems and to compare with monitoring data obtained during operations to determine if impacts have occurred.

BCM has comprehensive environmental monitoring programs in place that cover relevant aspects of biodiversity and water resources. As discussed, the Proposed Modification's impacts on groundwater and surface water systems will be generally consistent with the approved operations. It is therefore proposed to continue the existing monitoring regimes in accordance with the development consent and approved management plans.

45. The proponent has identified that there is the potential for local flow paths to form around the TSF and that monitoring of groundwater could be useful (KCB 2019, p. 83). The IESC agrees that additional groundwater monitoring (including sampling for metals and metalloids) should occur in this area and be targeted at detecting localised flow paths from the TSF, especially where discharge to alluvium and/or surface water could occur.

The changes proposed as a result of the Proposed Modification do not involve any material changes to groundwater interactions relative to existing approved operations.

As indicated by KCB and illustrated on Figure 13 and Figure 29 of **Appendix A**, groundwater gradients are expected to be predominantly toward the mining operations and toward the final void during operations and at closure due to the significantly lower permeabilities within spoil relative to the rock strata located between the TSF and Wollombi Brook. Despite this expectation, BCM has indicated that additional monitoring of the final void water quality and the surrounding groundwater quality will form part of the proposed monitoring plan. The monitoring in this area will include annual monitoring of standard metals and metalloids.

46. The proponent has not clearly identified expected discharge quality (particularly in relation to metal contaminants). This means that the appropriateness of the proposed mitigation or monitoring cannot be fully evaluated.

As discussed for comment 14, the Proposed Modification will not require any alteration to the existing regulatory or licensing arrangements for discharges, maintaining existing discharge quality limits. Therefore there is no change to the discharge quantity or quality relative to existing approved operations.

As discussed in **Appendix B**, monitoring of discharges from the BCC are driven by Section 120 of the POEO Act, which makes it an offence to pollute waters or cause harm unless licensed to do so. The EPL and HRSTS regulate discharges from the BCC mine water management system which would otherwise be considered a breach of the POEO Act.

BCC reuses water within the WMS as a first priority for dust suppression and in the coal handling and preparation plant (CHPP). Discharges only occur when surplus water cannot be managed on-site, and discharge opportunities are present. WaterNSW determines when discharges can occur and participants of the HRSTS are notified of events and associated limits.

47. The proponent has not considered the potential for groundwater seepage from the altered TSF to influence groundwater quality in the Permian aquifers and impact aquatic biota. The IESC notes that the proponent's modelling indicates that most of the seepage from the TSF will go into the final void lake, with some leakage to Mount Thorley (Paragraph 33). The proponent should provide further information on the extent and depth of the TSF and assess if seepage could impact aquatic biota.

As discussed for comment 26, the likely final void recovered water level is significantly below the elevation of the TSF. More detailed modelling of the TSF design and flows has also been undertaken to support the assessment of likely flows toward the void.

As outlined in the GIA, seepage from the relocated tailings is predicted to be strongly influenced by the subregional Permian gradients beneath the tailings, with flows during mining and post-mining predicted to fall under the deeper regional flow of the Permian units toward this sink that is formed by the open-cut void.

Final void water balance modelling indicates that the final void water body would reach an equilibrium level well below spill level. The Proposed Modification will alter the TSF slightly, the TSF is currently approved. There is not predicted to be any additional impacts resulting from groundwater seepage on groundwater quality in the Permian aquifers or aquatic biota.

48. The IESC notes that monitoring of the water management dams on site does not include any monitoring of metals and metalloids. Metals (both total and dissolved) and metalloids should be monitored especially in the Northern Dam and Surge Dam as this water can be discharged to the Hunter River.

As discussed for comment 13 above, BCM will expand the existing surface water monitoring program to include monitoring of a broader suite of analytes such as metals and metalloids. The annual program will include monitoring of on-site dams.

49. The IESC recommends the proponent develop a Receiving Environment Management Plan (REMP) that specifies actions to ensure that the downstream environment is not adversely affected by discharges or storage overflows from the proposed mine. The REMP should:

- **a. include a program of regular and event-based water quality monitoring of discharge water, and of surface water upstream and immediately downstream of the mine or licenced discharge points;**
- **b. provide a TARP, in line with ANZG (2018) guidelines, which uses site-specific data from reference sites;**
- **c. include site-specific guidelines that have been derived from reference sites as outlined in Huynh and Hobbs (2019);**
- **d. integrate with the existing Surface Water Management Plan (SWMP) so that the mitigation and management measures will adequately protect environmental values within and downstream of the project area;**
- **e. include ecohydrological conceptual models that illustrate potential pathways and mechanisms of the effects of altered surface flows on groundwater and alluvial recharge, instream water quality, and surface and groundwater ecosystems. These conceptual models would help the proponent justify strategies proposed to mitigate and manage potential impacts; and,**
- **f. include a mechanism for evaluating the effectiveness of selected mitigation and management measures and adopting new approaches if the current approaches are found ineffective.**

The BCC operates in accordance with a range of managements plans, required by the conditions of the SSD 4960 and other approvals, which detail management and mitigation measures. Under this management plan framework, the BCC manages water capture, supply, consumption, storage, disposal and hydrological interception in accordance with the WMP and associated sub plans.

The BCC WMP can be found at the following location: https://www.bulgacoal.com.au/en/publications/management-plans/ManagementPlans/Water-Management-Plan-Approved-by-Commonwealth.pdf

Specific to the above requirements of a Receiving Environment Management Plan (REMP), the BCC WMP includes:

a. A Surface Water Monitoring Program under which regular monthly water quality monitoring is undertaken at various upstream and downstream locations on the creeks affected by the BCC. In addition to the monthly schedule, continuous monitoring is undertaken during discharge events. The monitoring schedule will be expanded to include annual monitoring of a broader set of analytes, including metals and metalloids. Refer to Sections 5.3.1, 9.3.1 of the BCC WMP.

b. A Trigger Action Response Plan (TARP) outlining required management actions in the event site-specific trigger values are exceeded. Refer to Table 31 of the BCC WMP.

c. Site-specific Surface Water Impact Assessment Criteria which defines trigger values for physical and chemical factors, based on background data, in accordance with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC Guidelines) and Deriving site-specific guideline values for physicochemical parameters and toxicants (Huynh T and Hobbs D, 2019).

d. An integrated Surface Water Monitoring Program. Refer to Section 9.3 of the BCC WMP.

e. Covered by other NSW state government management plans prepared for BCM.

f. An integrated Surface and Groundwater Response Plan which identifies the appropriate response to exceedances of trigger values. If regular exceedances occur, the response plan requires the Environment and Community Manager to notify and formulate corrective actions in consultation, as required, with any relevant stakeholders. Refer to Section 11 of the BCC WMP.

As identified above, the conditions required by a REMP are addressed as part of the existing NSW management plan framework required by SSD 4960. BCM is committed to continuing with the existing approach to the management of the Proposed Modification in order to continue to meet the SSD 4960 criteria, that is via the BCC WMP. It is not proposed to prepare a separate REMP for the BCC.

50. No water-dependent ecosystem-specific triggers appear to be proposed. Should amphibians be detected as part of monitoring proposed in Paragraph 38b, a TARP will be required to mitigate and manage potential impacts to these species.

Diurnal and nocturnal searches for the green and golden bell frog are currently undertaken as part of monitoring in the BCC annually. Should this or any other amphibian species be detected as part of this monitoring a TARP will be prepared to mitigate and manage potential impacts to these species.

51. If the proposed project will be included in the water management plan for the existing mine, all triggers should include timeframes for proposed responses. In addition, measures should be adopted to minimise impacts to aquatic biota and ecological processes. Currently, the approved water management plan for the existing mine includes triggers along Nine Mile Creek, Loders Creek and Wollombi Brook for negligible change in (Glencore 2017, pp. 55-56 and 65-66):

a. ecosystem functionality of the riparian vegetation: a floristic change that can be correlated with a hydrological change; and,

b. frog diversity and abundance: a 30% decline in species assemblage or abundance of frogs utilising riparian vegetation.

The Proposed Modification is located within the approved BCC Project Area and within the existing water management system. The existing WMP will updated to include the Proposed Modification.

As outlined in the SEE, the Proposed Modification design was prepared and refined with the objective of ensuring that the Proposed Modification could be undertaken in compliance with existing approved environmental impact criteria, to ensure that there is minimal incremental impact resulting from the Proposed Modification. The existing operations are operated under a comprehensive environmental management system, which includes monitoring of relevant water and ecological aspects. All monitoring will be continued in accordance with existing requirements for the life of the operations.

52. Based on the data from sampling stygofauna and aquatic biota (Paragraph 44), triggers should be developed that encompass declines in taxa richness or abundance of, for example, aquatic or groundwater invertebrates in response to changes in hydrology, water quality or groundwater regime due to the project.

As previously discussed, further stygofauna sampling is not considered to be warranted given the Proposed Modification's negligible additional impacts on alluvial aquifer systems. BCM will continue to undertake environmental monitoring in accordance with their existing approved management plans.

3.0 References

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APPENDIX A

KCB Response

26 March 2020

Umwelt (Australia) Pty Limited
75 York Street
Teralba, NSW
2284

Mr. Bret Jenkins
Senior Principal Environmental Consultant

Dear Mr. Jenkins:

SSD 4960 Mod 3 – IESC Comments
Hydrogeological Response

1 INTRODUCTION

Klohn Crippen Berger Australia Pty Ltd (KCB) is pleased to provide this letter report, in response to the hydrogeological related comments received from the Independent Expert Scientific Committee (IESC), to the submitted SSD 4960 Mod 3 report. The main objective of this report is to present the groundwater work already undertaken in a clear and direct manner to address the concerns raised by the IESC, following regulatory guidelines (EPBC Act and IESC Guidelines).

2 BACKGROUND

Bulga Coal Management (BCM) was granted approval for the Bulga Optimisation Project (SSD 4960) on 1 December 2014, which allowed for the continuation of the Bulga Surface Operations until 31 December 2035. SSD 4960 has been modified twice since it was approved, SSD 4960 Mod 1 in January 2017 to facilitate a revised Eastern Emplacement Area (EEA) design and a revised tailing management strategy and SSD 4960 Mod 2 in August 2018 to extend the period to complete the outer face of the noise and visual bund.

The proposed SSD 4960 Mod 3 would allow for the continuation of mining at the Bulga Surface Operations.

3 REPORT STRUCTURE

This document was structured to provide an itemised set of responses that contain further detail/explanation and/or pertinent figures, providing clarification to comments received by the IESC:

- <u>**Question 1:**</u> *Do the groundwater and surface water assessments within the Statement of Environmental Effects (SEE) provide adequate mapping and delineation of surface and groundwater resources?* – **Comments 1a, b, c, d, f and g**.

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- **<u>Question 2:</u>** *Are the assumptions used in the modelling reasonable and is there sufficient data within the model to provide meaningful predictions, including worst-case impacts on surface water?* – **Comment 3**.
- **<u>Question 3:</u>** *To what extent can decision makers have confidence in the predictions of potential impacts on surface water resources provided in the SEE, including in regard to potential stream flow losses, water quality, discharges and flooding?* – **Comments 18, 19, 20, 21, 22, 23a and b, 26, 27, 28 and 29a, b, c, d**.
- **<u>Question 5:</u>** *Are the assumptions and the range of scenarios applied in the groundwater modelling reasonable and is there sufficient data within the model to provide meaningful predictions, including worst-case impacts on groundwater resources?* - **Comments 30, 31 and 32**.
- **<u>Question 6:</u>** *Does the SEE provide an adequate assessment of cumulative impacts to water resources?* - **Comments 33, 34, 35, 43 and 45**.

The following section provides the sequential response to the received IESC comments and should be considered in conjunction with the KCB August 2019 Groundwater Impact Assessment (GIA) report.

Please note for all the responses the Approved Mining scenario (SSD 4960 Mod 2) has been referred to as the approved case and the Proposed Modification (SSD 4960 Mod 3) case is referred to as the proposed modification.

4 IESC COMMENTS

4.1 Comment 1

The assessment documentation generally provides adequate mapping and delineation of water resources within the project area. Some additional work is required to increase understanding of potential impacts and includes:

a) mapping of the current groundwater levels and flow directions;
b) improved spatial resolution of the extent of the alluvium in areas of current uncertainty such as Loders Creek, Nine Mile Creek and the Beltana Reach of Wollombi Brook;
c) improved characterisation of areas where the alluvium occurs and could be in hydraulic connection with Permian aquifers and the time scales of these connections;
d) identification of stream reaches where the Permian aquifers are connected, and potentially providing baseflow to, the surface water systems, either directly or via alluvial aquifers;
e) mapping of the occurrence of potential GDEs, including stygofauna and riparian vegetation; (ENGENY)
f) identification of the source of groundwater potentially used by the EPBC-Act listed Warkworth Sands Woodland and whether it is connected to any other groundwater or surface water sources; and (UMWELT)
g) groundwater quality data for potential contaminants (other than salinity) particularly in the Wollombi Brook alluvium.

a. Current groundwater level and flow directions

Using groundwater monitoring data from late 2019, the current groundwater contours and inferred flow directions for the shallow aquifer are provided in Figure 1 (using only the monitoring locations) and Figure 2, showing a more realistic representation which includes the mining area vibrating wire piezometer data and the mining plan for 2020.

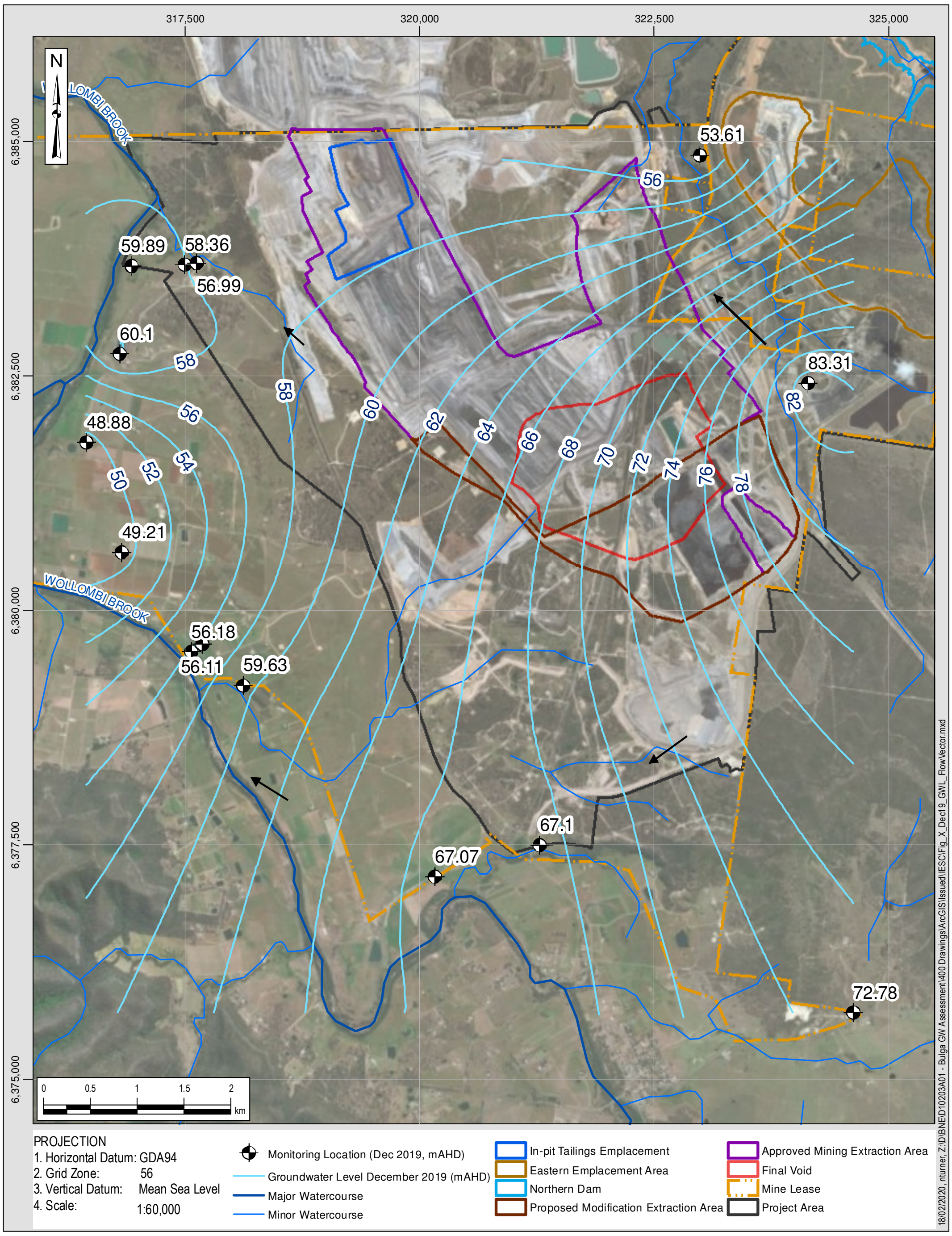

Figure 1 Groundwater contours and inferred flow directions (late 2019 using only groundwater monitoring bores and excluding mine area data)

Figure 1 indicates that the influence of the mining is almost not discernible, when only monitoring locations that are further afield are considered, suggesting that the drawdown impacts associated with mining activities are largely restricted to the operations. Figure 2 presents the same data but includes consideration of piezometer data and current mining depths. The piezometer data is also included in the Groundwater Impact Assessment report (KCB August 2019, Appendix I). The inferred late 2019 contours provide a more complete understanding of the groundwater conditions in the project area. Inferred flow directions are toward the mining operations, with steep groundwater gradients near the operations, becoming progressively less pronounced further afield.

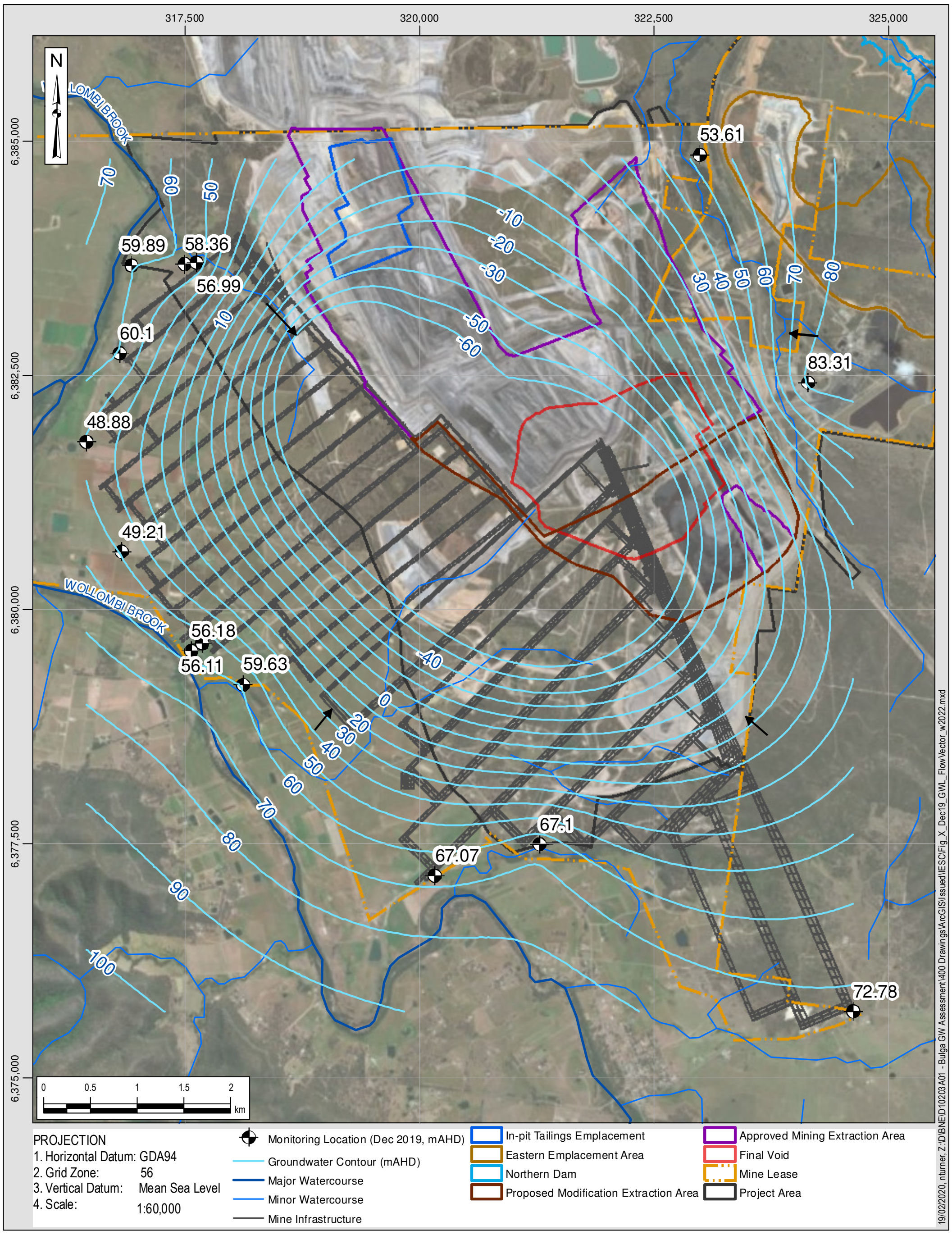

Figure 2 Groundwater contours and inferred flow directions (late 2019 using all data)

b. Alluvial extent in areas of current uncertainty

The mapped areas of the alluvium and the associated monitoring are provided in Figure 3. The monitoring points are provided for context for the hydrographs provided in subsequent sections (Sections 4.2,4.3,4.7,4.10,4.19) of these responses.

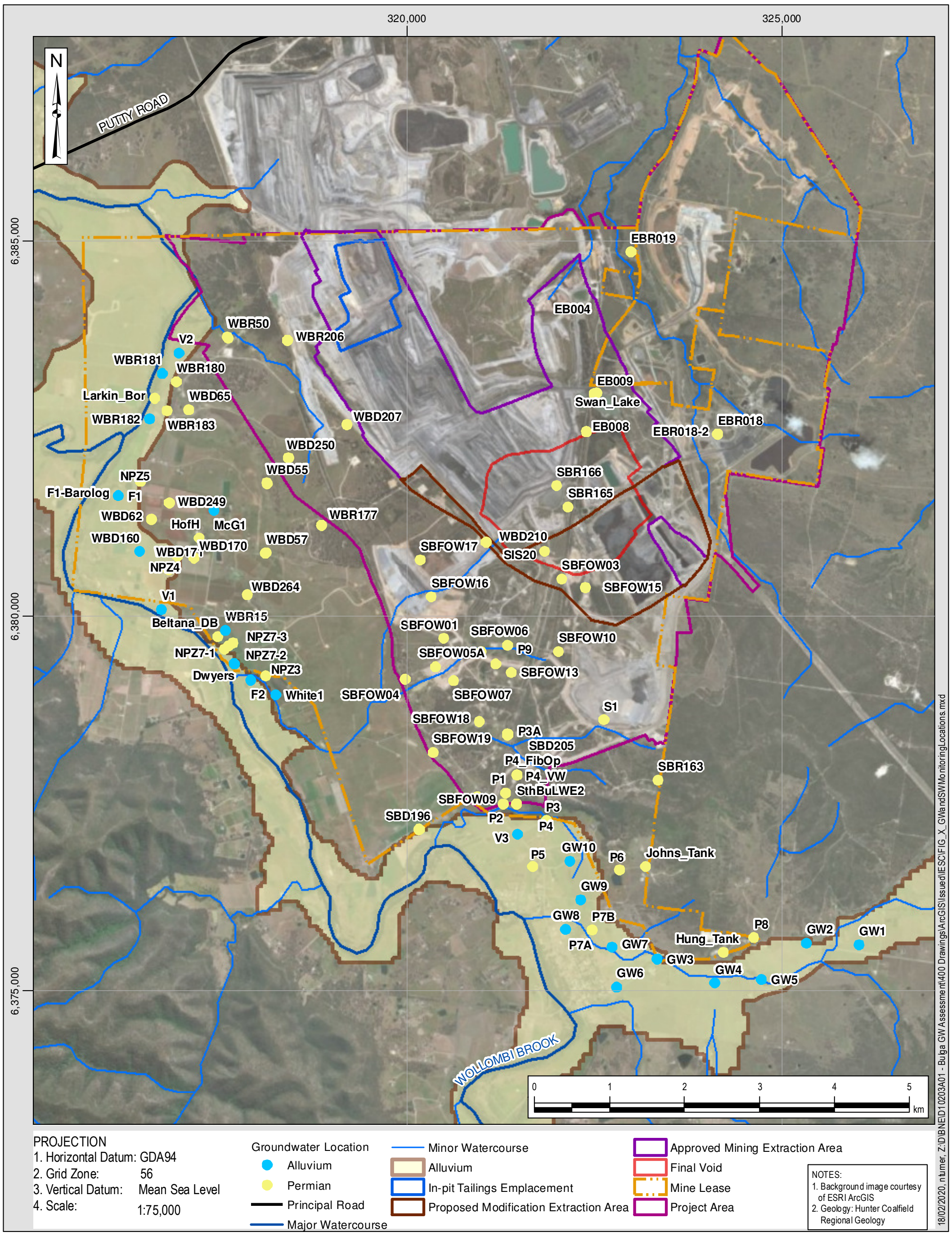

Figure 3:Water monitoring relative to local geology and alluvium

Several bore pairs were selected to illustrate the sharp difference in responses of the alluvial and adjacent sedimentary units (Figure 4). This is shown by both water level elevation (alluvial bores have high elevations surrounding bores) as well as the temporal variation between these pairs. To better illustrate that this response is consistent across the project site, the selected bore pairs have been taken from various areas across the site. Alluvium exhibits a small seasonal vertical variability (generally sub-metre scale) and a strong relationship to large flow events in the creeks.

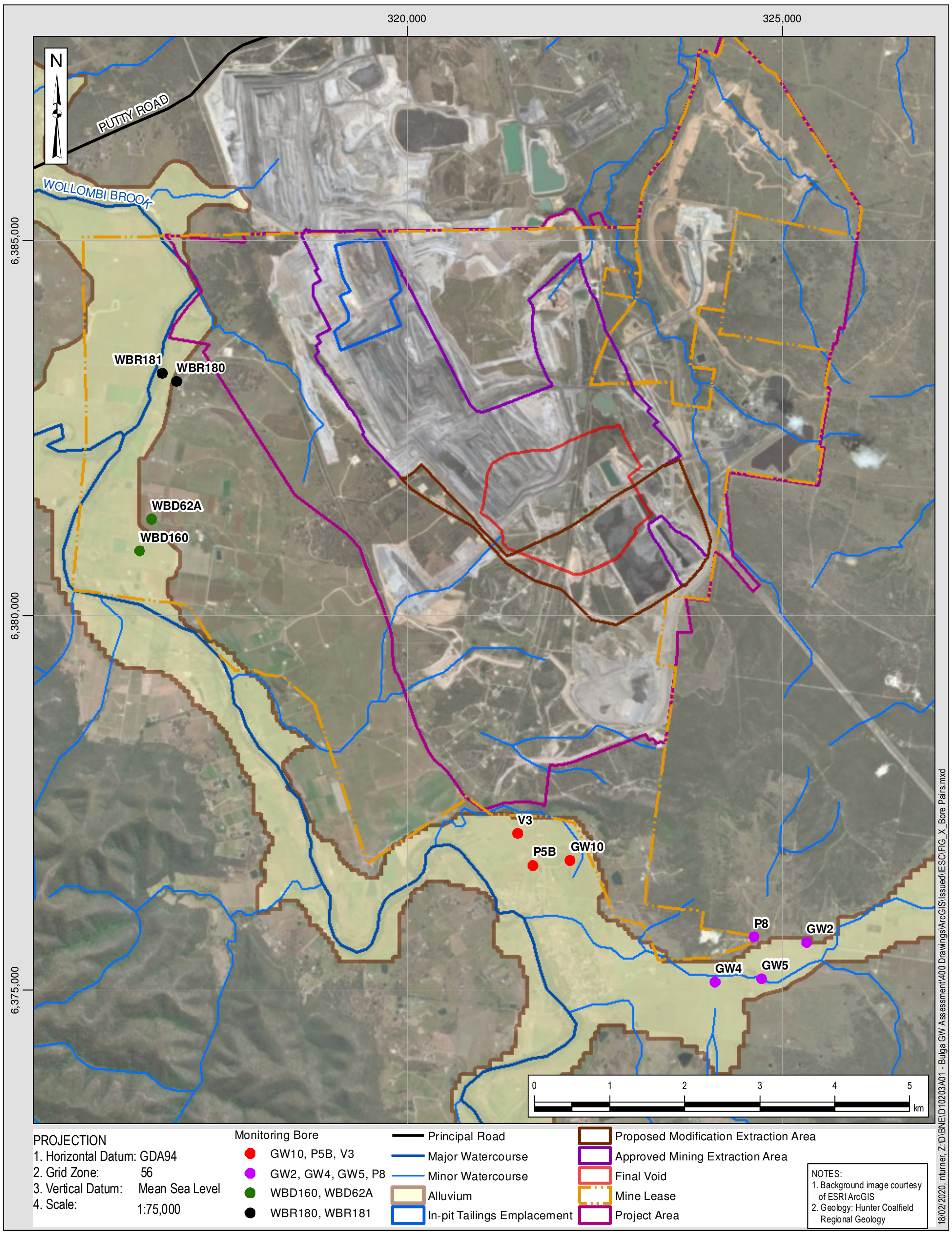

Figure 4: Areas used to compare alluvial to Permian groundwater responses

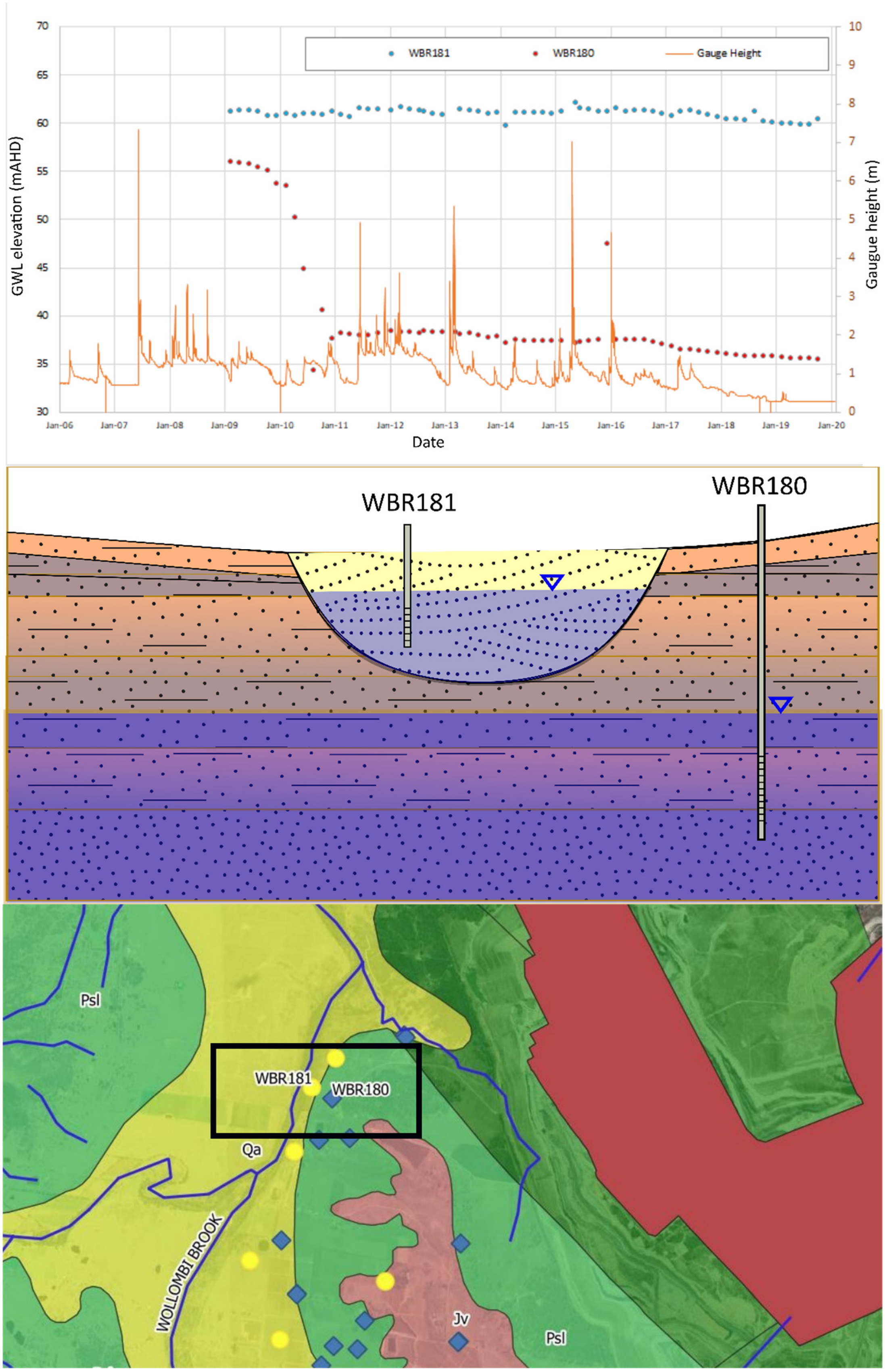

Figure 5: Hydrograph and simplified conceptual section for WBR181 (alluvial) and WBR62A (The▽ symbol indicates the water level in each system).

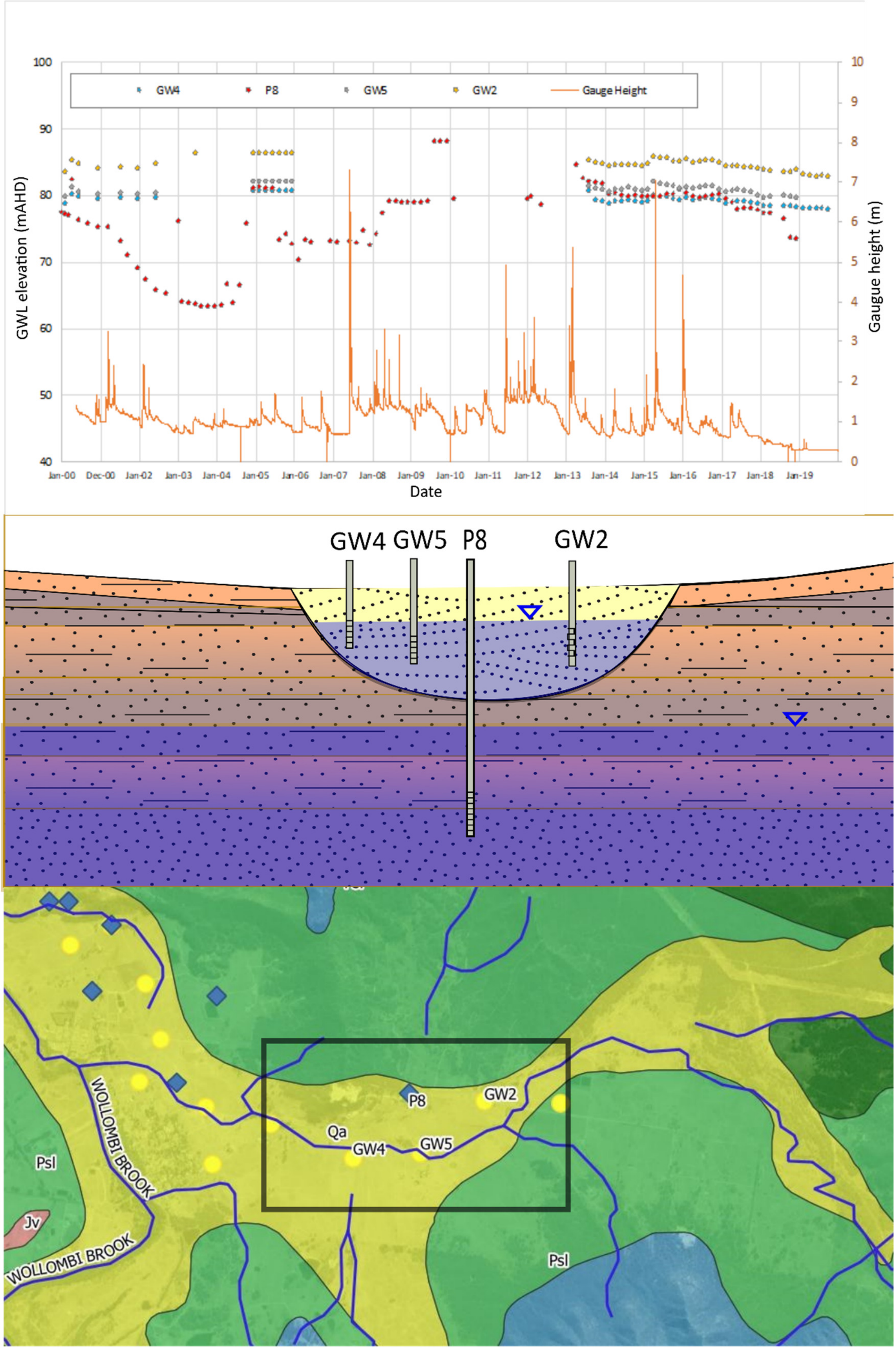

Figure 6: Hydrograph and simplified conceptual section for GW2, GW5 and GW5(alluvial) and P8

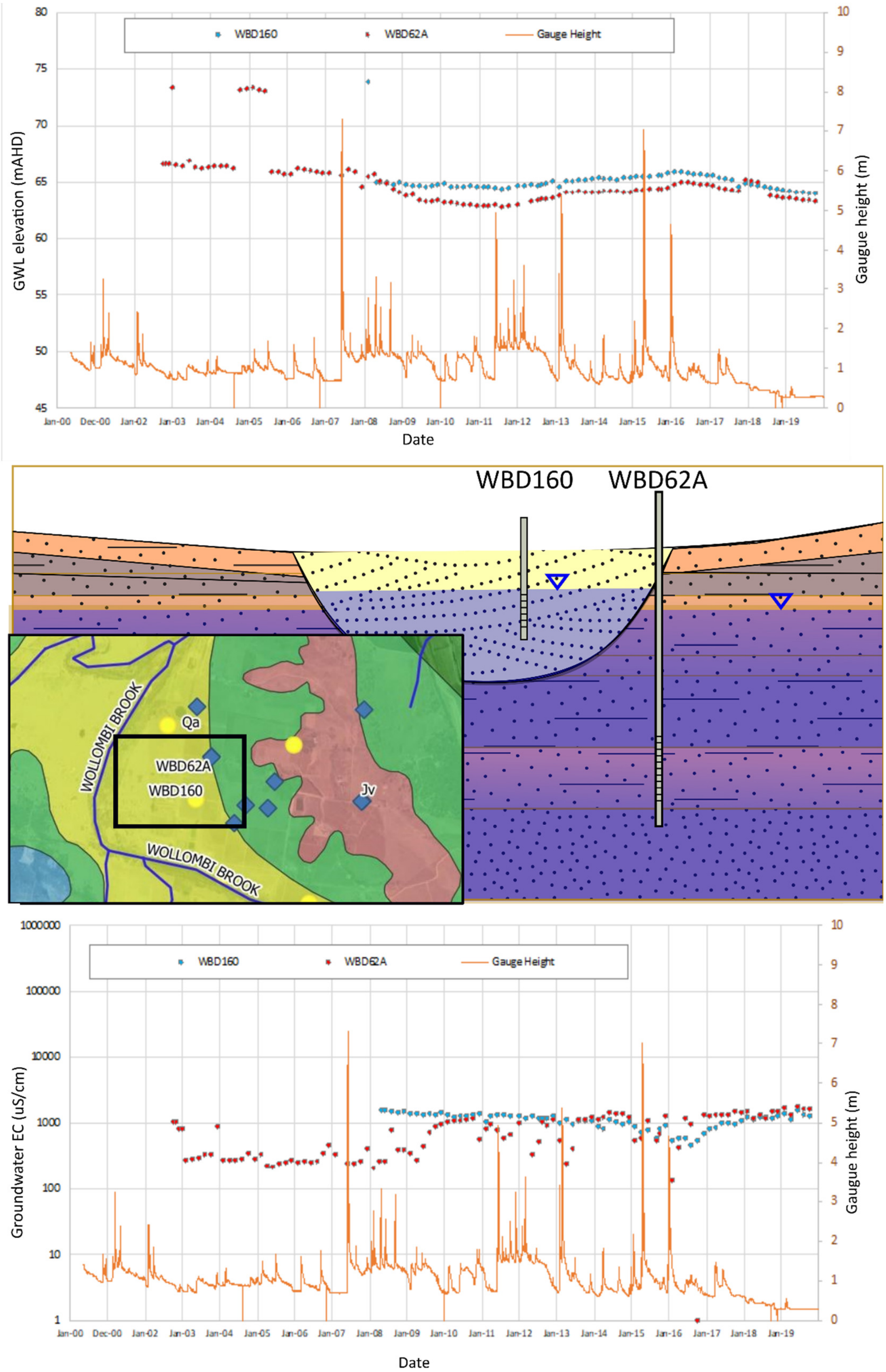

Figure 7: Hydrograph, EC time series and simplified conceptual section for WBD160 (alluvial) and WBD62A

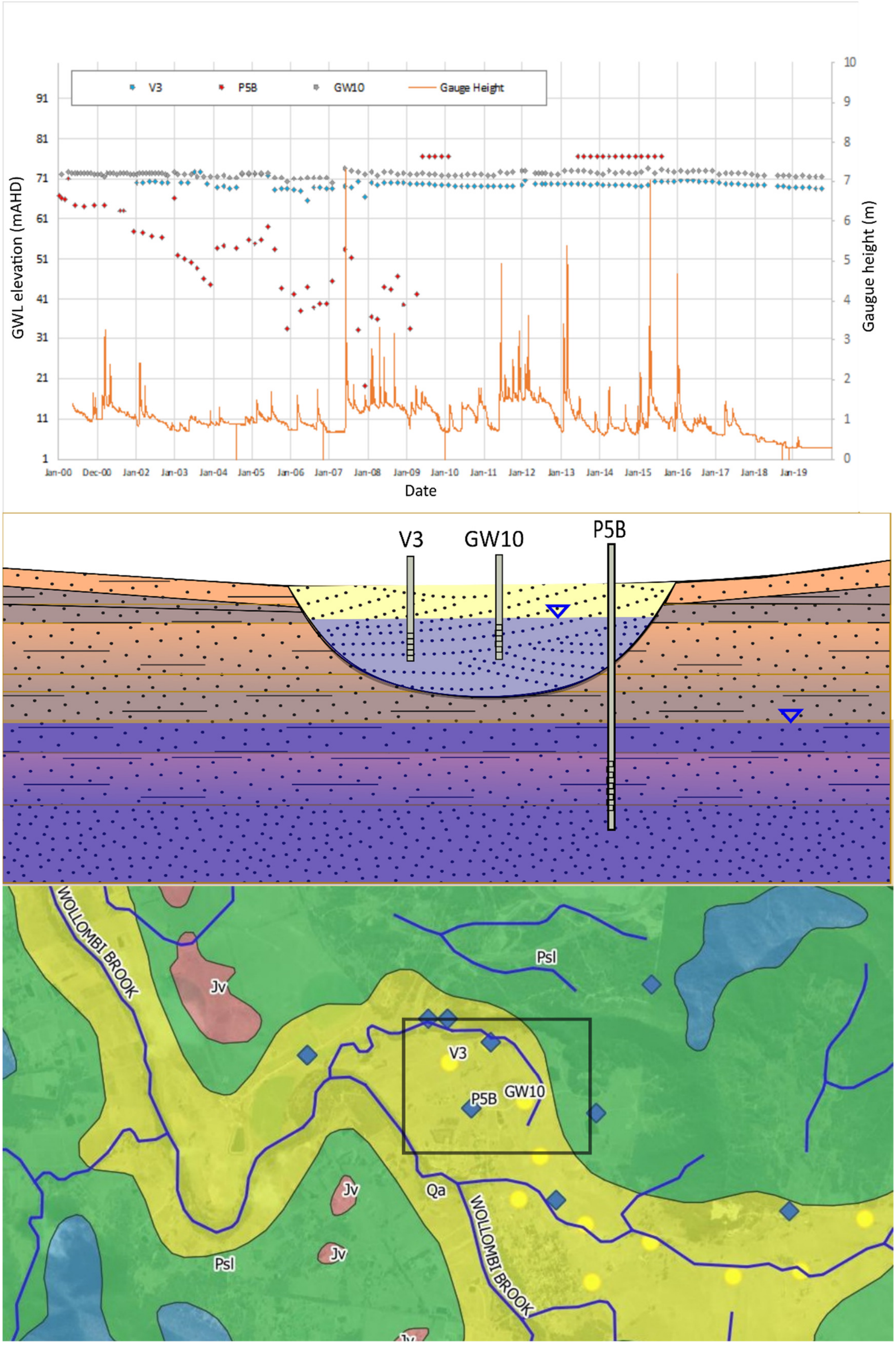

Figure 8: Hydrograph and simplified conceptual section for V3/GW10 in alluvial and P5B

c and d. Hydraulic connection with Permian aquifers

Previous interpretation of the available groundwater monitoring data supported the hydraulic disconnection between the Permian and alluvial units in the project area. In addition to the information provided in the preceding point, further data has been considered to confirm these interpretations. More recent monitoring data up to the end of 2019 has been provided and collated. These results support the previous interpretation and show that the alluvium is largely hydrogeologically disconnected from the Permian in the study area. Examples are provided in a series of hydrographs (Figure 9 and Figure 10)

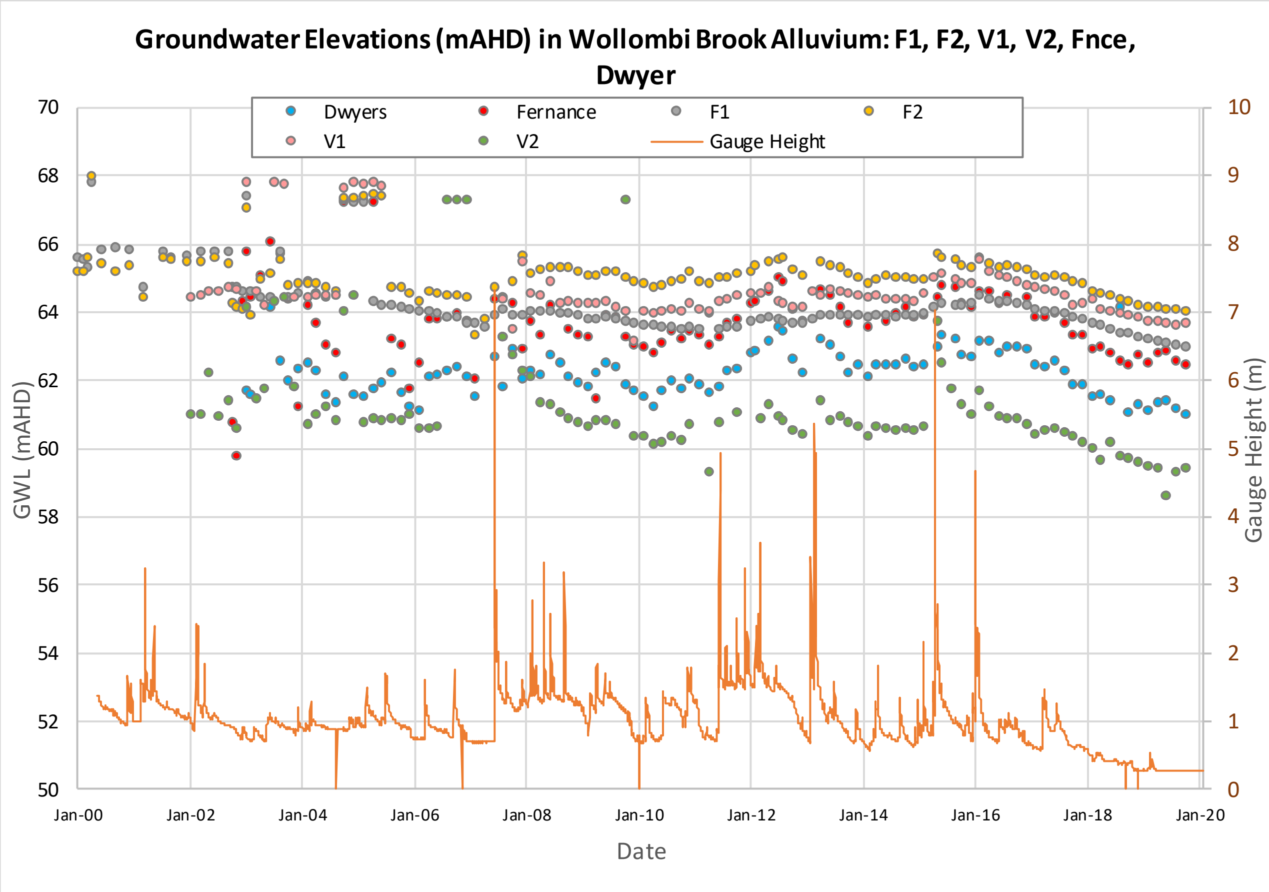

Figure 9: Time series of groundwater levels within the Alluvium

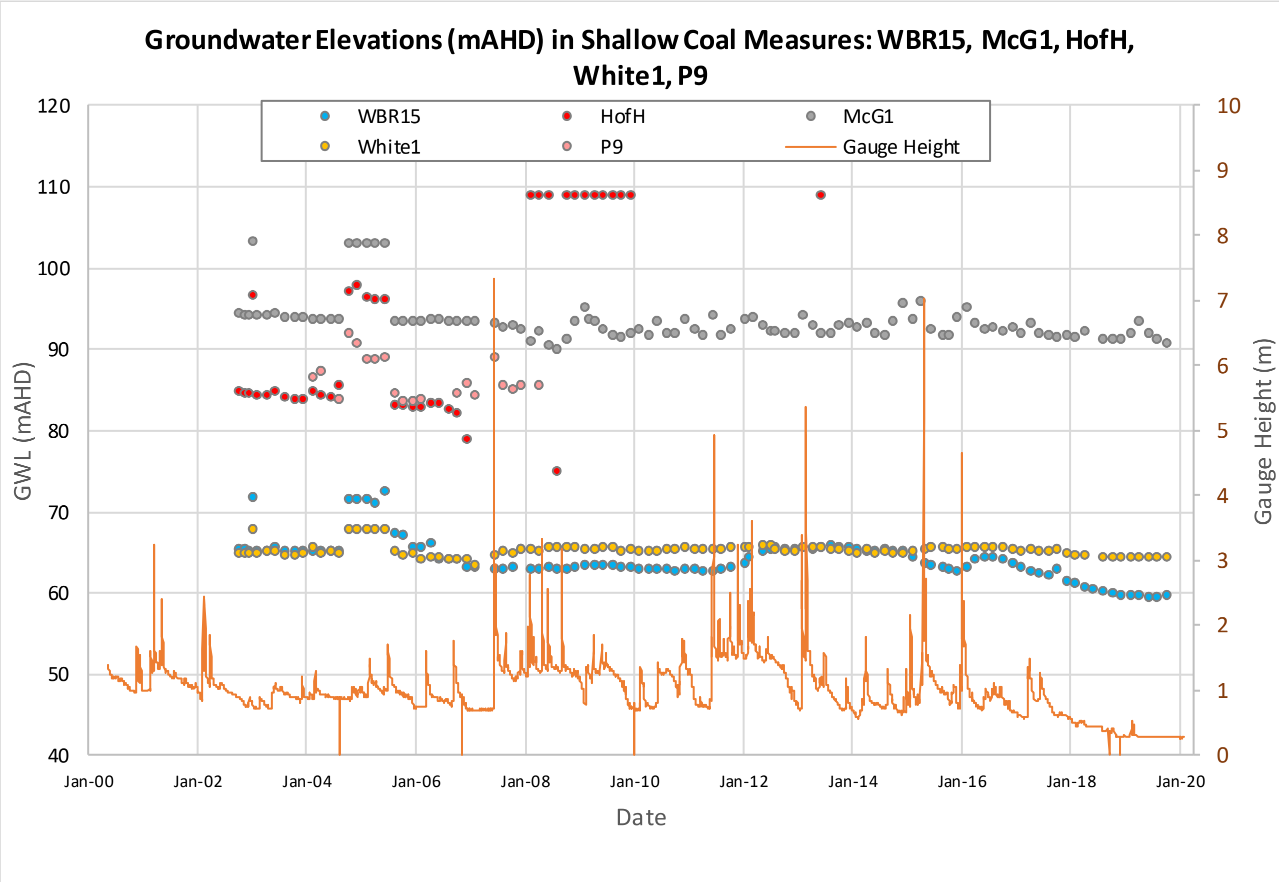

Figure 10 Time Series of GWL within the Shallow Coal Measures (up to end of 2019)

Monitoring data presented from piezometer records show a very strong linkage between alluvial aquifer response and creek elevation. The amount of water passing from the groundwater system to the surface drainage is, therefore, more strongly influenced by rainfall and consequent creek flow, than changes that may occur in the underlying Permian units. The poor hydraulic disconnection between the alluvium and the Permian strata is consistent with the conceptual understanding of the area.

Areas, where the alluvial aquifer system could potentially be connected to the Permian aquifer system, are indicated in Figure 11.

Figure 11 provides the potential change in water levels as a result of the project likely presents a conservative scenario, since the alluvium is represented in the model as zone(s) of higher conductivity within Layer 1 in the numerical model.

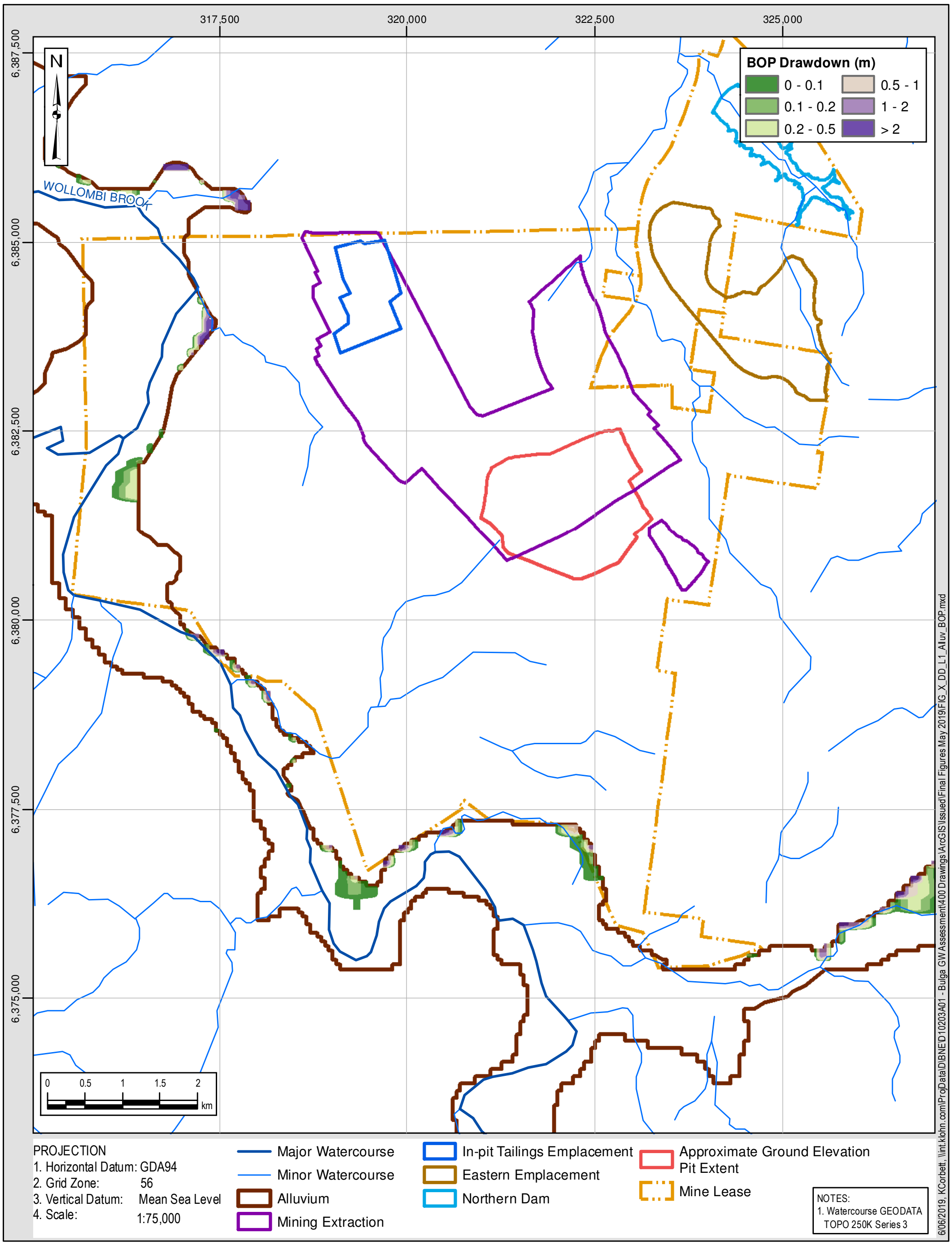

Figure 11: Areas of potential Alluvium and Permian connection (as indicated by maximum drawdown)

While Figure 11 indicates several small zones of potential water level change, these changes should be considered in the context of the already-approved case. The comparison of the predicted water levels in the alluvial sections are provided again for consideration (Figure 12) and, in addition, the end of mining comparison of water levels across the model domain for the end of mining are provided in Figure 13. For both cases, the total cumulative impact of historical, existing and future approved mining has been included. Including all the approved underground mining provides the most conservative case as future underground mining, while approved may not proceed.

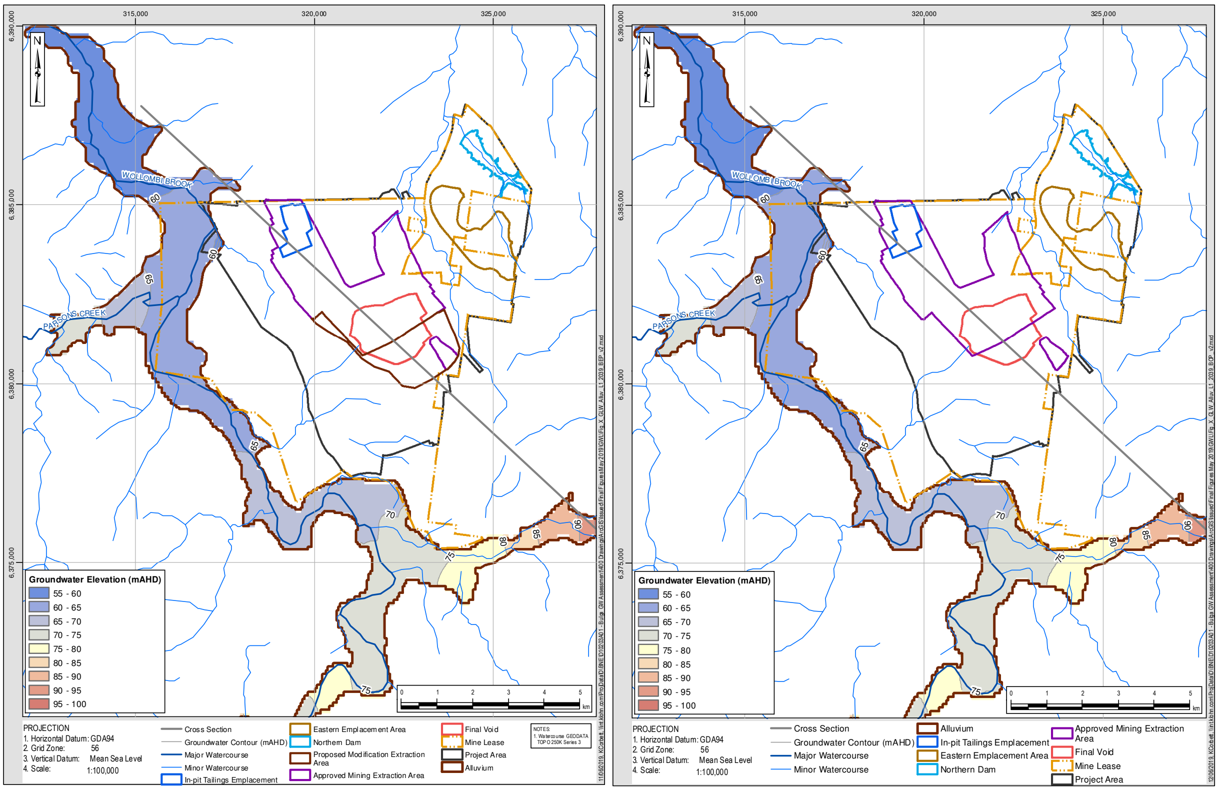

Figure 12: Predicted Groundwater Elevation in Alluvium – Largest Impact (Year 2039), Proposed Modification (L) and Approved Operation (R). A larger-scale version is presented in KCB 2019.

Figure 13 shows that, while there are significant differences in the water levels at or adjacent to the mining operations (as would be expected with the modification), further afield toward the alluvial areas, the difference between the approved and proposed modification cases is negligible. As indicated previously predictions of drawdown in the Permian are of the order of 100's of metres, which are consistent with observed VWP records in previously mined areas of the operation. This drawdown is largely due to the impact from the approved underground mining operations.

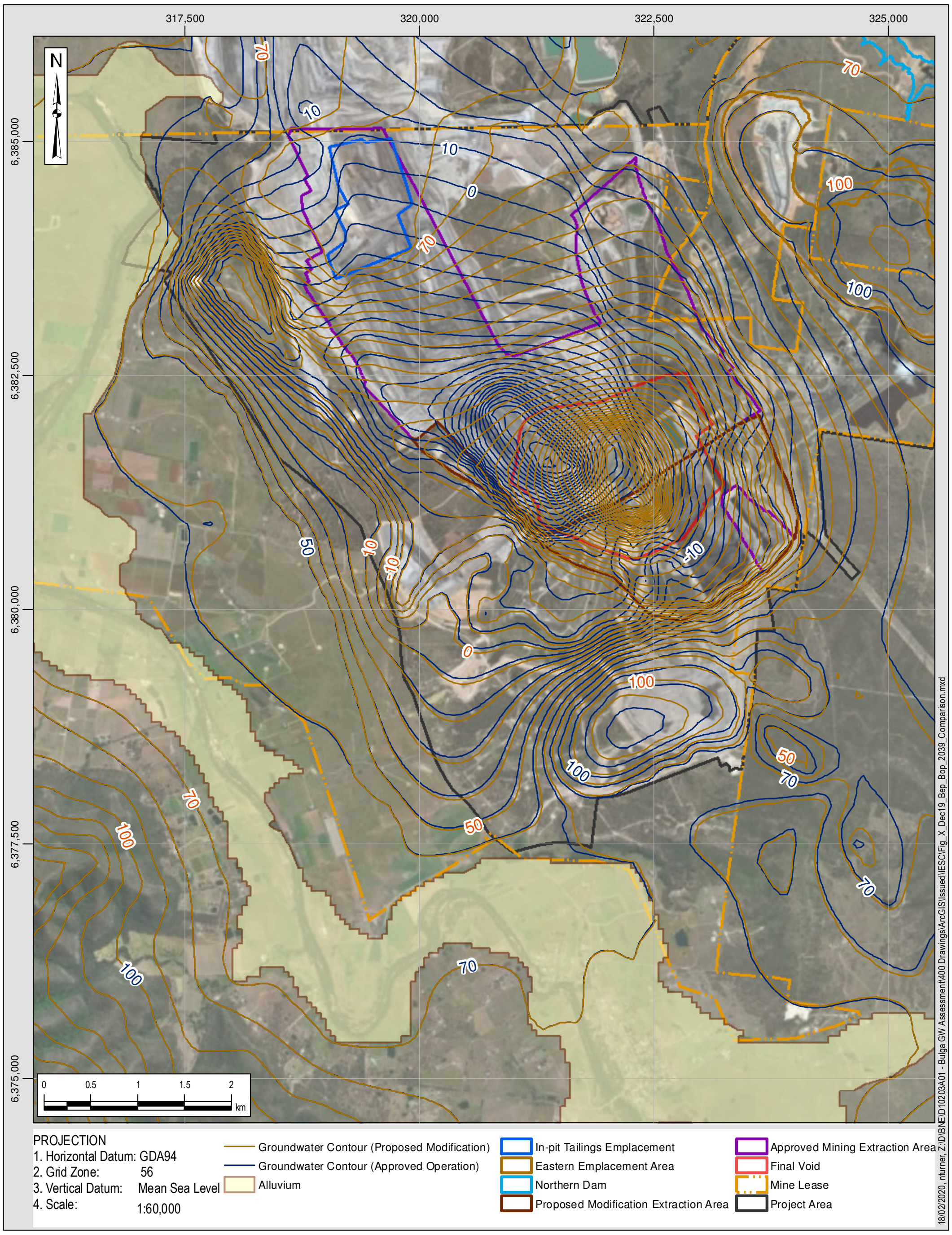

Figure 13: 2039 predicted groundwater level contour comparison for the approved and proposed modification case

f. Warkworth Sands Woodlands:

The Warkworth Sands are a perched groundwater system overlying low permeability weathered Permian and recharged by rainfall. While the Warkworth Sands are assessed as disconnected to the modelled Permian layers, model results for the Proposed Modification suggest that no additional drawdown will occur in the Permian units immediately underlying these sands (underground mining at ~750 m south of the Warkworth Sand Woodlands), as a result of the Proposed Modification. The model results (Figure 5 3, p.79), as well as the probable long-term presence of perched conditions, suggest that it is unlikely that ongoing mining under the Proposed Modification scenario will negatively impact on groundwater conditions in the Warkworth Sands.

Glencore has undertaken additional characterisation of the area and has installed further monitoring to confirm this.

g. Contaminants in the Wollombi Brook

The monitoring data up to the end of 2019 shows that the Wollombi Brook alluvial bores have a relatively stable water quality, largely driven by the surface water flows rather than by the adjacent Permian water quality; the monitoring data shows no trends of persistent increasing concentrations in measured water quality parameters (including salinity and sulfate) This aspect is discussed in more detail in the response to Comment 27 (Section 4.10).

4.2 Comment 3

The proponent states that the project will impact Wollombi Brook and Loders Creek through changes to catchment areas, and because of reductions in baseflow due to increased groundwater drawdown. The main changes include a reduction of the Loders Creek catchment by 397 ha and an increase in the Wollombi Brook catchment of 354 ha. Baseflow in Wollombi Brook is predicted to decrease by up to 1.38 ML/day (Engeny 2019, pp. 28-29). The proponent states that the assumptions used to assess baseflow impacts were conservatively high as all leakage from Wollombi Brook was assumed to be lost from the surface water system. However, this analysis does not consider the large uncertainty in the groundwater modelling relevant to baseflow impacts, nor the evident bias associated with under-prediction of Layer 1 groundwater levels (as discussed in Paragraphs 18, 19, 22 and 31).

The response provided in Section 4.1 addresses several of the conceptual aspects of the model and the data underpinning the model. To reiterate the main points:

- Historical and the recently updated monitoring data shows that the alluvial systems and the adjacent Permian sediments/coals have a markedly different hydraulic response and that the main drivers on the alluvial systems are the changes in rainfall and creek flows. The focus of the numerical groundwater modelling was to understand which additional impacts (over-and-above the already-approved mining case) may arise in the groundwater system. The model simulations predict that around the mining activities a marked difference in groundwater response between the approved case and the proposed modification is expected in the Permian sediments, largely as the direct result from an increase in the open-cut depth; these predicted differences are consistent with the observations of groundwater responses in the Permian in the monitoring record.

- Conversely, the model results indicate that the difference in groundwater levels in the alluvials (at the maximum case at the end of mining prior to rebounding groundwater around the mining operations and recovery of water levels in the mining pit) is small to negligible.

Following on from the response detailed in Section 4.1: More recent monitoring data has been collated and interpreted, following IESC guidelines. The recent results support the hydrogeological conceptualisation that the alluvium is mainly hydrogeologically disconnected from the Permian in the study area. This evidence of the poor hydraulic connection between the alluvium and Permian aquifer systems is consistent with the modelling approach adopted.

The modelling objective was to assess the incremental impact on the groundwater environment as a result of the SSD 4960 Mod 3 implementation (mining activities within the Permian), in comparison to the already approved SSD 4960 Mod 2 mining activities.

The alluvium is presented as a higher conductive zone(s) within Layer 1 in the numerical model. Since the model was largely focused on calibrating the impacts of the mining and these have been shown to occur in the Permian, the model shows good comparison to the Permian but underpredicts groundwater levels in Layer 1 (uppermost layer of the model); further discussion is provided in the response to Comment 18 (Section 4.3).

Additional support for the conceptual hydrogeological setting is presented by an alluvium study conducted based on geological logs and supported by the water quality data from piezometers installed in this area. This study concluded that the Northern Drainage Line (NDL) alluvium is a localised groundwater system, recharged by rainfall, with discharge to the Wollombi alluvium. The extent of the NDL alluvial is limited, and generally comprises clay and silty clay about 4-5 m in thickness, with a low hydraulic conductivity (0.02 to 0.01 m/d). This classifies the NDL alluvium as a poor aquifer to aquitard (Katarina David 2014).

With this understanding, the numerical model was used to present the potential worst-case impact (at the end of mining in 2039 prior to groundwater level recovery) on the natural drainage system from SSD 4960 Mod 3 as presented in Table 4-7 (p.68, KCB August 2019). The results and the development of water take to each of these indicates that the Proposed Modification will have a small to negligible incremental impact on the alluvial take to each of these reaches.

Table 1 (Originally provided as Table 4-7 of KCB's 2019 report, p.68 refers): Predicted Natural Drainage Impact Summary

Natural Drainage	Approved Project – Flow Rate @ 2039 (m^3/d)	Proposed Modification – Flow Rate @ 2039 (m^3/d)	Incremental Impact of Proposed Modification (m^3/d)	Incremental Impact of Proposed Modification (ML/d)	Assessment
Wollombi Brook (Beltana Reach)	1392	1380	-12	-0.012	<1% baseflow take
Wollombi Brook (Bulga Reach)	528	528	-	-	Negligible impact
Lower Monkey Place Reach	389	382	-7	-0.0007	<1.7% baseflow take
Upper Monkey Place Reach	450	449	-1	-0.001	Negligible impact
Loders Creek	31	31	-		Negligible impact
Nine Mile Creek	14	9	-5	-0.005	~36% baseflow take in average conditions (~ 0.05 L/s)

The relative differences in baseflows for each of the drainage lines between the approved project and the proposed modification case can be illustrated in Figure 13 and Figure 14 for 2020 and 2039 respectively. These figures illustrate that while there are differences in the contributions to each creek section, these differences are small and are unlikely to be measurable in absolute terms or be observable relative to natural variability.

From the multiple model runs completed, the model is behaving as expected to the stresses, and is producing very strong repeatability. This repeatability is shown by the predictive simulations but also the sensitivity, with differences between 1% to 2% in comparison, suggesting a small (and likely unmeasurable) difference in baseflow take between the already approved and proposed projects.

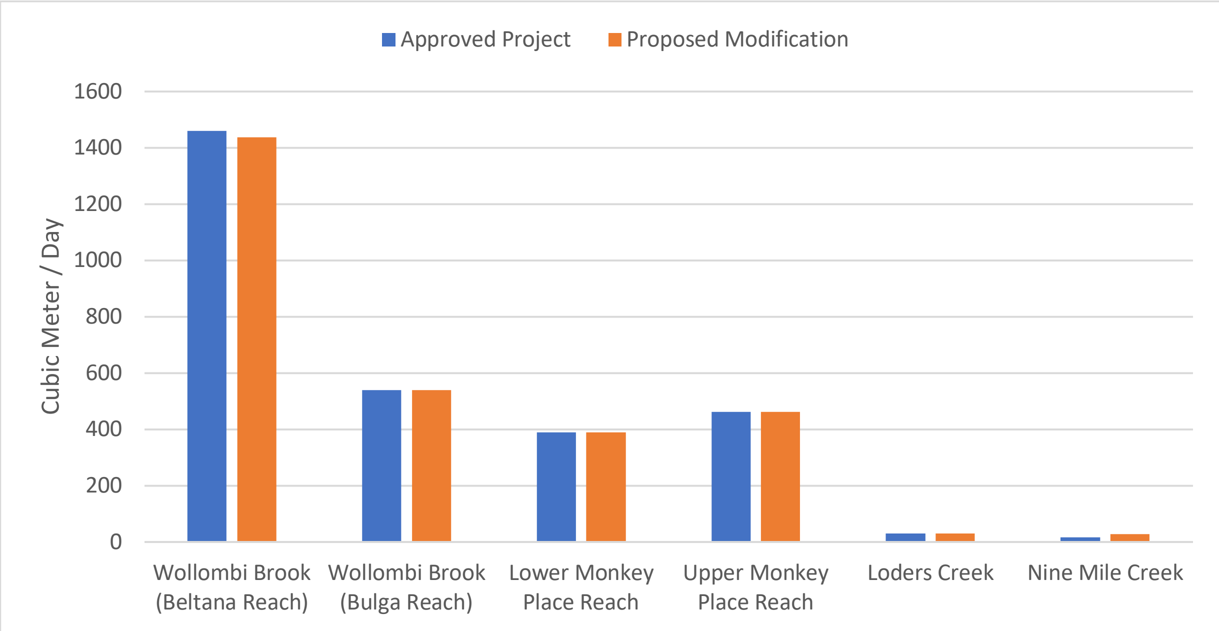

Figure 14: Predicted flows to each reach (Approved and Proposed Modification): 2020

Figure 15: Predicted flows to each reach (Approved and Proposed Modification): 2039

KCB also presented the impacts of sensitivity uncertainty analysis as Appendix III of the 2019 groundwater report. For the sake of brevity, details of this assessment are not repeated in full in this response but results from the sensitivity analysis are provided in Table 2.

Table 2: Range of flows from all sensitivity models (proposed modification case) for Predicted Natural Drainage

Natural Drainage	2020 (All sensitivity model runs)			2039 (All sensitivity model Runs)		
	Max (m^3/d)	Min (m^3/d)	Median all models (m^3/d)	Max (m^3/d)	Min (m^3/d)	Median all models (m^3/d)
Wollombi Brook (Beltana Reach)	1956	1108	1477	1616	1118	1420
Wollombi Brook (Bulga Reach)	734	422	586	734	422	573
Lower Monkey Place Reach	507	319	393	441	326	385
Upper Monkey Place Reach	629	341	469	528	357	458
Loders Creek	32	10	19	33	11	19
Nine Mile Creek	33	11	15	20	7	17

4.3 Comment 18

The proponent notes that currently the alluvium is not represented in detail in the groundwater model because the model is intended to predict impacts on Permian aquifers (KCB 2019, p. 68). The IESC considers this to be a significant limitation severely reducing confidence in the predicted impacts of groundwater drawdown within the alluvial aquifers. The history-matching hydrographs provided for Layer 1 of the groundwater model, which include the alluvial aquifers, indicate bias as the modelled hydrographs are unable to replicate the observed variability and systematically under-predict groundwater levels. As a result, the current groundwater model has limited application for predicting impacts to the alluvial aquifer, GDEs and baseflow changes. The groundwater model requires further work including improved representation of the alluvial aquifer and should be history-matched with field data to provide confidence in predicted impacts.

Following on from the responses detailed in Sections 4.1 and 4.2: There are three general hydrogeological systems across the BCC area:

- Alluvial aquifers associated with the Monkey Place Creek and Wollombi Brook which overlie Permian strata and wrap around the south and west of the main mining area.;
- Warkworth Sands Woodlands (WSW), adjacent to the west of the existing operations and the Mount Thorley open cut mines. This system is interpreted as perched, positioned over lower permeable Permian and not in hydraulic connectivity with the underlying groundwater system; and
- the Permian coal measures of the Singleton Super Group which host the mined resource and represent outcrop in all areas where regionally mapped alluvium is absent (low yielding, confined aquifers).

The alluvium of the Wollombi Brook and Monkey Place Creek are well instrumented, with 11 and 5 piezometers in each aquifer respectively, all with relatively intact records which show good correlation to Wollombi Brook flow elevation. In the Beltana mining area, coverage is relatively dense along the western margin of the mine footprint where it spatially approaches the edge of the alluvium. The distribution of monitoring in the area of drainage from Monkey Place Creek to Wollombi Brook also indicates that this is portion is well-instrumented.

This network is extensive and is considered adequate for verification of hydrogeological concepts and model calibration purposes. Depending on the location and depth of monitoring, and the timing of data collection, Permian strata have observed significant response to mining development, of the scale of 10's to 100's of metres. This is in contrast to the response of the alluvium which is more strongly aligned with creek flow (and possibly local alluvial abstraction), which only observe metre to sub-metre scale vertical variations of groundwater level.

The two systems are therefore assessed as having limited connectivity (hydrogeologicaly disconnected); further supporting information is provided by the monitoring data records.

The VWP records in Appendix I (KCB August 2019) show the nature of multiple level monitoring available for the site. A good example of this is SBF09, reproduced below (Figure 16), which monitors confined strata between the Lower Whybrow Seam and the Vaux Seam (KCB 2019, p.34). This shows two periods of mining impact: the first is from about 2010 to 2013 and has a similar effect on the four shallower seams. The second period is from 2014 to 2018; and shows a variable impact to each of these layers, although all respond to the mining activity. Data from V3, located in alluvium in close proximity, was included to demonstrate that the two systems (alluvium and Permian) behave independently.

	01. Regolith
	01. Alluvium
	02. Narabeen Group
	03. Permian CM
	04. Alcheringa Seam
	05. Permian CM
	06. Permian CM
	07. Permian CM
SBFOW04A-6, -7	08. L.Whybrow Seam
	09. Permian CM
	10. Permian CM
SBFOW04A-5	11. Blakefield Seam
	12. Permian CM
SBFOW04A-4	13. Glen Munro Seam
	14. Permian CM
SBFOW04A-1, -2, -3	15. Woodlands Hill S.
	16. Permian CM
	17. Vaux Seam
	18. Permian CM
	19. Permian CM
	20. Saltwater Ck. Fm

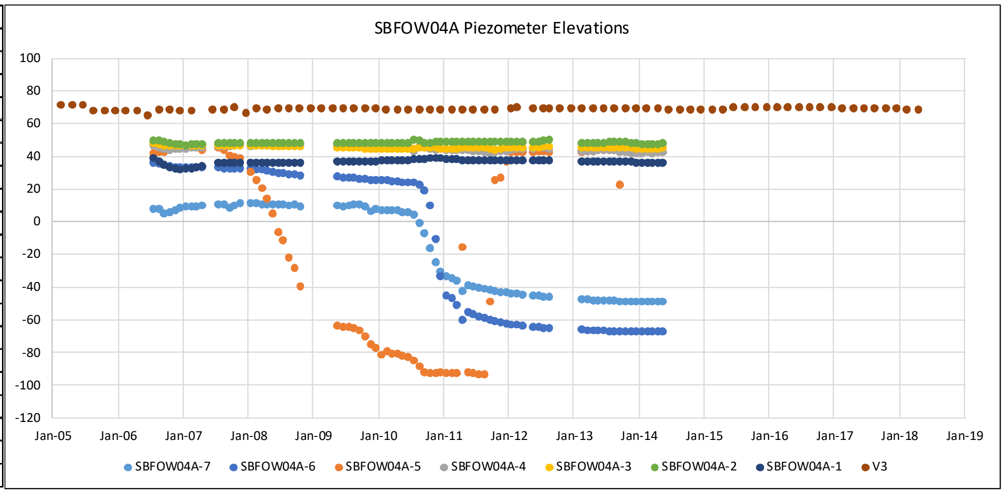

Figure 16: Example Vertical VWP Data, SBFOW09 1-6

Alluvium exhibits a small seasonal vertical variability (generally sub-metre scale) and a strong relationship (recharge response) to large flow events in the main creek systems. The response of these flow events is observable in a number of hydrographs – both in terms of their physical head or pressure response and in several sites, a noted reduction post-flow in EC level (dilutional effects). Any possible aquifer responses from mine depressurisation of the underlying Permian strata, are either too small to discern or are masked by the stronger recharge events which drive the shallow alluvium water balance.

The consistency between the conceptual understanding and model representation suggest that the numerical model is appropriate and fit for purpose to assess the incremental impact on the groundwater environment from the proposed SSD 4960 Mod 3 (in comparison to the already-approved SSD 4960 Mod 2 mining activities).

Head predictions in the alluvium (KCB 2019, p.60) indicate no visual difference between the Proposed Modification (SSD 4960 Mod 3) and the Approved Mining scenario (SSD 4960 Mod 2). Mining impacts, which are predicted to continue to be small consistent with the current monitoring data, appear in localised areas of the alluvium and are the consequence of the Approved Mining activities. The Proposed Modification does not appreciably change groundwater conditions in the mapped alluvial areas, compared to the Approved Mining scenario.

4.4 Comment 19

The history-matched hydrographs provided by the proponent highlight that in many layers simulated and observed heads vary considerably (sometimes by greater than 50 m). Discussion of the history-matching results was limited and focused primarily on the improvement between model versions rather than providing an analysis of potential causes for the observed mismatches. Additionally it was stated that there were limited data available for history-matching (KCB 2019, p. 53) though this was not explained. It also appears that not all available data were used for history-matching, for example, groundwater inflows to the mine do not appear to have been used as a direct history-matching target in the groundwater model. The proponent compared predicted mine inflows from the current model with those calculated in a previous version of the groundwater model (KCB 2019, p. 54) rather than providing a comparison to measured inflows. Further discussion and analysis is required of the data used for history-matching and how groundwater model predictions compare to observations to provide confidence in the ability of the groundwater model to predict impacts to important environmental assets such as the Wollombi Brook alluvium, surface waterways and GDEs. Further monitoring of the groundwater levels in the alluvium is recommended to provide more relevant data for history-matching.

Matching of the modeled predicted levels to available observed data has been provided in Appendix II as a summary of the model calibration (KCB August 2019).

KCB extracted transient monitoring points across all bores in the calibration period (up to 2018); and achieved a normalised RMS error of 10% focussed on the Permian mining sequence. This suggests that the model better replicates late-time observations; that is observations that are not as influenced by misalignment of mining stress timing; and represents a considerable improvement on previously reported values, used for the approved SSD 4960 Mod 2.

Figure 17 provides a visual comparison of modelled versus observed data for the entire transient data set used. A comparison is also shown on this figure that provides a subset of this information focussed on late calibration period (2018 data). Furthermore, this improvement supports the use of the “end of calibration period” modelled state for use as the initial state groundwater environment for use during predictive simulations.

Since the modelling was focussed on the potential incremental change to the groundwater regime (i.e. additional changes to the groundwater system in addition to the already-approved case), the focus for calibration remained on obtaining a good match to observed groundwater responses in the Permian layers, aligning measured mining flows to the modeled values and improving the calibration of the model when compared to the approved case.

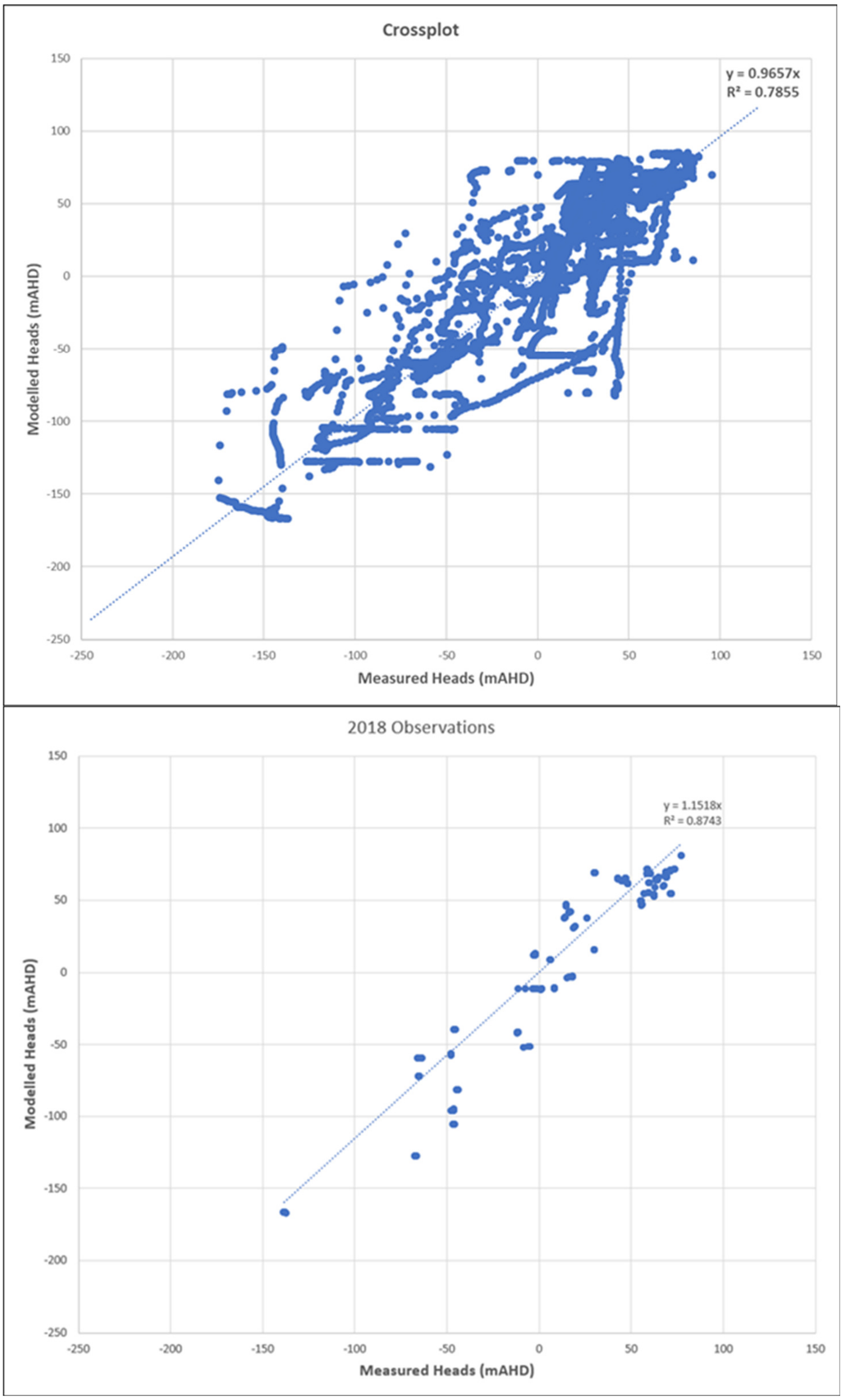

Figure 17: Crossplot of Model Observations and Measured Data for the Transient Calibration period – all data (T), 2018 data only (B).

4.5 Comment 20

The IESC considers confidence in impact predictions could be further increased by undertaking additional sensitivity and uncertainty analyses (Middlemis and Peeters 2018). The reported sensitivity analysis only varied specific yield. It is unclear which parameters were varied in the uncertainty analysis, whether the model used in the uncertainty analysis was constrained by history-matching (noting it was not the current model) and what prior parameter distributions were used. The additional analyses should be used to identify which parameters have the greatest influence on impact predictions under a range of plausible parameterisations and rainfall scenarios. These analyses are needed to assist understanding of how the groundwater model limitations affect impact predictions. Once the likely range of potential impacts is established, the proponent should undertake further work to identify any additional management measures required to address the range of impacts.

As part of the model construction, and calibration process, sensitivity and uncertainty analyses were completed for the model (KCB August 2019, Appendix III).

The uncertainty analysis approach broadly followed the Explanatory Note, Uncertainty Analysis in Groundwater Modelling from the IESC (Middelmis and Peeters 2018), with the approach used for Bulga consistent with the more advanced “stochastic modelling with Bayesian probability” approach outlined by the IESC note. The modeling also considered uncertainty as an integral part of the model development and assessment of results; and included the input of the external model peer-reviewer to assist in framing the approach.

For the penultimate model configuration, a suite of sensitivity analysis was completed for three specific runs, being variants of spoil recharge and spoil hydrogeological conditions, aimed at understanding the potential changes these may have on prediction of interactions between alluvium and Permian strata; and on potential groundwater derived baseflow discharge in mine proximal creeks. The three scenarios were:

- SA1 - Spoil Kh = 1 m/day; Spoil Kv = 0.1 m/day; Recharge factor = 1% of daily rainfall
- SA2 - Spoil Kh = 0.05 m/d; Spoil Kv = 0.05 m/d; Recharge factor = 5% of daily rainfall
- SA3 - Spoil Kh = 0.1 m/d; Spoil Kv = 0.01 m/d; Recharge factor = 2% of daily rainfall

In addition, a non-linear, Monte-Carlo methodology was applied for the uncertainty analysis. This methodology allows a suite of models, which collectively include the plausible range in key input parameters, to be run so that the range of outcomes can be obtained from the suite of models. A total of 360 model runs were completed.

A total of 96 parameters were adjusted during calibration and include K_h, K_v, S_s, S_y and Recharge factors (KCB August 2019, Section 4.3 – p.52 and Appendix II).

The process of automated calibration has resulted in the estimation of all parameters in an unbiased sense; importantly this includes storage parameters. Visual comparison of previous models can be used as a general indicator of the changes made to the simulation. These show:

- Improved RMS of the KCB model over that of the previous models;
- Similar overall mine production rates;

- Head predictions are similar for the calibration period for the models used for previous approvals; and,
- Late calibration time (2018) which represents starting conditions for the transient model observed improved calibration performance statistics of less than 23.5 m RMS error and 8.7% normalised RMS.

Further discussion of the uncertainty results is provided in the response to Comment 21 (Section 4.6).

Glencore has undertaken to include additional groundwater monitoring as part of future environmental management plans for the sites, focused on the future underground mining should it proceed) and in the north/northwest associated with the TSF. Data collected from these additional points (including assessments of aquifer parameters and vertical gradients/separation between units) will be used to update the model once these are in place to confirm the current conceptual understanding and to further bolster the data set used for modelling to date. These future model updates will include further assessment of uncertainty, however, based on the site monitoring and the small incremental impact predicted to arise (from the comparison of the Approved and Proposed Modification cases), this uncertainty assessment is expected to refine the understanding rather than indicate a large-scale impacts. Should the approved underground areas go ahead, additional monitoring around these is expected to provide data to further refine the understanding around the mining area.

4.6 Comment 21

The proponent has identified that there are no privately owned registered bores located within the predicted 2-m drawdown contour. The IESC notes that the range of uncertainty in drawdown has not been clearly presented in the assessment documentation. The results of the uncertainty analysis should be presented as drawdown contours at a range of likelihoods (Middlemis and Peeters 2018) so that decision-makers can have confidence that no privately owned bores are likely to be impacted by the project.

As indicated Monte Carlo analysis on 360 model cases was undertaken. The results of the uncertainty analysis previously provided in Appendix III are presented here again as histograms, using common scale axes, and presented as a percentage of successful runs versus drawdown variance at the eight locations shown in Figure 18 and the summary of results is provided in Figure 19.

The following general comments were previously provided in Appendix III of KCB 2019 but are worth repeating, especially in light of the alluvial areas and the locations of registered bores (See Figure 20):

- Upper Monkey Place alluvium (Segment 8): over 80% of model runs aligned with the cumulative model case predicted value, with the balance of runs falling in the +0.50 m (head decline) group of results;
- Lower Monkey Place alluvium (Segment 9): 100% of model realisations aligned with the 0.00 m drawdown of results, with the cumulative model case predicting a slight water level rise of 0.50 m, indicating minimum impacts in these alluvium segments;

- The stochastic model outcomes indicate the potential for a groundwater level decline in the Wollombi Brook, Bulga Reach (Segment 10): However, the range is between 0.0 and 0.5 m;
- Wollombi Brook, Beltana Reach (Segment 11): the uncertainty analysis predicts a range of outcomes which are generally indicative of groundwater level decline in the alluvium. A maximum groundwater level decline of 1.5 m is possible at this location;
- Nine Mile Creek, Eastern Embankment: A possible groundwater level decrease of between 1.0 and 4.0 m is indicated at this point, which is consistent with other modelling results and observations of decreased flow in this drainage due to a deeper open-cut;
- Nine Mile Creek, Mine Area: there is potential for groundwater level decrease of up to 4.50 m at this location. The cumulative model case predicted a decrease of 2.5 m. This location is in the weathered rock, and not modelled alluvium;
- Loders Creek, Upstream: shows a range of possible groundwater level rise outcomes between 0.00 m and 6.50 m. Again, the cumulative model case predicted a groundwater level rise of between 3.00 m and 3.50 m. This location is also in weathered rock and relates to increased seepage from the spoils.
- Loders Creek, Northern: stochastic model outcomes indicate a potential for groundwater level rises of up to 6.5 m for this location. The cumulative model case predicted a groundwater level rise of 1.50 m.

In general, the uncertainty analysis has shown that there is the potential for slight groundwater level drawdowns in the alluvium segments of the Wollombi Brook (Bulga Reach). The range of predicted drawdowns in these segments is localised and indicates a relatively high level of confidence with similar predictions made by the cumulative case predictive model. In considering these predictions, it is noted that real monitoring data show that the groundwater level response in the alluvium from flow events in the creek will be far greater in magnitude than the model predicted impacts from mining.

In the case of Nine Mile and Loders Creeks, uncertainty analysis shows that there is generally potential for groundwater levels to vary at nearby points to the creek, that potentially translate as decreased or increased baseflows; these creeks are ephemeral and the magnitude of the changes to stream flow are expected to be negligible. It is further noted that the creeks do not have regionally mapped alluvium at a scale that permits them to be represented in the groundwater model.

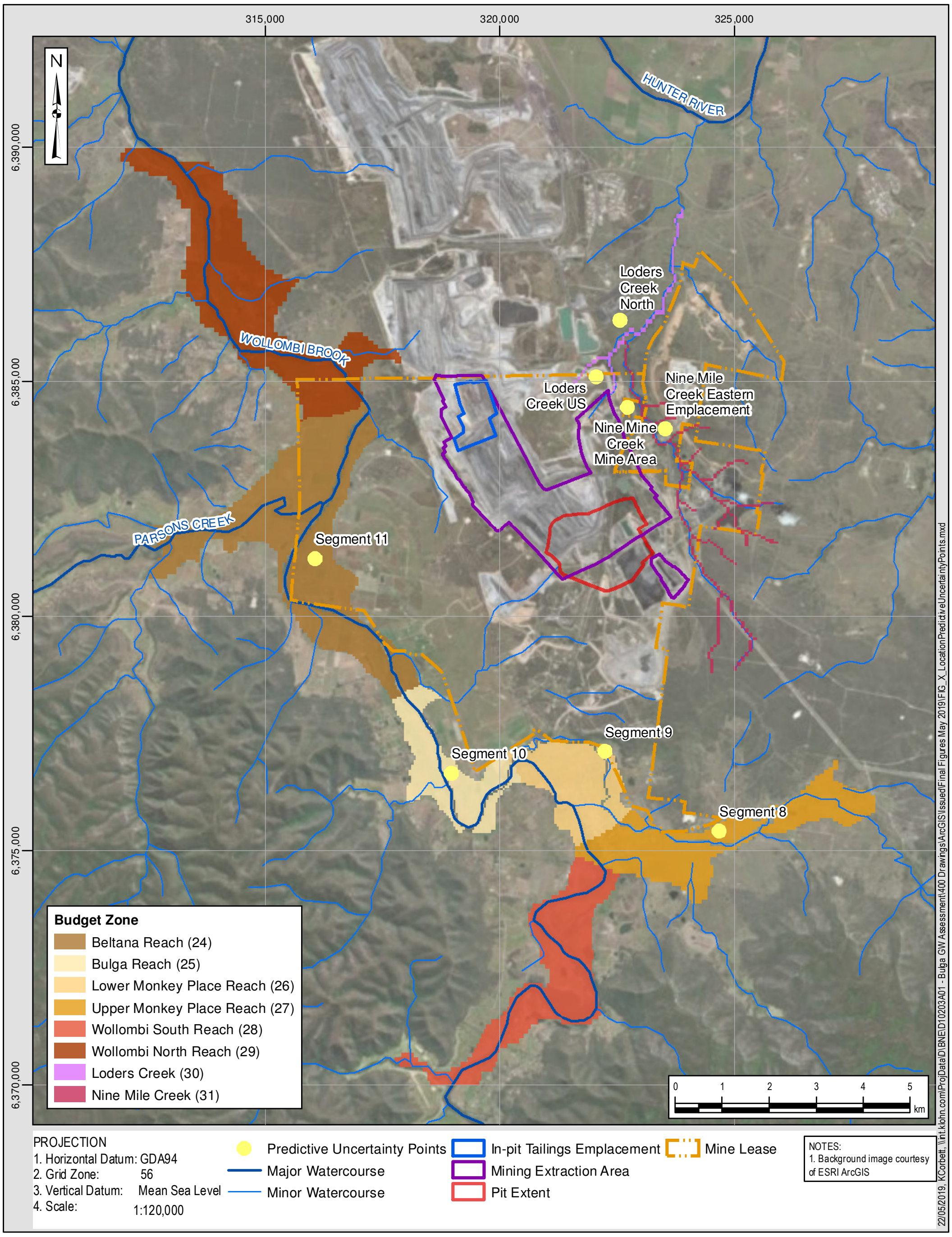

Figure 18: Location of Points used in Predictive Uncertainty Assessment

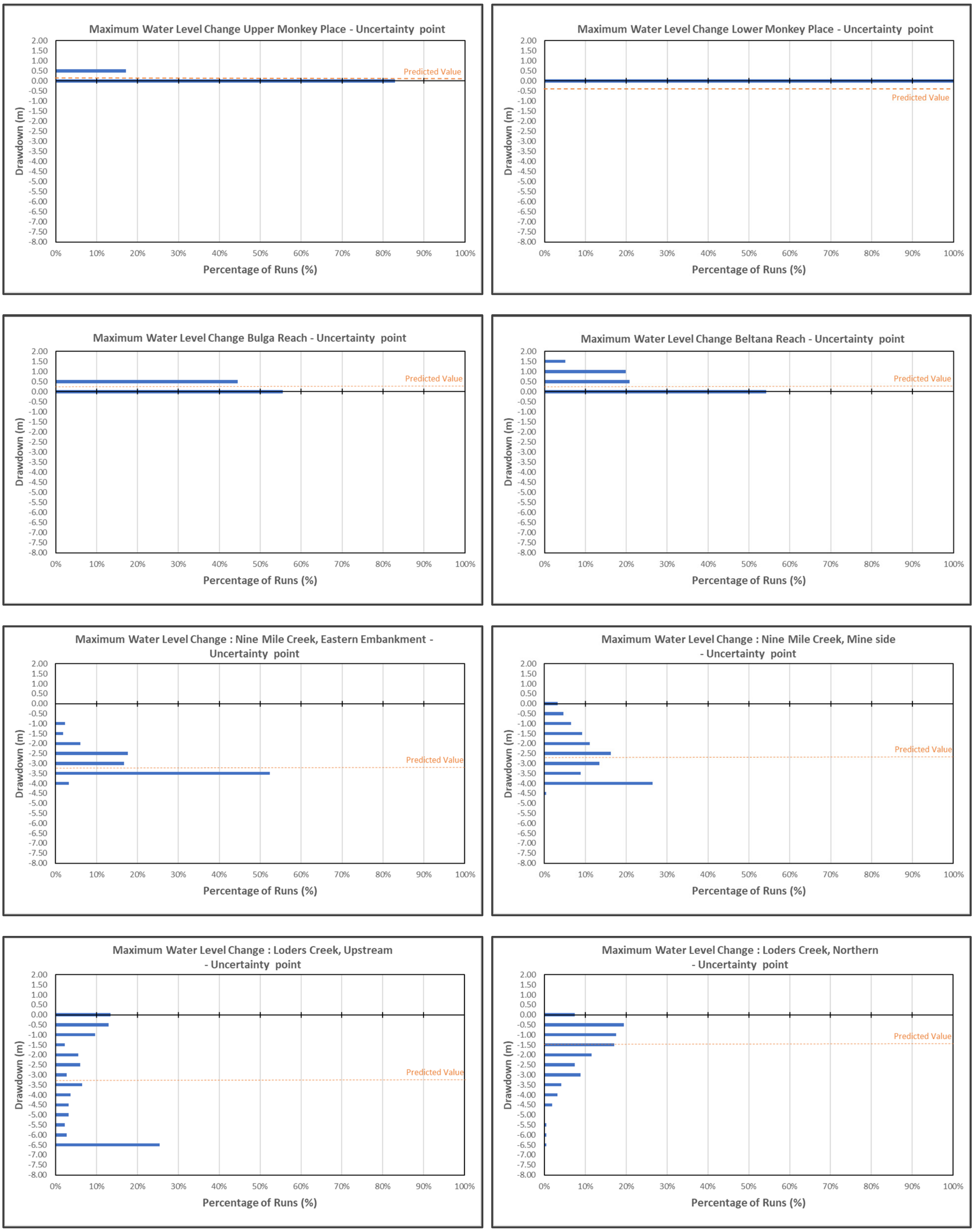

Figure 19: Model Uncertainty Analysis Output

In addition to this, the inferred drawdown extent is significantly distal to any registered bores and, more pertinently for the proposed modification case, the extent of drawdown near the registered bores is unchanged compared to the approved case (i.e. incremental change from the proposed modification is neglible in the areas close to registered bores).

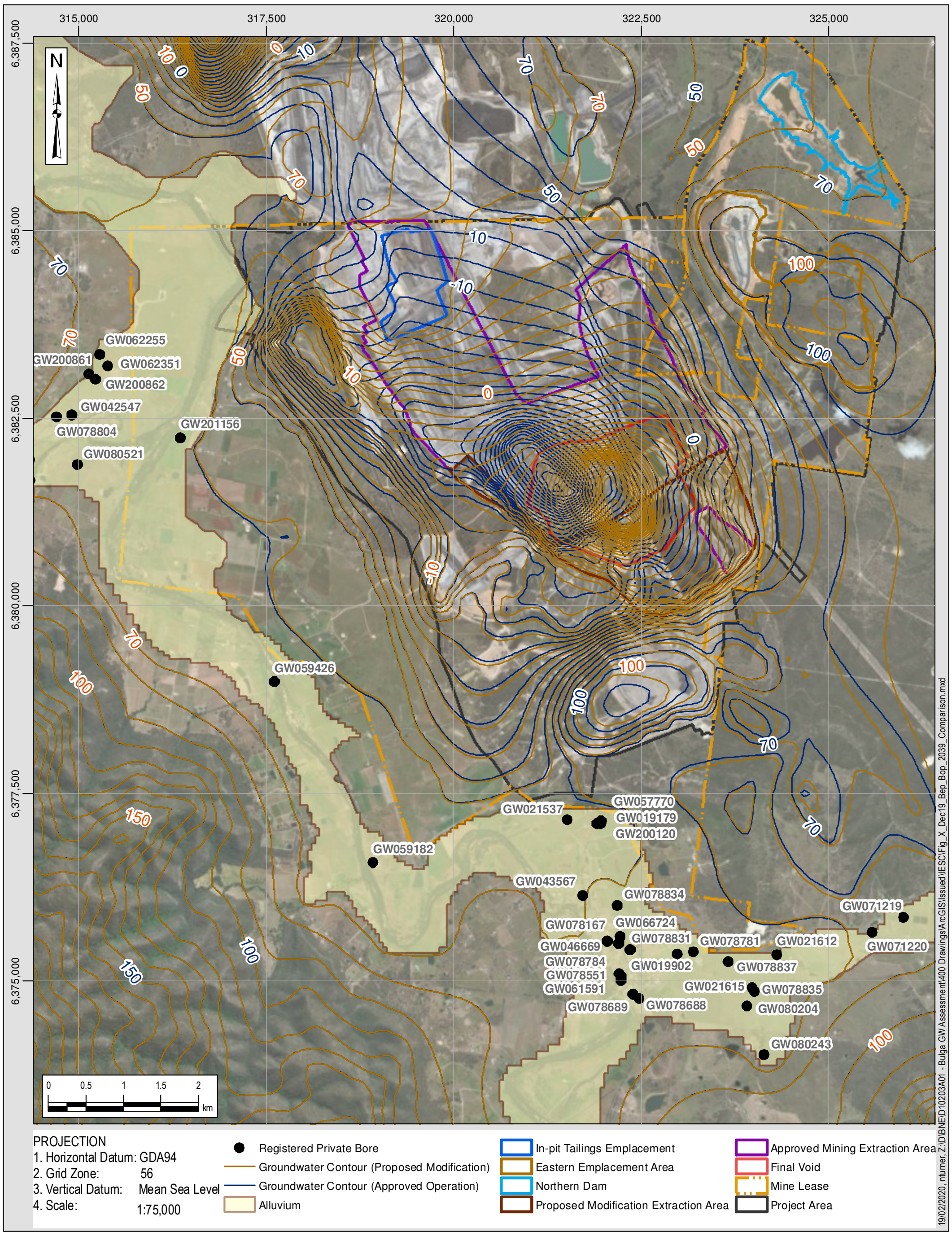

Figure 20: Positions of registered bores shown with approved and proposed modification groundwater contours at maximum drawdown 2039

4.7 Comment 22

The proponent notes that the groundwater model is intended primarily for impact prediction in the Permian aquifers, and that the alluvium is not included in detail in the groundwater model (KCB 2019, p. 68). Consistent with this, the IESC notes that the shallow groundwater level dynamics were not represented well within the model, which has implications for the reliability of predictions and long-term drawdown impacts on the shallow alluvium. This reduces confidence in predictions of flux to surface waters including the Hunter River, Monkey Place Creek, Wollombi Brook and their associated alluvial aquifers (and GDEs). While some uncertainty analysis has been provided to aid understanding of how the project may change flux to surface waters, further comprehensive uncertainty analysis and presentation of the results incorporating likelihoods are needed (Middlemis and Peeters 2018). These should include a description of the prior parameter distributions used in the uncertainty analysis. Given the known high connectivity between some surface waters and the groundwater, the potential for changes to groundwater levels, flux and quality to impact GDEs and aquatic biota, plus the dependence of agriculture on surface water and alluvial groundwater, it is important to understand variability in flux under a range of plausible hydraulic parameterisations and different climate and rainfall scenarios.

As outlined in the responses to comments 1,3 and 18 (Sections 4.1, 4.2 and 4.3), there is a robust data set of monitoring to indicate that the groundwater responses in the alluvial aquifers are strongly tied to the surface water flows and that these alluvial systems have poor hydraulic connectivity to the adjacent Permian units. This is demonstrated in both the regional contours, the difference in hydraulic response for bore pairs located in different units (see Comment 1, Section 4.1) and in the response of individual alluvial bores.

Further examples of these differing responses can be shown by considering the most recent data for the various sets of dual piezometers which confirm this differentiated response.

Assessments of potential worst case changes to surface flows have been provided as part of the groundwater modeling. Since the focus of the modelling was to provide an assessment of the potential impact of the mining, detailed modeling of the surface water/alluvial interactions under variable surface water flow conditions was not considered pertinent to consider for the proposed modification as these changes would occur at a temporal scale that is far more rapid than the mining-associated groundwater level changes (see Figure 2) and the changes in alluvial conditions would be influenced for more strongly by surface flow and climatic influences.

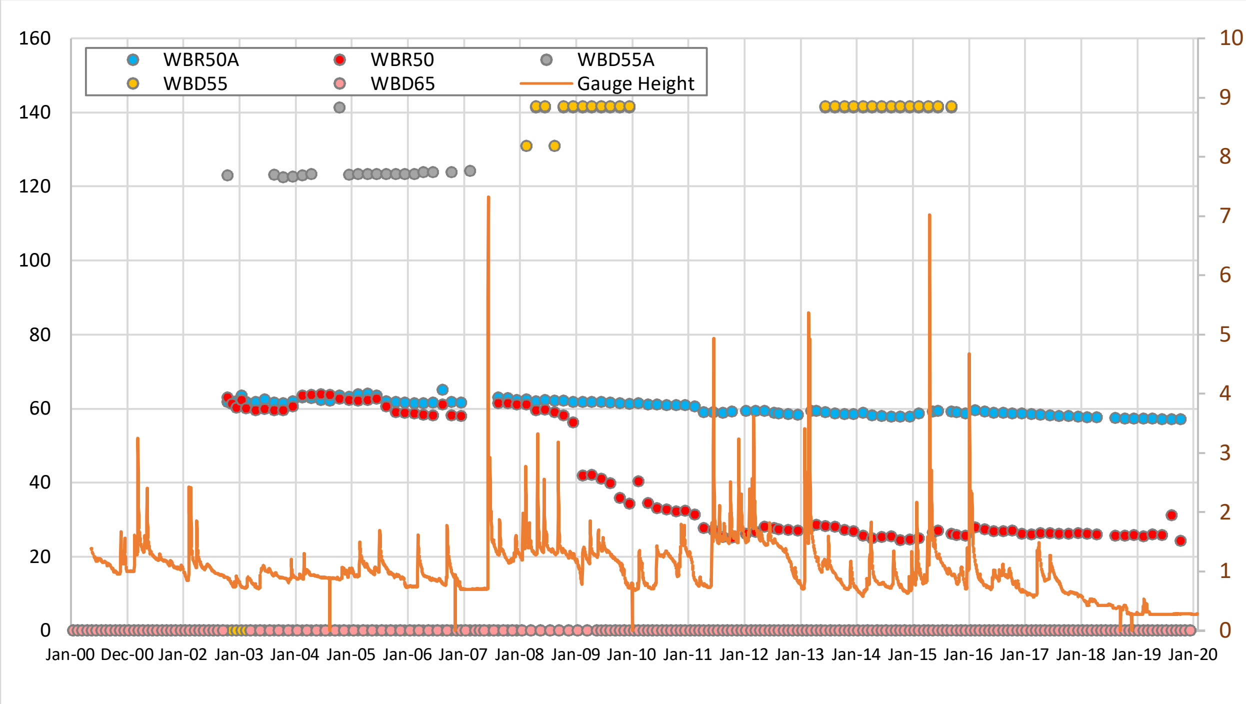

Figure 21: Groundwater level and EC response of several dual piezomter bores

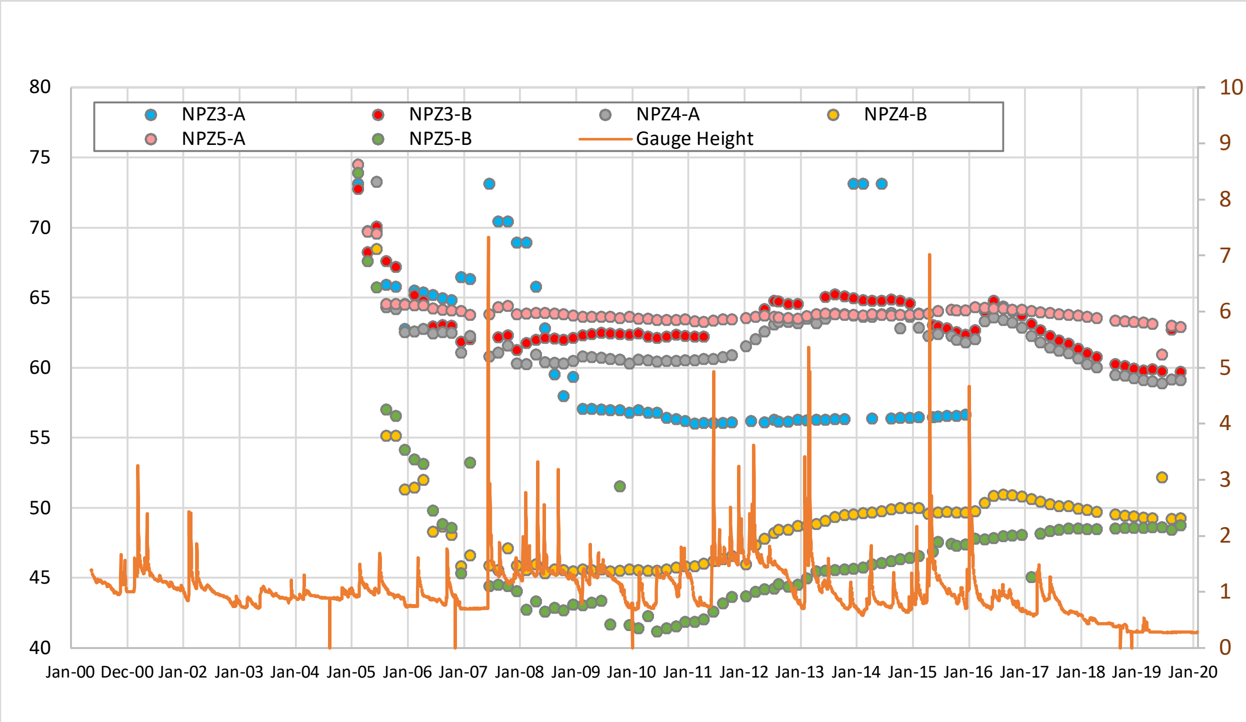

Figure 22: Groundwater level and EC response of several dual piezometer bores

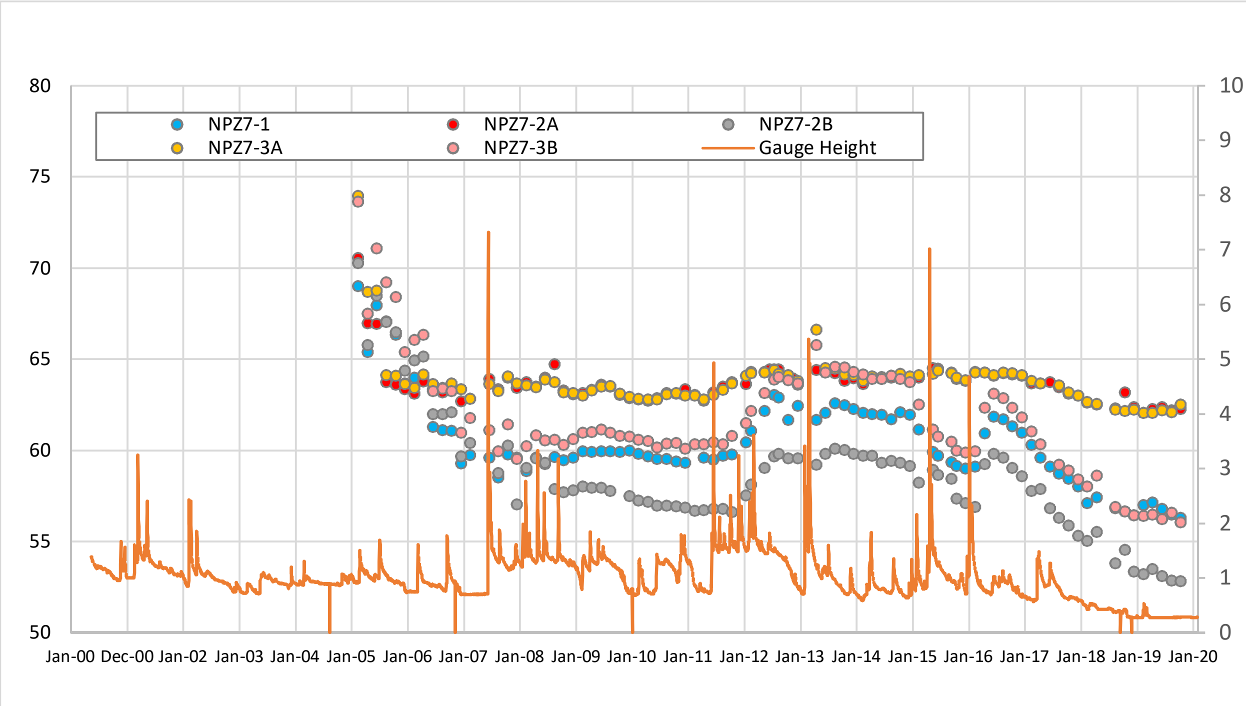

Figure 23: Groundwater level and EC response of several dual piezometer bores

4.8 Comment 23

To investigate how changes in flux may impact water-dependent ecosystems, the proponent should provide ecohydrological conceptual models. These models should include potential changes to flow regimes (e.g. frequency, duration and timing of low- and zero-flow periods) and how this could impact biota, including through changes in refugial pool persistence. At a minimum, ecohydrological conceptual models should be developed for:

a. *the potential impacts to ephemeral streams and Wollombi Brook; and,*

b. *the Warkworth Sands Woodland CEEC to show how the perched aquifer and associated GDEs may be affected by the project.*

Several conceptual sections provide an indication of the relative rates of exchange that may be possible for each of the reaches. For consistency, the same creek reaches as reported on previously (Beltana Reach of Wollombi, Bulga Reach of Wollombi, Lower Monkey Place, Upper Monkey Place, Loders Creek and Nine Mile Creek) have been simplified to conceptual sections that indicate the relative flow exchanges for the approved case and the comparison to the proposed modification case.

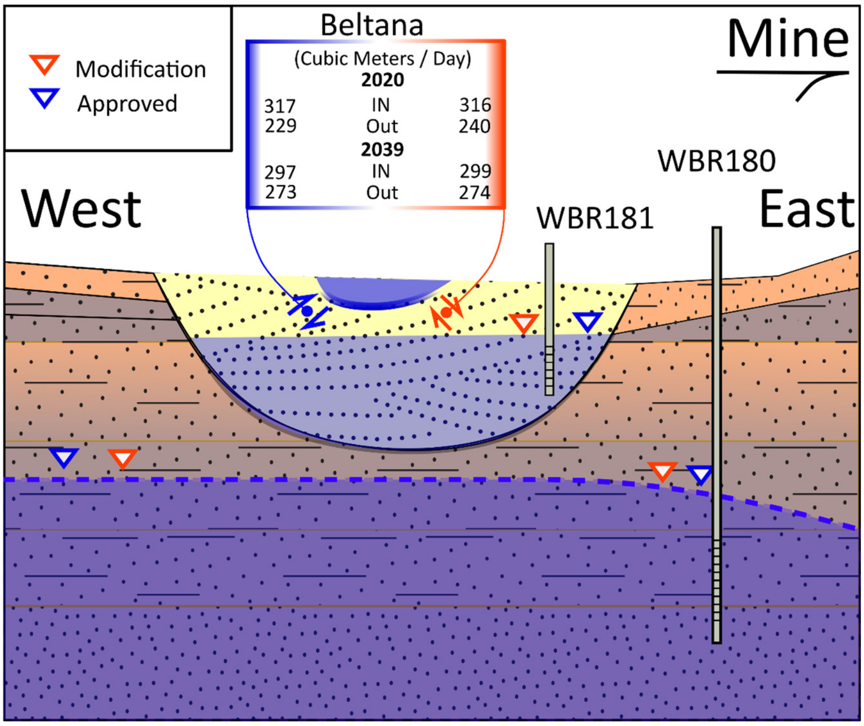

Figure 24: Wollombi Beltana Reach Potential groundwater exchanges for 2020 and 2039 for the Approved and Proposed Modification Case (indicative water levels for each case are illustrated by ▽)

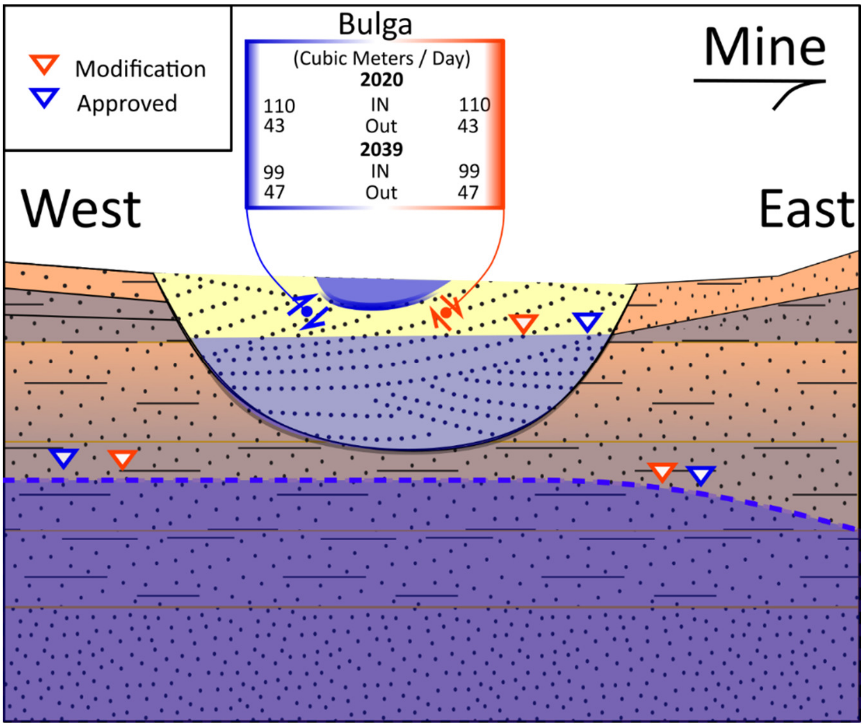

Figure 25: Wollombi Bulga Reach Potential groundwater exchanges for 2020 and 2039 for the Approved and Proposed Modification Case

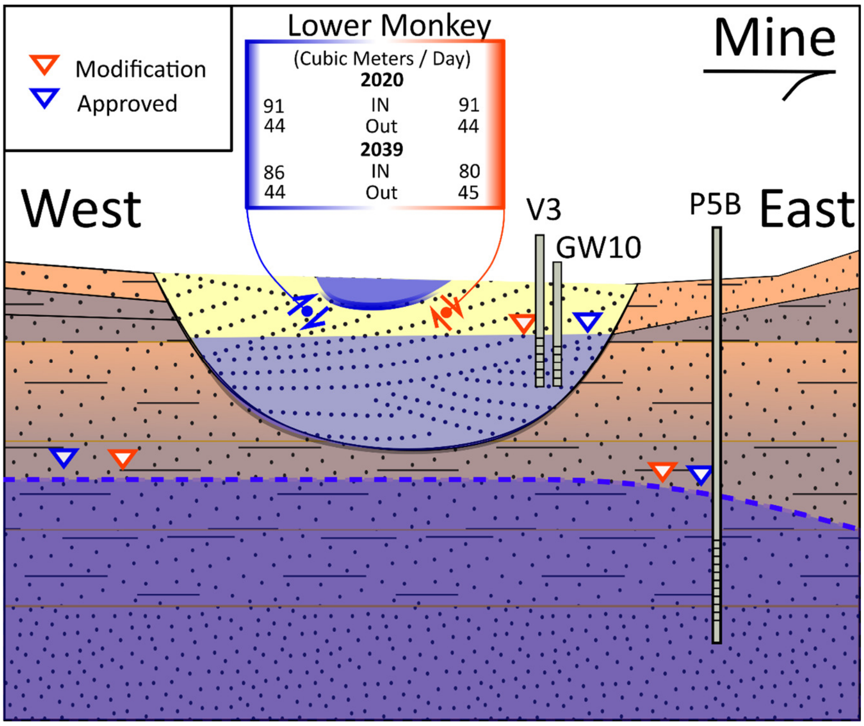

Figure 26: Lower Monkey Place potential groundwater exchanges for 2020 and 2039 for the Approved and Proposed Modification Case

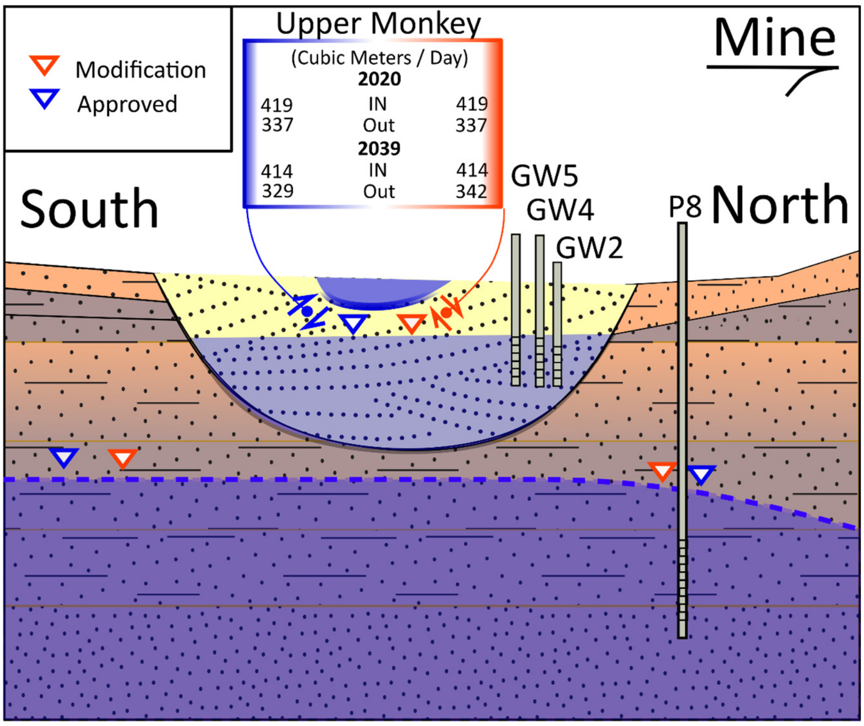

Figure 27: Upper Monkey Place potential groundwater exchanges for 2020 and 2039 for the Approved and Proposed Modification Case

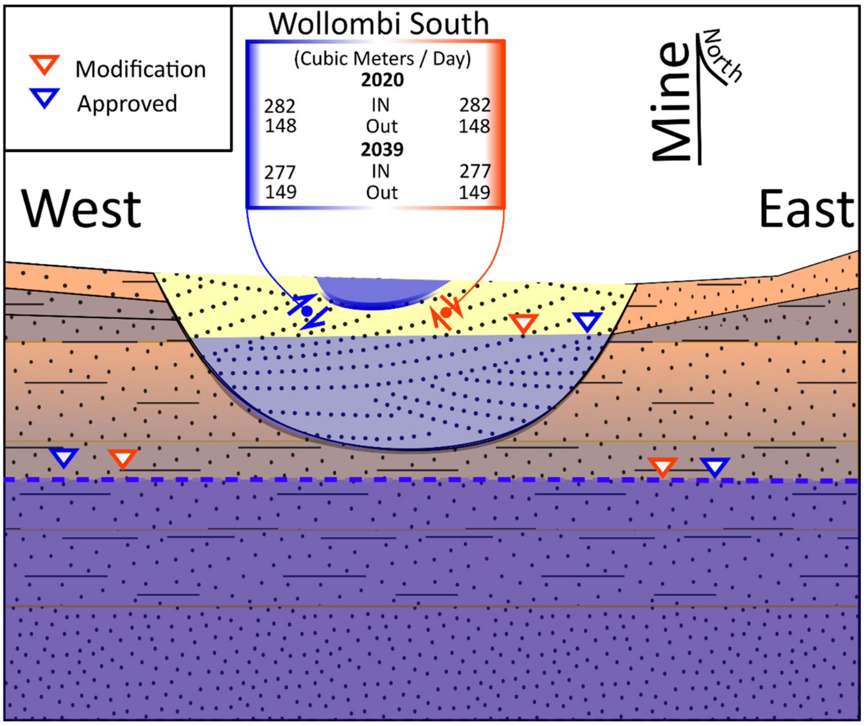

Figure 28: Upper Monkey Place potential groundwater exchanges for 2020 and 2039 for the Approved and Proposed Modification Case

4.9 Comment 26

From the groundwater impact assessment, it is unclear what the likelihood is that groundwater levels will recover to a point at which saturation of the TSF occurs and, if so, how this could impact both groundwater and surface water quality. While the proponent has identified that most discharge from the TSF will ultimately drain to the void lake, they suggest that local flow paths could possibly develop. Information on where these flow paths could discharge is needed to understand and manage the potential impacts on receiving environments.

Recovery of the final void water body was an iterative process between the groundwater modelling team and the surface water team. Rates of groundwater inflow/outflow at various elevations were assessed in the post-closure scenario and based on the consideration of surface water inflows, groundwater flows and evaporation, the final pit lake elevation has been assessed to be in the range of – 40 m RL. A schematic indication of the groundwater flow and other influences at closure and once the pit lake has recovered is provided by Figure 29.

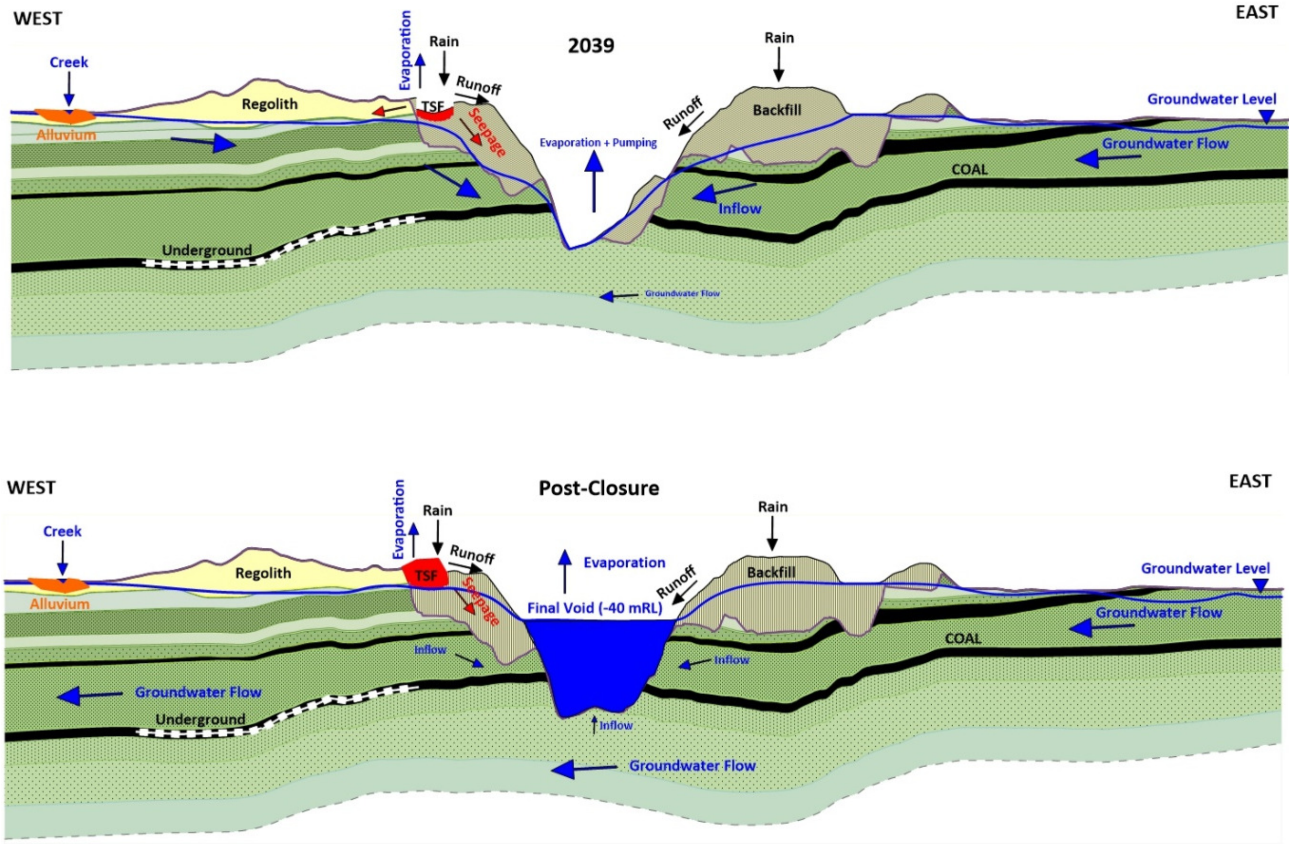

Figure 29: Conceptual Hydrogeological Model (CHM) for 2039 and post-closure conditions. Key components include negligible interconnectivity between Permian and alluvial units as well as the influence of mining alteration (changing hydraulic properties, effects of goafing from long-wall panels, re-placement of tailings providing transient elevated heads)

Further comments regarding the post-closure recovery are worth emphasising:

- The likely final void recovered water level is at ~ - 40mRL. At this elevation, the groundwater gradients remain strongly toward the final void (see also Figure 4-13 in KCB 2019 and the particle tracking provided by Figure 5-6).
- This elevation is significantly below the elevation of the TSF.
- More detailed modelling of the TSF design and flows has also been undertaken by WSP to support the assessment of likely flows toward the void.
- The balance between surface inflow and evaporation (rather than groundwater contributions) will play the most important role in the transient changes to this long-term equilibrium level. Above an elevation of around – 51 mRL some reversal of flow into the workings may occur.
- Further groundwater and surface water monitoring will be put in place to confirm the current understanding and to allow detection of unexpected flows away from the final mine void, especially in the area of the proposed TSF.

4.10 Comment 27

Groundwater quality data are required that includes monitoring for a range of potential contaminants other than salinity, particularly for the Wollombi Brook Alluvium. This information is needed to understand the current condition of the water resources and for comparison with monitoring data collected during and post-mining to identify whether impacts are occurring. The effectiveness of mitigation strategies can also be assessed using this information.

The groundwater quality to date indicates that the groundwater in the Permian and the alluvial aquifers is circa-neutral pH with variable salinity. As indicated in previous responses, the alluvial aquifer bore respond far more significantly to surface water flow conditions and the variability in quality does not appear to be associated with groundwater quality changes in the Permian due to mining. Current groundwater gradients are strongly toward mining operations, and a poor hydraulic connection exists between the Permian and alluvial aquifers; under these conditions, no groundwater quality effects are currently expected as a result of mining-influenced groundwater quality changes (if any) in the Permian units.

The near-neutral pH values limit the solubility of most common metals and salinity influences are considered to be the most likely influence should any occur.

The long-term trends in salinity in the alluvial and Permian measures can be illustrated by the monitoring record. Neither of these series shows an overall increasing trend but the Wollombi alluvials do show lower salinity, greater variability and a stronger response to surface water flow over the ~20 year period (2000 to 2020).

Figure 30: Groundwater EC (uS/cm) in Wollombi Brook Alluvium: F1, F2, V1, V2, Fernance, Dwyer

Figure 31: Groundwater EC (uS/cm) in adjacent Permian: WBR15, HofH, White1, P9

In the Wollombi alluvial, pH has remained neutral (without any discernible downward or upward trend). In addition to EC as a measure of salinity, sulfate as a potential indicator of mining impacts has been considered and as indicated by the time series plot, no upward trend, which may have indicated a mining-associated groundwater contribution) is evident.

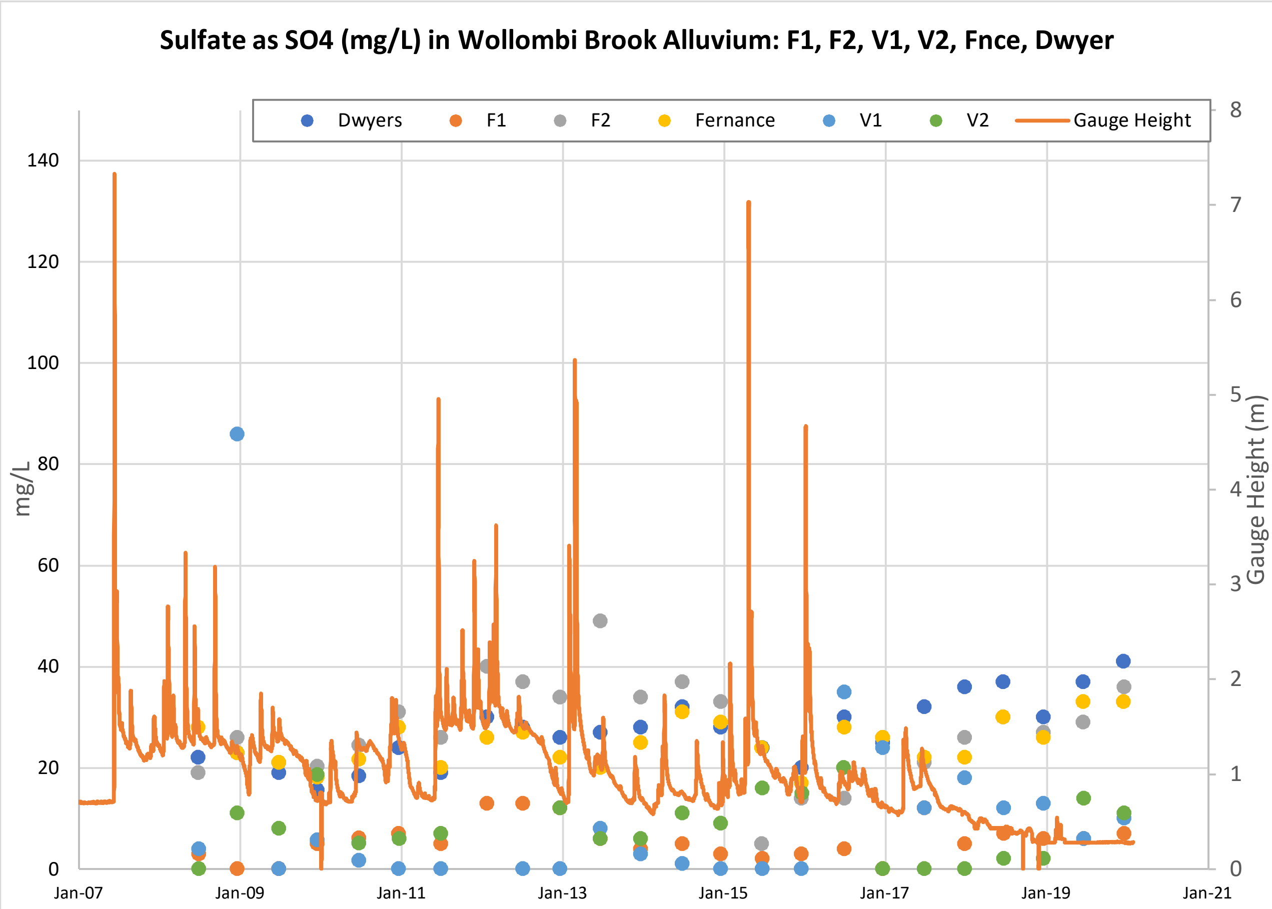

Figure 32: Groundwater SO_4 (mg/L) in Wollombi Brook Alluvium: F1, F2, V1, V2, Fnce, Dwyer

4.11 Comment 28

The nature of connectivity between the underground workings and the final void post-mining requires further investigation. It is unclear from the hydrogeological conceptualisation whether this water, which could be contaminated depending on the geochemistry of the target coal seams, will also flow toward the final void lake. Site-specific data should be used to justify the parameter functions applied in the model for hydraulic conductivity and specific storage, particularly between the longwall panels and the open cut pit.

Please refer to the response to Section 4.9.

4.12 Comment 29

The proponent currently predicts that no impacts will occur to the Warkworth Sands Woodland CEEC. This is based on the assumption that the CEEC accesses groundwater from perched aquifers disconnected from the underlying Permian aquifers and that drawdown of the water table will not extend to the Warkworth Sands Woodland. Confidence in this impact prediction is limited. The measures suggested by the consultants (KCB 2019, pp. 86-87) should be implemented to address and manage the limited confidence. The IESC also suggests the following:

a. *undertaking concurrent ecological monitoring of the Warkworth Sands Woodland CEEC, including species recruitment and persistence, to identify potential impacts;*

b. instigating a groundwater monitoring program (using nested monitoring bores) which would continue during and after operations to identify potential water table drawdown at the Warkworth Sands Woodland CEEC;

c. undertaking an uncertainty analysis to determine the likelihood and magnitude of water table drawdown in the area of the Warkworth Sands Woodland; and,

d. developing a management plan if the additional measures identify the potential for impact to the Warkworth Sands Woodland CEEC. This plan should utilise the ecohydrological conceptual modelling discussed in Paragraph 23.

The response to this issue is provided separately by Umwelt.

4.13 Comment 30

The justification in the report (KCB 2019) for the input data used in the model is limited for some parameters and scenarios. Furthermore, there are significant data gaps. Some of the model design assumptions and selected parameterisations do not appear credible as evidenced by the poor history-matching (for example, in many instances the anomalies between simulated and observed heads exceed 50 m). Currently, the modelling does not consider worse-case situations and the uncertainty analysis provided is not consistent with the most recent iteration of the groundwater model (KCB 2019, p. 73). Future uncertainty analyses should use a groundwater model incorporating the current mine plan.

The progression of the approved and proposed mining operations are simulated using "Drain" cells which are activated in accordance with the current mining schedule provided, to reflect the progression of mining in both the underground and open cut operations (Table 4-2, KCB 2019, p.49).

Under transient conditions, the boundary conditions are not constant (for example the simulation time step, compared to measured observations and timing of the underground development in the Permian). Any minor difference in timing of the initiation or cessation of underground areas has a cascading effect but for consistency, the mining sequences for both cases are identical for all mining other than the proposed modification. Where mismatches between the modelled and observed data occur, these difference are largely adjacent to the mining operations (in the Permian layers) and occur as a result of inconsistency between modelled/idealised timing of the underground operations and the operational progression of the approved mining. The impact on the alluvial predictions is not significant.

From the multiple model runs completed, the model is behaving as expected to the stresses, and is producing very strong repeatability, despite the (minor) non-uniqueness and differences in timing of the underground development in the Permian. This repeatability is shown by the predictive simulations and the sensitivity, behaving in accord with the conceptual understanding.

The intent of the model was to provide an indication of the incremental changes to the groundwater environment over the duration of mining and into closure. As discussed in the response to Comments 19 and 20 (Sections 4.4 and 4.5), Glencore has undertaken to include additional groundwater monitoring as part of future environmental management plans for the sites. Data collected from these additional points (including assessments of aquifer parameters and vertical gradients/separation between units) will be used to update the model once these are in place to confirm the current conceptual understanding and to further bolster the data set used for modelling to date. These future model updates will include further assessment of uncertainty.

4.14 Comment 31

Given the long history of mining at the site, the IESC would expect the proponent to present more data for history-matching, representing the potential impacts of deepening the open cut and for in-pit tailings placement. History-matching targets are not available for all model layers. Where targets are available, history-matching fits are sometimes poor and importantly when simulating impacts on surface waters and existing bores, do not represent the dynamics (or even the median response) of the aquifer within the shallow layers. Uncertainty analysis testing a range of plausible parameterisations is needed to understand how these limitations may affect impact predictions. Reporting of any uncertainty analysis should include a description of the parameters varied and their prior and posterior probability distributions (Middlemis and Peeters 2018).

See response to Section 4.4 and also refer to the groundwater contours and groundwater monitoring data provided in the response to Sections 4.1 and 4.2 particularly.

4.15 Comment 32

Additional limitations of the groundwater model noted by the proponent include the boundary conditions influencing the prediction of creek discharge and that local impacts such as groundwater extraction for irrigation and high rainfall events are not incorporated into the model (KCB 2019, p. 68). These limitations should be considered in the updated version of the model and uncertainty analyses suggested in Paragraphs 20 and 22, and during future model updates.

Glencore has committed to increasing the groundwater and surface water monitoring for the site (see Section 4.5) followed by an update to the groundwater modelling (including further assessment of uncertainty), should the underground mining be extended. Responses provided to Section 4.1, 4.2, 4.3 and 4.5 provide the context and intent of the groundwater model for the proposed modification, discuss the poor hydraulic connection between the alluvial and Permian units and the consequent focus on the Permian calibration, as well the degree of sensitivity and uncertainty analysis already undertaken.

4.16 Comment 33

The current groundwater model is used as the basis for assessing cumulative impacts. However, the groundwater model has a number of limitations as outlined in Paragraphs 18-20. In addition, while the current groundwater modelling provides predictions of cumulative impacts the presentation of these predictions makes it difficult to clearly identify the changes in groundwater levels from current conditions and to determine the contribution of the proposed project to cumulative impacts. These limitations need to be addressed so that the incremental changes of the project and the total cumulative impacts to groundwater can be clearly identified and assessed.

The modelling completed focused on assessing the potential incremental change of the proposed modification, compared to the currently approved mining case. The comparison to the approved case is shown on Figure 13, and the magnitude of incremental change has been provided in several tables in this document and in KCB 2019. In addition, the areas of potentially greatest drawdown impact in the alluvials have been provided in Figure 11. Several preceding responses contextualise the potential impact and indicate the monitoring data to support the expected small drawdown impacts on the alluvial aquifers. The long-term groundwater flow gradients will continue to be toward the final void over the duration of operations and into closure (see for example Figure 29).

4.17 Comment 34

It is noted by the proponent that irrigation impacts are not incorporated into the groundwater model (KCB 2019, p. 68). Incorporating irrigation water use into groundwater models can be complicated as pumping volumes may not be known and timing is often not at the temporal scale of the modelling. Further discussion of irrigation water extraction and return flows should be provided and incorporated into future groundwater model updates, and their impacts should be considered on alluvial aquifers and their dependent ecosystems along Wollombi Brook.

Understanding the irrigation water use and surface water impacts on the alluvial aquifer was beyond the intended scope of the model. From a catchment management perspective, irrigation impacts should be considered and may be the dominant groundwater influence on the alluvials but as indicated by the modelling and available data, the change in groundwater conditions as a result of the proposed modification (compared to the approved case) is far smaller than changes to groundwater conditions due to surface flows and/or irrigation.

As indicated in the response to Sections 4.5, 4.13 and 4.15, the Bulga model will be updated once further monitoring has been installed and sufficient new data has been collected. At that time, the potential influences of irrigation return flows will be considered, either as part of an updated numerical groundwater model for the mining complex or as a separate/standalone assessment.

4.18 Comment 35

The proponent identifies that flows of approximately 100 m3/day may occur from the TSF to Mount Thorley, the adjacent mine site (KCB 2019, p. 80). This potential cumulative impact is not fully considered in the groundwater impact assessment. Further information and analysis are needed of where these flows discharge. If they enter the final void of the Mount Thorley Mine (which is likely), consideration is needed of whether these discharges change the predicted water levels in the Mount Thorley final void, increase the chance of spills from the final void and/or change the void's water quality.

Modeling results for the Proposed Modification by both KCB and WSP has indicated that a small groundwater mound will develop adjacent to Mount Thorley as a result the head from the TSF and the assumed groundwater elevations to the north in the Mount Thorley workings. As indicated in KCB 2019, the magnitude of this flow will be a function of the head in the TSF and in the adjacent workings and is expected to vary seasonally, averaging at less than 1 L/s over the longer-term. The TSF as a facility has already been approved, with consideration of these minor flows to the north. Depending on timing of water level increases in Mt Thorley this flow will be distributed across a length of around 1km. These factors suggest that the proposed northward flow is likely a small proportion of the Mt Thorley water balance to be accounted for.

4.19 Comment 43

Additional monitoring of the groundwater in the alluvium is needed to better understand how impacts in the Permian aquifer propagate to the alluvial aquifer and influence surface water flows.

A considerable number of groundwater monitoring points are already in place particularly in the areas where potential impacts may occur in the alluvials. Current monitoring locations are provided in Figure 33.

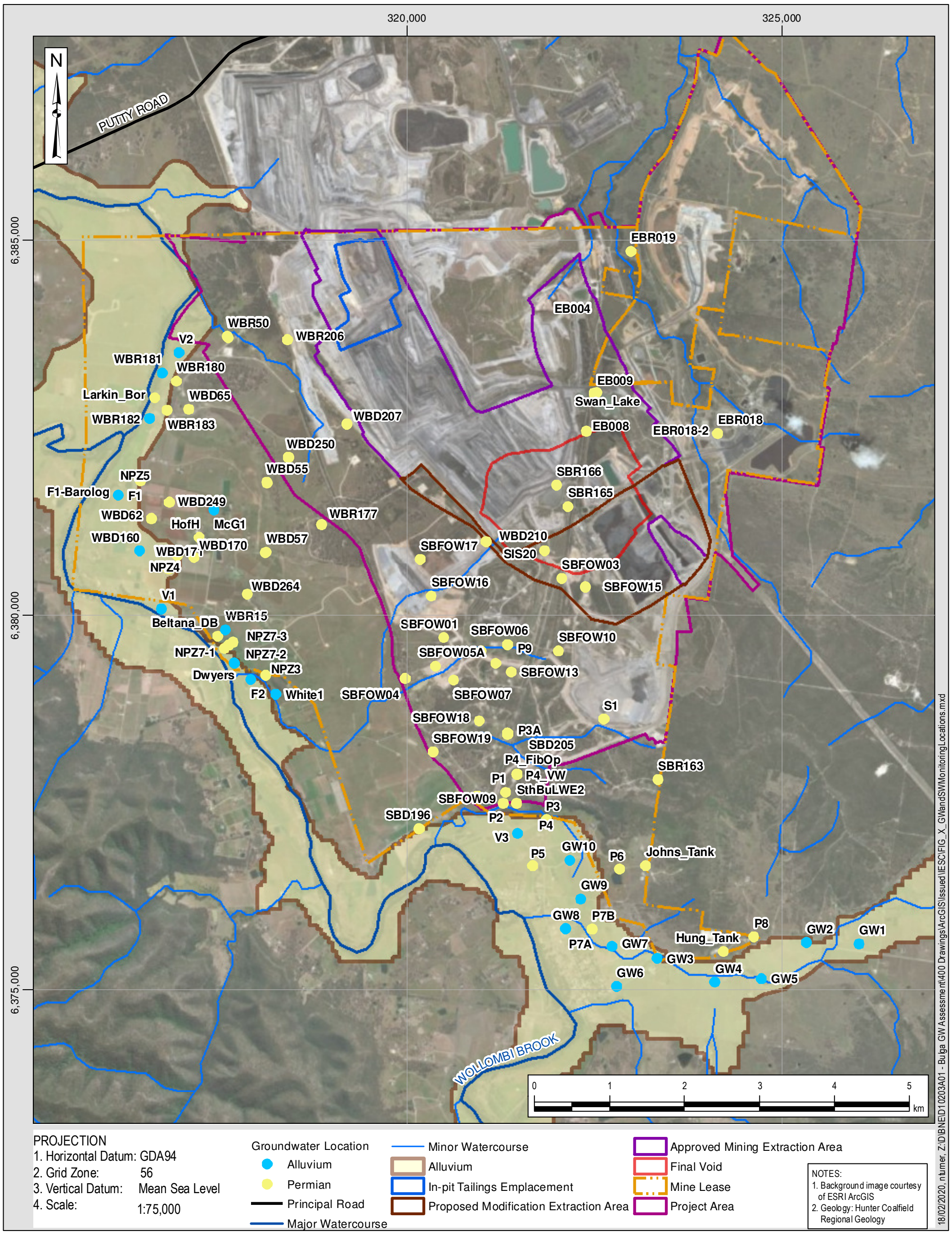

Figure 33: Current monitoring. Note alignment and focus on alluvial

Glencore is in the process of assessing the need for additional groundwater monitoring around the site. Areas where additional monitoring is proposed in future, are indicated on Figure 34. The proposed areas targeted are based on the potential areas of interaction with the alluvials, the Permian units between the operations and the alluvials to west and south, while to the north these relate to monitoring in the Permian along the northern boundary. The latter monitoring will have two separate objectives since there is a need to understand the potential flows toward Mt Thorley immediately north of the TSF as well as understanding and providing an early warning (if needed) of potential drawdown toward the Warkworth Sand or other alluvials.

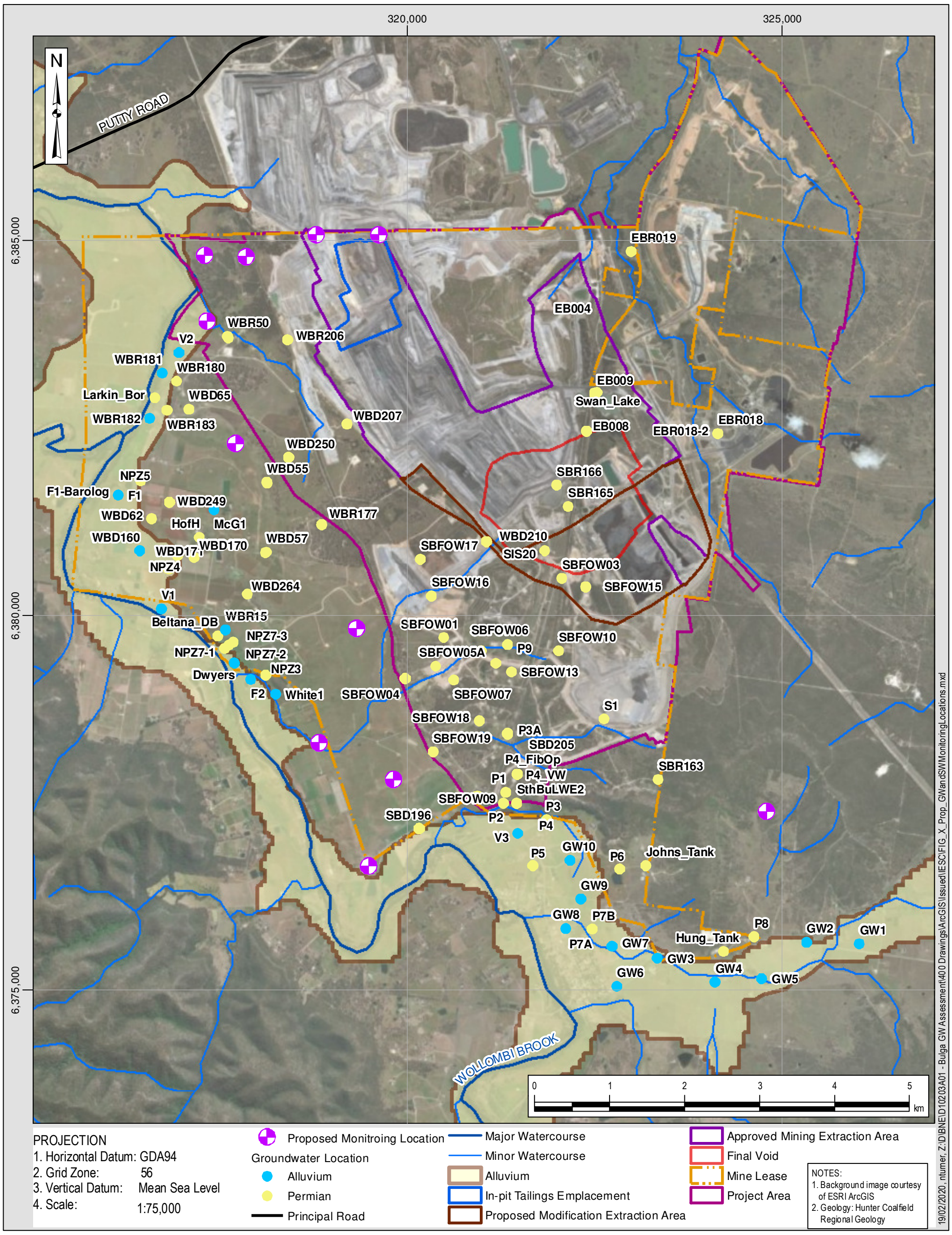

Figure 34: Proposed future groundwater monitoring (Target Symbols)

4.20 Comment 45

The proponent has identified that there is the potential for local flow paths to form around the TSF and that monitoring of groundwater could be useful (KCB 2019, p. 83). The IESC agrees that additional groundwater monitoring (including sampling for metals and metalloids) should occur in this area and be targeted at detecting localised flow paths from the TSF, especially where discharge to alluvium and/or surface water could occur.

As indicated in KCB 2019, and illustrated on Figure 13 and Figure 29, groundwater gradients are expected to be predominantly toward the mining operations and toward the final void during operations and at closure. Despite this expectation, Glencore has indicated that additional monitoring of the final void water quality and the surrounding groundwater quality will form part of the proposed monitoring plan. Areas targeted by future groundwater monitoring are indicated on Figure 34, with an explanation in the preceding comment.

5 CLOSING

This letter report is an instrument of service of Klohn Crippen Berger Australia Pty Ltd (KCB). The report has been prepared for the exclusive use of Umwelt (Australia) Pty Limited (Client) for the specific application to the SSD 4960 Mod 3 – IESC Comments, and it may not be relied upon by any other party without KCB's written consent.

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4. KCB should be consulted regarding the interpretation or application of the findings and recommendations in the report.

Yours truly,

KCB AUSTRALIA PTY LTD.

HM:BU

APPENDIX B

Engeny Response

UMWELT (AUSTRALIA) PTY LTD

Bulga Optimisation Project Modification 3

Surface Water - Response to IESC Advice




April 2020

N1600_007-REP-002

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REV	**DESCRIPTION**	**AUTHOR**	**REVIEWER**	**APPROVED BY**	**DATE**
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Rev 1	Client Issue	Susan Shield	Adam Wyatt	Susan Shield	18 March 2020
Rev 2	Client Issue	Susan Shield	Adam Wyatt	Susan Shield	31 March 2020
Rev 3	Client Issue	Susan Shield	Adam Wyatt	Susan Shield	2 April 2020
Signatures		SShield		SShield	

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1. INTRODUCTION

The Statement of Environmental Effects (SEE) for the Bulga Optimisation Project Modification 3 and Bulga Underground Modification 7 (Umwelt, 2019) was placed on public exhibition from 8 October to 4 November 2019. This Response to Submissions Report addresses specific issues raised by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) relating to surface water.

The Bulga Coal Complex (BCC) is an open cut and underground coal mining operation located approximately 12 kilometres (km) south west of Singleton in the Hunter Valley, of New South Wales (NSW) (refer to Figure 1.1). Bulga Coal Management Pty Ltd (BCM) operates the BCC on behalf of the Bulga Joint Venture, with mining operations occurring at the site for over 35 years. The BCC consists of open cut operations (Bulga Surface Operations) and underground operations (Bulga Underground Operations) that use shared coal washing and rail loading infrastructure as well as having an integrated water management system (WMS).

BCM is seeking to modify both the Bulga Surface Operations (SSD 4960 Modification 3) and the Bulga Underground Operations (DA 376-8-2003 Modification 7) through a modification application under section 4.55 (2) of the Environmental Planning and Assessment Act 1979 (EP&A Act) for both these planning approvals.

This Surface Water Response includes:

- A summary of the SSD 4960 Modification 3 and DA 376-8-2003 Modification 7 to provide context for the submissions (refer to Section 1.1).
- A detailed response to the IESC submission relating to surface water (refer to Sections 2 to 4).

1.1 Overview of the Project

On 1 December 2014 BCM was granted approval for the Bulga Optimisation Project (BOP) (SSD 4960), which related to ongoing operation of the Bulga Surface Operations until 31 December 2035. Since approval, SSD 4960 has been modified twice: SSD 4960 Modification 1 in January 2017 to facilitate a revised Eastern Emplacement Area (EEA) design and a revised tailing management strategy; and SSD 4960 Modification 2 in August 2018 to extend the period to complete the outer face of the noise and visual bund.

The Bulga Underground Operations at the BCC operate under a separate development consent (DA 376-8-2003) granted in 2004 (Bulga Underground Consent). The Bulga Underground Operations ceased mining in May 2018 and the mine was sealed in July 2018. The Bulga Underground Operations approvals are being retained and BCM is actively evaluating opportunities to recommence underground operations in the future.

SSD 4960 Modification 3 will maximise resource recovery within the approved Project Area through an extension of the open cut operations. The proposed extension of the open cut pit to the south-east also enables extraction of additional deeper resources below parts of the currently approved Bulga open cut operation. An additional disturbance of 20.2 hectares (ha) is required to accommodate the proposed extension of the mining areas. Approximately 200 ha of mine rehabilitation will also be re-disturbed and re-established as a result of SSD 4960 Modification 3. SSD 4960 Modification 3 will maintain the current approved open cut coal extraction rate of up to 12.2 Million tonnes per annum (Mtpa) of run of mine (ROM) coal while enabling the extraction of an approximately 63 Mt of additional coal. SSD 4960 Modification 3 will extend the life of the development consent by approximately four years until 2039.

SSD 4960 Modification 3 will require the removal of the tailings material currently stored in the existing Tailings Storage Facilities (TSF) and relocation to the Main Pit TSF, which is located within the existing Main Pit mining area. The capacity of the currently approved Main Pit TSF will be increased to receive the relocated tailings by increasing the depth of the emplaced tailings within the in-pit facility, whilst maintaining a similar surface area. SSD 4960 Modification 3 will also require the upgrade, relocation or removal of some components of the infrastructure servicing the Bulga Surface Operations as well as removal of components of the Bulga Underground Operations infrastructure, through DA 376-8-2003 Modification 7, including workshops, gas-fired power generation plant and associated gas infrastructure, electrical substation, fuel and oil storage.

The Bulga Surface Operations will continue to use the BCC shared infrastructure approved to service both the open cut and the underground mining operations including the Coal Handling and Preparation Plant (CHPP), raw coal stockpiles and conveyors, train loading facilities, workshops, stores, offices and deployment areas, water management system, etc.

Figure 1.2 shows SSD 4960 Modification 3 in relation to the currently approved open cut mining operations at BCC. Further details, including a comparison between the approved development under SSD 4960 and SSD 4960 Modification 3, are provided in the main text of this Response to Submissions (Umwelt, 2020).

FIGURE 1.1

Locality Plan

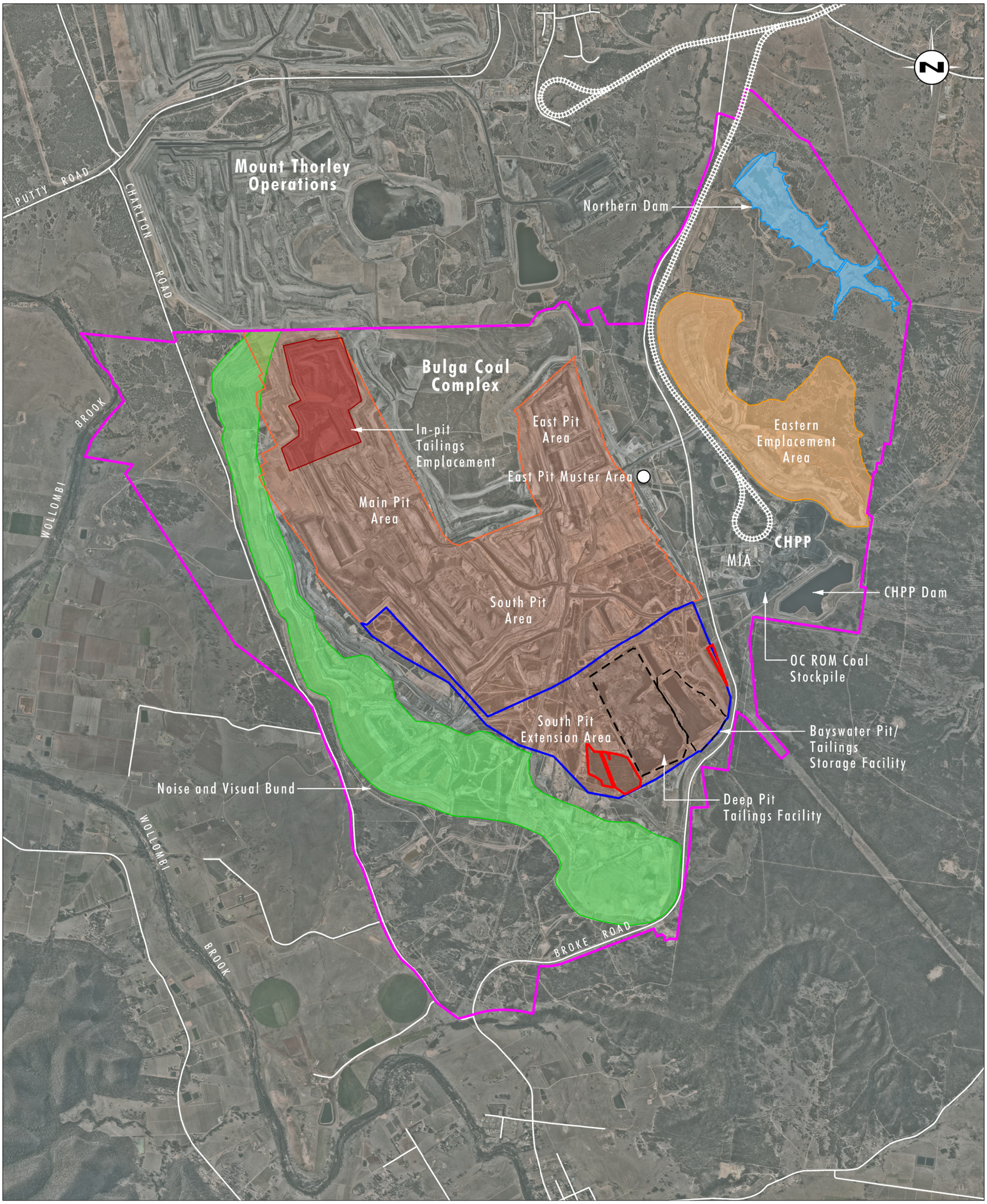

Image Source: Nearmap (Sep 2018)
Data Source: Bulga (2019)

Legend

- Project Area
- Additional Disturbance Area
- South Pit Extension Area
- Mining Area
- Noise and Visual Bund
- Eastern Emplacement Area
- In-pit Tailings Emplacement
- Northern Dam
- Rail Line

FIGURE 1.2

SSD 4960 Modification 3 and DA 376-8-2003 Modification 7 Key Mining Features

File Name (A4): R13/4100_211.dgn
20191204 11.35

2. QUESTION 2

<u>Surface water</u> - Question 2: Are the assumptions used in the modelling reasonable and is there sufficient data within the model to provide meaningful predictions, including worst-case impacts on surface water?

2.1 Item 3

The proponent states that the project will impact Wollombi Brook and Loders Creek through changes to catchment areas, and because of reductions in baseflow due to increased groundwater drawdown. The main changes include a reduction of the Loders Creek catchment by 397 ha and an increase in the Wollombi Brook catchment of 354 ha. Baseflow in Wollombi Brook is predicted to decrease by up to 1.38 ML/day (Engeny 2019, pp. 28-29). The proponent states that the assumptions used to assess baseflow impacts were conservatively high as all leakage from Wollombi Brook was assumed to be lost from the surface water system. However, this analysis does not consider the large uncertainty in the groundwater modelling relevant to baseflow impacts, nor the evident bias associated with under-prediction of Layer 1 groundwater levels (as discussed in Paragraphs 18, 19, 22 and 31).

It should be noted that the Surface Water Impact Assessment (Engeny, 2019) indicated that the 1.392 ML per day and 1.380 ML per day were predicted baseflow losses for the Approved Operations and Proposed Modification (respectively). The baseflow loss values reported have since been clarified by Umwelt and KCB as modelled flows within the alluvial aquifers (i.e. not the flux between the surface water and alluvial aquifers).

The difference between the modelled flows of the Approved operations and the Proposed Modification is 0.012 ML per day, as reported in the Surface Water Impact Assessment.

The Groundwater Impact Assessment (GIA) (KCB, 2019) predicts that the leakage from the alluvial aquifers to the underlying Permian strata with the Proposed Modification are similar to the predictions for the Approved Operations. The groundwater model predicted slight decreases in discharge to creeks with the Proposed Modification. The modelled groundwater flow contribution and associated modelled baseflow losses are summarised in Table 2.1. The modelled variability is presented in Table 2.2. The relatively narrow variabilities indicated in Table 2.2 compared to the absolute flows in Table 2.1 suggest that the relative uncertainties in the groundwater modelling are minor in comparison to the flows in the Wollombi Brook and do not alter the flow regime.

Table 2.1 Predicted Creek Flows (i.e. modelled groundwater contribution) (KCB, 2020)

Creek	Existing Conditions (m^3/d)	Approved Operations (maximum impact) (m^3/d)	Proposed Modification (maximum impact) (m^3/d)
Wollombi Brook (Beltana Reach)	1616	1392	1380
Wollombi Brook (Bulga Reach)	604	528	528
Lower Monkey Place Reach	457	389	382
Upper Monkey Place Reach	502	450	449
Loders Creek	34	31	31
Nine Mile Creek	45	14	9

Table 2.2 Predicted Creek Flow Variability (i.e. modelled groundwater contribution) (KCB, 2020)

Natural Creek	10th Percentile Difference in Baseflow between the Approved Project and Proposed Modification (m^3/d)	Average Difference in Baseflow between the Approved Project and Proposed Modification (m^3/d)	90th Percentile Difference in Baseflow between the Approved Project and Proposed Modification (m^3/d)
Wollombi Brook (Beltana Reach)	12	19	26
Wollombi Brook (Bulga Reach)	0	0	0
Lower Monkey Place Reach	-1	2	7
Upper Monkey Place Reach	0	0	2
Loders Creek	0	1	1
Nine Mile Creek	-4	2	6

As was discussed in Section 4.2.2 of the Surface Water Impact Assessment (Engeny, 2019), modelling indicates that the Proposed Modification will decrease the rate of groundwater flow within Wollombi Brook by up to 0.012 ML/day (i.e. a <1% flow reduction) relative to the approved operations (i.e. 1,392 m^3/d to 1,380 m^3/d).

The predicted changes to streamflows associated with catchment area changes are described in Item 4.

2.2 Item 4

The surface water assessment modelling concluded that the impacts on baseflows were negligible as they represent a reduction in flows of less than 1%. However, reporting baseflow decreases as a volumetric proportion of the average fails to recognise the potential impacts on ecologically important aspects of the flow regime (e.g. impacts on the frequency, duration and timing of low- and zero-flow periods). Analysis of the groundwater drawdown impacts indicates that baseflow decreases of 1.38 ML/day will increase the number of zero-flow days by around 50%. The timing and duration of these impacts is illustrated in Figure 1 (Attachment A of this advice), where it is seen that the nature of these impacts on the flow regime are of material concern. For example, longer periods of zero- and low-flows will affect the completion of life cycles by aquatic stages of stream biota and maintenance of refugial pools. Evapoconcentration due to reduced flows may further increase salinity.

As was discussed in Section 4.2.2 of the Surface Water Impact Assessment (Engeny, 2019,) modelling indicates that the Proposed Modification will decrease the rate of groundwater discharges to Wollombi Brook by up to 0.012 ML/day (i.e. a <1% flow reduction). This is a change from the Approved Project reduction in baseflow of 1.392 ML/day to 1.380 ML/day with the Proposed Modification.

To provide further information on the potential nature that incremental and cumulative groundwater and catchment impacts may have on the flow regime, an analysis of streamflow sequencing for Wollombi Brook and Loders Creek has been undertaken to identify potential impacts on the flow regimes, including low- and zero-flow periods.

2.2.1 Wollombi Brook

Flow Gauging Data

As discussed in Section 4.2.1 of the Surface Water Impact Assessment (Engeny, 2019), WaterNSW maintains three steam flow monitoring/gauging stations on Wollombi Brook. The Bulga gauge (gauge 210028) is located adjacent to the BCC at the Putty Road crossing. The data recorded at the Bulga gauge is considered representative of flows in Wollombi Brook adjacent to and downstream of the BCC. The analysis, including data to January 2020, is presented in Figure 2.1 .

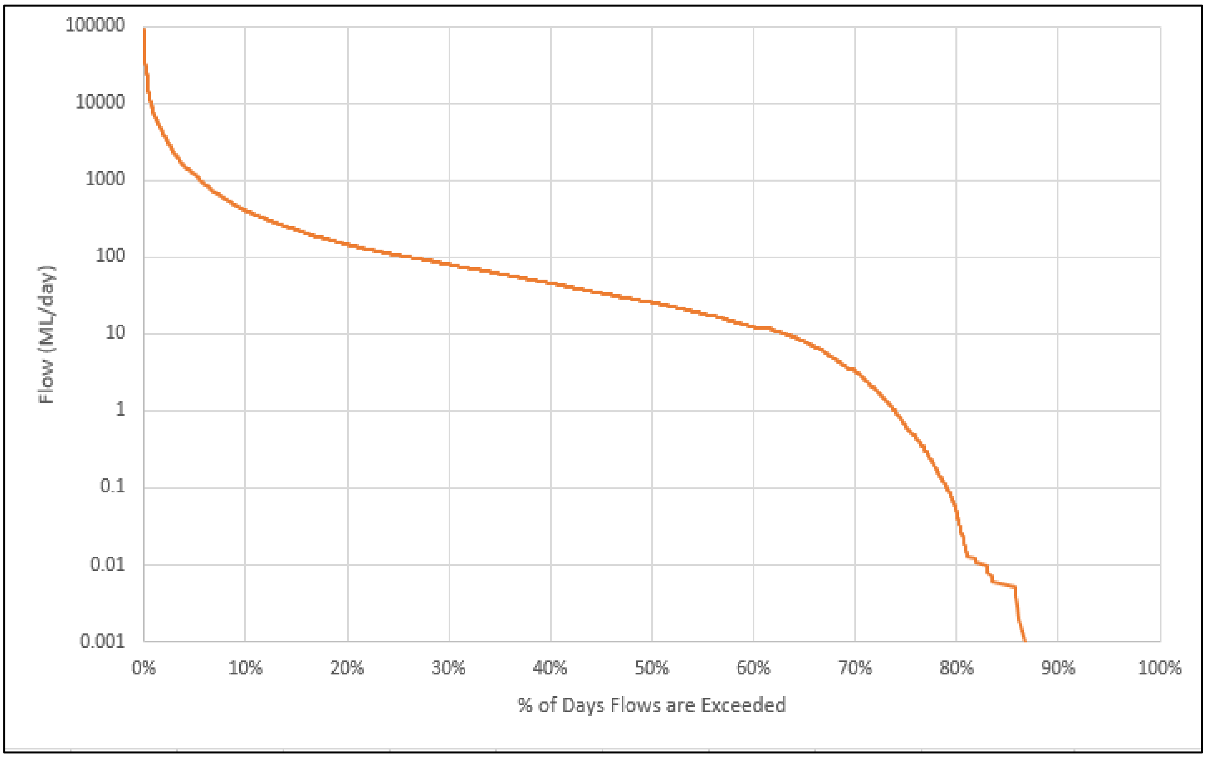

Figure 2.1 Flow Duration Curve (Flow Gauging Data – Wollombi Brook at Bulga (gauge 210028))

Assessment

Baseflow impacts (refer to KCB, 2019) associated with mining at the BCC vary over the life of the project and were assessed as part of the Groundwater Assessment (KCB, 2019).

It should be noted that the Surface Water Impact Assessment (Engeny, 2019) indicated that the 1.392 ML per day and 1.380 ML per day were predicted baseflow losses for the Approved Operations and Proposed Modification, with a predicted change of 0.012 ML per day between the Approved Operations and Proposed Modification. The values presented of 1.392 ML per day and 1.380 ML per day have since been clarified as modelled flows within the alluvial aquifers (i.e. not the flux between the surface water and alluvial aquifers).

Flow sequencing analysis of Wollombi Brook was undertaken to simulate streamflow conditions for the Approved Operations and the Proposed Modification. The changes in catchment area reporting to the Wollombi Brook and impacts to baseflow losses for each scenario are presented in Table 2.3.

Catchment area is predicted to increase with the Proposed Modification.

Table 2.3 Predicted Impacts on Catchment Area – Wollombi Brook

Scenario	Catchment Area (ha)	Modelled Groundwater Contribution (m^3/d)	Modelled Baseflow Losses (m^3/d) (relative to existing conditions)
Existing Conditions	200,000	1,616	-
Approved Operations – Maximum Impact	199,931	1,392	224
Proposed Modification – Maximum Impact	200,285	1,380	236

The flow sequencing results for Wollombi Brook are presented in Figure 2.2 .

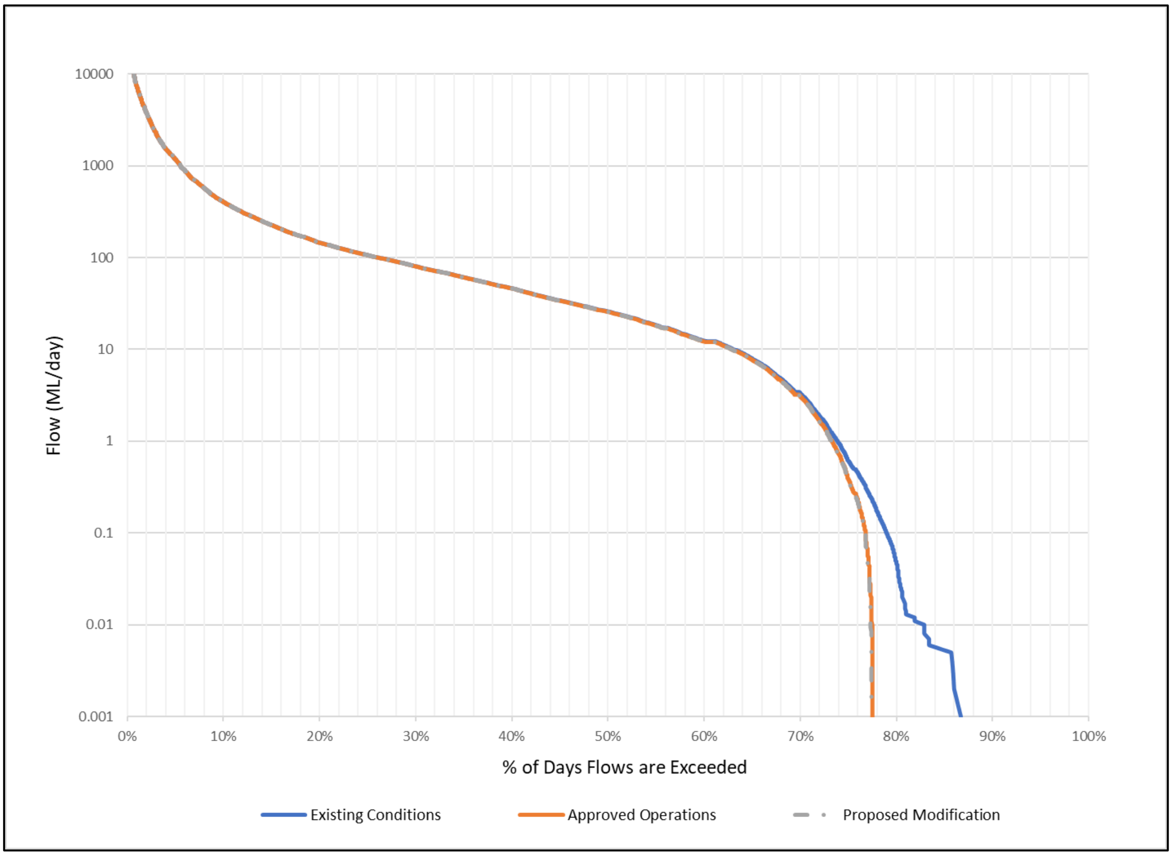

Figure 2.2 Flow Duration Modelled Results – Wollombi Brook

The modelling indicates negligible change in the period that Wollombi Brook will potentially have no flows for the Proposed Modification compared to the Approved Operations. The average annual dry days (identified as days with flows less than 0.1 ML per day) and flow volumes for Wollombi Brook are summarised in Table 2.4 .

Table 2.4 Average Annual Flow Conditions – Wollombi Brook

Scenario	Average Annual Dry Days	Average Annual Flow Volume (ML/yr)
Existing Conditions	77	133,702
Approved Operations	85	133,582
Proposed Modification	85	133,862

Wollombi Brook is predicted to be dry on average approximately 23% of days (i.e. about 85 days per year) for both the Approved Operations and the Proposed Modification. That is, a flow of 0.1 ML/ per day (approximately 1 L/s) would be exceeded 77% of the time. The analysis also indicates small increase in the average annual flow volumes in Wollombi Brook with an increase of 280 ML per year (0.2% increase) for the Proposed Modification compared to the Approved Operations.

The analysis indicates that there will be no discernible impacts on streamflows or dry days with the Proposed Modification when compared to the Approved Operations. As such it is considered that there would be negligible impact on stream biota or water quality with the Proposed Modification.

2.2.2 Loders Creek

Flow Gauging Data

Flow gauging data is collected in NSW by WaterNSW. There is limited flow gauging data for ephemeral creek systems, with flow gauging typically discontinued many years ago. As presented in the *Mount Owen Continued Operations Modification 2 Surface Water Impact Assessment* (MOCO Mod 2 SWIA) (Engeny, 2018), a hydrologic model was developed and calibrated using the AWBM and Swamp Creek data to determine flow sequencing impacts of the Proposed Modification at Mount Owen. Historical flow gauging data is available for a discontinued site located on Swamp Creek (Station 210050) for the period from 1958 to 1968. The model and process presented in the MOCO Mod 2 SWIA was accepted by state and commonwealth agencies. BCC is located approximately 28 km from the Mount Owen Complex, exhibiting similar soil properties and similar order of magnitude catchment areas (i.e. approximately 2,000 ha for Swamp Creek dataset and approximately 5,000 ha in Loders Creek). The calibrated Swamp Creek model has therefore been identified as suitable for use at Loders Creek.

Assessment

The AWBM hydrologic model developed as part of the MOCO Mod 2 SWIA was used to model the potential flow sequencing impacts of the Proposed Modification on streamflows in Loders Creek.

AWBM relates daily rainfall and evapotranspiration to runoff using five functional stores; three surface stores to simulate partial areas of runoff, a base flow store and a surface runoff routing store.

The hydrological model was calibrated to the historical flow gauging data available for Swamp Creek due to the completeness of the data. The calibration fit is presented in Figure 2.3 with the calibration parameters provided in Table 2.5, where:

- C1 to C3 = surface storage capacities.
- A1 to A3 = partial areas represented by surface storages.
- BFI = baseflow index.
- K = daily baseflow recession constant.
- Ks = daily surface flow recession constant.
- Kb = daily baseflow recession constant.

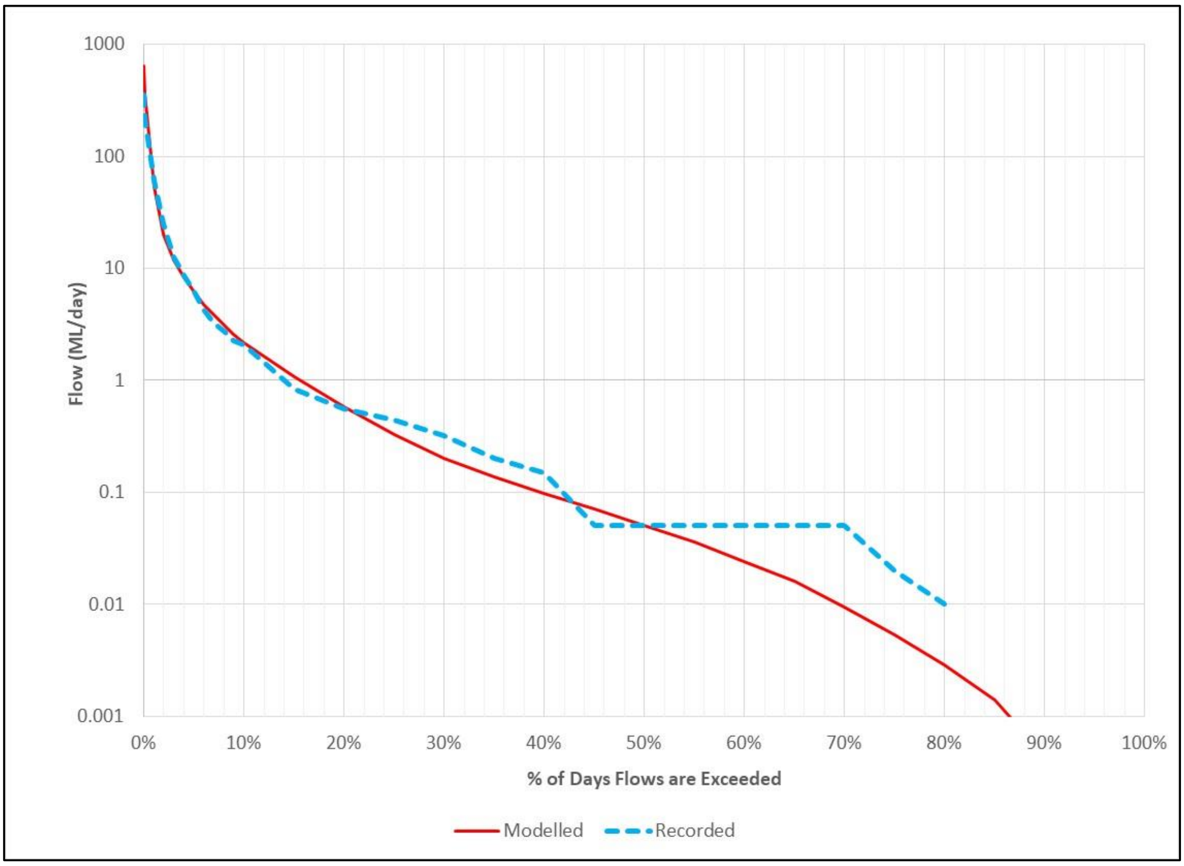

Figure 2.3 Calibration – AWBW Catchment Model – Flow Duration Curve

Table 2.5 AWBM Parameters

Parameter	C1	C2	C3	A1	A2	A3	BFI	KS	KB
Value	20	60	80	0.10	0.45	0.45	0.15	0.95	0.5

The calibrated AWBM model was used to simulate pre-mining streamflow conditions, Approved Operations stream flow conditions and streamflow conditions resulting from the Proposed Modification. The modelling was undertaken using SILO climate data for 139 years of data. Inputs to the post mining streamflow AWBM models include both predicted catchment changes. The scenarios listed in Table 2.6 were modelled for Loders Creek.

Table 2.6 Flow Duration Model Scenarios

Scenario	Catchment Area (ha)	Modelled Groundwater Contribution (m^3/d)	Modelled Baseflow Losses (m^3/d) (relative to existing conditions)
Existing Conditions	3,538	34	-
Approved Operations – Maximum Impact	5,071	31	3
Proposed Modification – Maximum Impact	4,674	31	3

The hydrological modelling results for Loders Creek are presented in Figure 2.4.

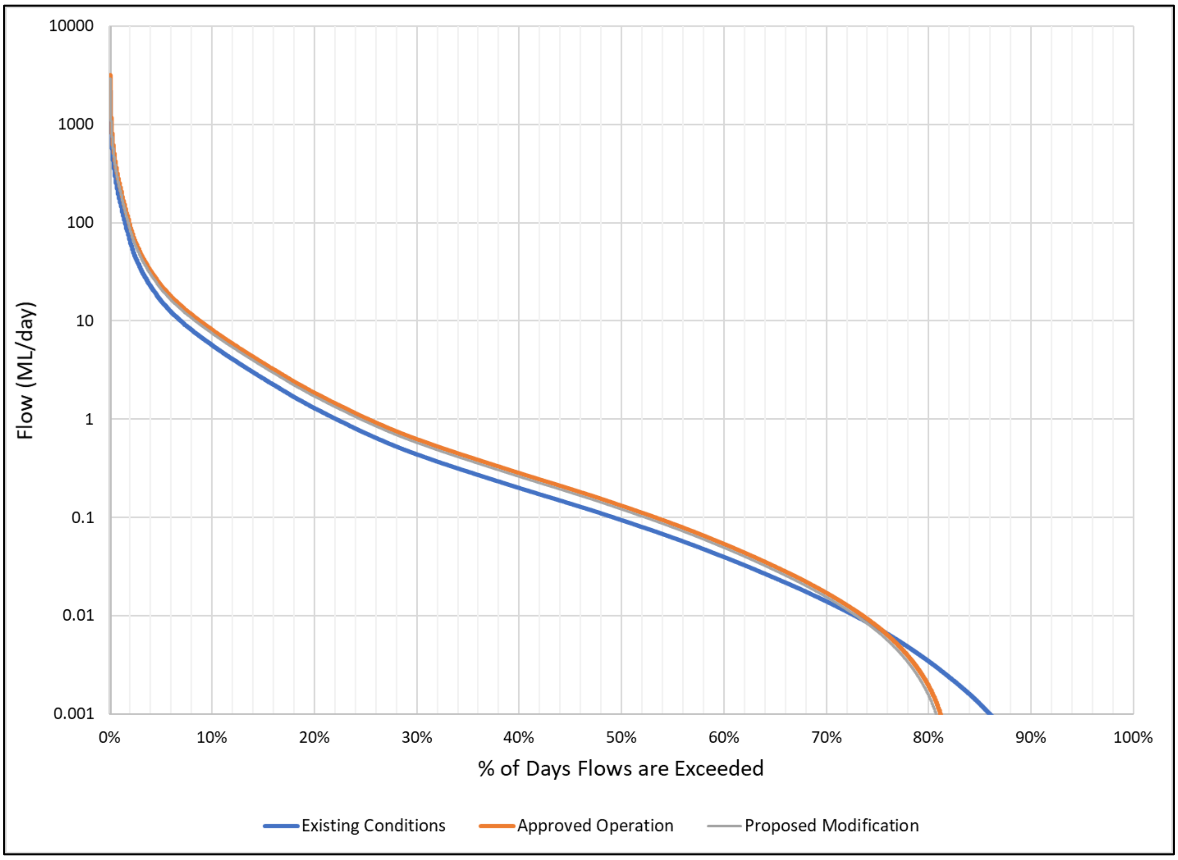

Figure 2.4 Flow Duration Modelled Results – Loders Creek

The modelling indicates a slight increase in the estimated frequency of no-flow periods in Loders Creek for the Proposed Modification compared to the Approved Operations. The average annual dry days (defined as flows less than 0.1 ML day) and flow volumes for Loders Creek, sourced from the AWBM model outputs are summarised in Table 2.7Table 2.7.

Table 2.7 Average Annual Flow Conditions – Loders Creek

Scenario	Average Annual Dry Days	Average Annual Flow Volume (ML/yr)
Existing Conditions	184	2,517
Approved Operations	169	3,606
Proposed Modification	173	3,324

Loders Creek will potentially be dry (i.e. flows less than 0.1 ML day) on average 4 days more per year with the Proposed Modification (moving from a modelled average of 169 days per year to 173 days per year), however this represents a decrease relative to existing conditions under which it is calculated that there are approximately 184 dry days on average.

The net impact on streamflow as a result of the Proposed Modification is observed in changes to the predicted average annual flow volumes in Loders Creek with a reduction from 3,606 ML per year with the Approved Operations to 3,324 ML per year with the Proposed Modification (refer to Table 2.7). It is noted that these incremental impacts are associated with changes to catchment areas, with the Proposed Modification's impacts on groundwater systems not predicted to have any additional baseflow impact on Loders Creek.

The analysis indicates that there will be minor impacts on streamflows and dry days with the Proposed Modification when compared to the Approved Operations. As such, combined with the ephemeral nature of Loders Creek (i.e. the creek being dry on average nearly half the year), it is considered that there would be negligible impact on stream biota or water quality with the Proposed Modification.

2.3 Item 5

The proponent presented flood modelling which suggests that there will be lower peak flows and reduced flood levels in Loders Creek due to the landform modifications over the life of the project (Engeny 2019, p. 36). The modelling is based on an approach and assumptions sometimes adopted for urban environments but which are not consistent with national flood guidance provided for rural catchments (Hill and Thomson, 2019). No attempt was made to relate flood estimates to nearby gauged catchments or other regional information. It is noted that the 1% Annual Exceedance Probability (AEP) flood estimate is around half the magnitude of the flood estimate based on regional flood information and only slightly higher than the corresponding lower 5% confidence limit (http://rffe.arr-software.org/). While the use of ARR87 procedures is reasonable for the purposes of assessing impacts relative to previously provided estimates, it does not provide a suitable basis for assessing current flood risks.

There are no additional flood protection works required with the Proposed Modification.

The purpose of the flood modelling was to assess the potential relative changes in flood risks because of the proposed modifications associated with changes to catchment distribution, not (necessarily) to assess the current absolute flood levels. The flood modelling undertaken was based on the previous (approved) flood modelling, including the general modelling approach, assumptions, and parameterisation. This was considered reasonable for the purposes of estimating the relative impacts on flooding for the proposed modification.

As discussed in the Surface Water Impact Assessment (Engeny, 2019), the ARR 1987 Intensity-Frequency-Duration (IFD) data was used in the assessment of the Proposed Modification to enable comparison to previous models, as has been the accepted process for the approval of modifications for surrounding mines in the Hunter Valley.

A comparison of the adopted ARR 1987 rainfall depths with the updated ARR 2019 rainfall depths is presented in Table 2.8.

Table 2.8 Comparison of ARR 1987 and ARR 2019 Rainfall Depths

Annual Exceedance Probability	AR&R 1987 Rainfall Depth (mm)	AR&R 2019 Rainfall Depth (mm)
39% AEP	59.76 (39% AEP / 2 yr ARI)	57.5 (39% AEP / 2 yr ARI)
5% AEP	103.68	97.9
1% AEP	139.2	134

The comparison identifies that the ARR1987 IFD provides greater rainfall depths and associated average rainfall intensities than the ARR2019 IFD for the modelled events.

As stated above, no additional flood protection works are proposed as part of the Proposed Modification. The operation is currently protected by the flood levee included in the noise and visual bund that provides in excess on the 0.1% AEP protection. The only change is due to minor modifications to the catchment areas.

As the IESC has noted, it is considered that the ARR1987 data provides a conservative assessment for the Proposed Modification in regard to current flood risk and is sufficient for impact assessment.

2.4 Item 6

The sensitivity of flood impacts to climate change was assessed by reference to the difference between 0.5% and 0.2% AEP flood events, although the rationale and nature of the inferences to be drawn from this assessment are not explained. No consideration was given to assessing the impacts of climate change on rainfall intensity as discussed in national flood guidelines (Bates et al. 2019).

As discussed in the Surface Water Impact Assessment (SWIA) (Engeny, 2019), flood modelling of the 0.5% AEP and 0.2% AEP storm events was undertaken as proxies for climate change, in accordance with the Department of Planning and Environment (DPE) General Standard Secretary's Environmental Assessment Requirements (SEARs) (dated December 2015). This approach was undertaken to meet the NSW state government requirements.

The ARR1987 and ARR2019 design rainfalls do not include potential climate change effects. The recommended process for assessing the impacts of climate change in accordance with the ARR2019 Guidelines (Book 6, Bates et al. 2019) is to increase the rainfall (intensity or depth) by 5% per °C of predicted local warming (i.e. a temperature-scaling approach).

Alternatively, the Climate Futures Tool (www.climatechangeinaustralia.gov.au) provides projected estimated changes to the 20 year Average Recurrence Interval (ARI) (approximately equivalent to the 5% AEP) storm event rainfall. This is used as a proxy for the potential change in storm rainfall intensity (noting that average annual rainfall is expected to reduce). The projected changes to the storm rainfall intensity for the RCP4.5 climate change scenario is included in Table 2.9.

Table 2.9 Projected Mean Changes in Rainfall using the Climate Futures Tool

Climate Variable	2030	2040	2050
Annual Rainfall	-2.7%	-2.3%	-2.4%
20 year Rainfall	3.3%	6.0% [A]	8.6%

[A] Linearly interpolated from 2030 and 2050 estimates

Adjusting the 1% AEP design rainfall intensities using the mean changes indicated in Table 2.9 for the year 2040 (i.e. increase of about 6%) are summarised in Table 2.10.

Table 2.10 Adjusted 1% AEP Rainfall Depth

Scenario	ARR1987 Rainfall Depth (mm)	ARR2019 Rainfall Depth (mm)
1% AEP base case	139.2	134.0
1% AEP climate change scenario	147.5	142.0

From Table 2.10 it can be seen that the adjusted climate change scenario rainfall depths for ARR2019 are similar (within 2%) of the ARR1987 1% AEP base case (refer to Table 2.8). The base case modelling in the SWIA is therefore conservative in the prediction of climate change impacts, as the IFDs are higher than the design storm intensity under future climate change for ARR2019.

2.5 Item 7

The flood modelling also did not consider potential impacts on the downstream environment from spills from the Northern and Surge Dams during high rainfall events (HEC 2019, Figures 31-33, p. 39). The IESC recommends a sensitivity analysis should be undertaken to assess the likely impacts of a range of rainfall events (including extreme events), and the potential for spillage post-mining by considering climate change. The influence of climate change on expected storage levels in these dams could be informed through the use of the Climate Futures Framework and Tools (Whetton et al. 2012) (https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/projections/) which allows for various climate regimes to be simulated.

It should be noted that the Proposed Modification will not change the Northern Dam or Surge Dam, or their respective catchments or the adopted design and operational criteria.

In order to meet the pollution requirements of the *Protection of the Environment Operations Act 1997* (POEO Act), NSW Government approved water containment and design mechanisms are put in place at BCC. For management purposes, three classes of water are identified. These classes and design criteria for the BCC are summarised in Table 2.11.

Table 2.11 Water Management Classification and Design Criteria

Water Category	Water Description	Design Criteria
Clean Water	Runoff from undisturbed or rehabilitated areas.	Release, where practicable, to downstream environment.
Dirty Water	Runoff from disturbed areas (does not include water captured in mining pit areas or runoff from mine infrastructure areas).	Managed in line with the Blue Book (Managing Urban Stormwater: Soils and Construction Volumes 1 and 2E). Designed to manage runoff from the 5 day, 95th percentile rainfall event.
Mine Water	Runoff from areas exposed to coal or water used in coal processing or from coal stockpile areas.	Designed, installed and maintained to contain events up to and including the 1% AEP 24 hour storm event.

As stated above, the Proposed Modification does not change the Northern Dam or its catchment, nor the Surge Dam and the design measures adopted for their operation. That is, to meet the mine water design requirements, mine water dams, such as the Northern and Surge Dams, are maintained at operating water levels such that there is sufficient freeboard to contain the 1% AEP 24 hour storm event.

Both the Northern Dam and the Surge Dam have limited catchment areas and the dams can only discharge from the controlled release points (i.e. under the Environment Protection Licence (EPL) and Hunter River Salinity Trading Scheme (HRSTS)). Climate change will have no impact on the operation of the Northern Dam or the Surge Dam, as the dams are controlled releases points with no external catchment for the Surge Dam and 49 ha for the Northern Dam. Mine affected water is pumped from the pits to the dams for release or reuse. The minor predicted increases in rainfall intensity will mean that immediately following a storm additional water will be stored in the pits. Discharges from the system will continue in accordance with the current EPL and HRSTS requirements.

3. QUESTION 3

<u>Surface water</u> - Question 3: To what extent can decision makers have confidence in the predictions of potential impacts on surface water resources provided in the SEE, including in regard to potential stream flow losses, water quality, discharges and flooding?

3.1 Item 13

The proponent has presented monitoring data for pH, EC (electrical conductivity) and TSS (total suspended solids) which are monitored under their EPL. Future monitoring should include a broader suite of analytes such as sulfate, metals and metalloids for all current surface water monitoring sites, and should include new sites in Loders Creek, downstream from licenced discharge points. Discharges are likely to contain a number of metals and metalloids which have the potential to adversely affect biota. The proponent should also provide water quality data for water used in dust suppression.

BCM monitor surface water quality in accordance with the NSW Government and EPBC approved Bulga Coal Water Management Plan (WMP) (Approved 2017). As discussed in the Surface Water Impact Assessment (Engeny, 2019), this program includes monthly monitoring of pH, TSS, EC and flow conditions, at various upstream and downstream locations on the creeks affected by BCC operations. This includes future monitoring of additional locations on Loders Creeks downstream of the proposed Hunter River Salinity Trading Scheme (HRSTS) discharge point.

Monitoring at Environment Protection Licence (EPL) licensed discharge points (LDP) is summarised in Table 3.1. Monitoring is undertaken in accordance with the EPL and meets the requirements of the NSW EPA under the *Protection of the Environment Operations Act 1997* (POEO Act). BCM is committed to continue meeting these monitoring requirements.

Table 3.1 Monitoring of Licensed Discharge Points

Site	Location	Parameters	Frequency
LDP3	Swan Lake	pH, TSS, EC, Dam Level, Discharge Volume, Oil and grease	Monthly Continuously under discharge. TSS and pH daily when discharged.
LDP4	CHPP Surge Dam	pH, TSS, EC, Dam Level, Discharge Volume, Oil and grease	Monthly Continuously under discharge. TSS and pH daily when discharged.

The WMP does not currently commit BCC to monitoring of a broader set of analytes including sulfate, metals and metalloids. In addition to the existing monthly monitoring program, BCC will implement further speciation analysis at existing and future monitoring locations on a six monthly basis. The speciation analysis will include the following:

- pH, TSS, EC in accordance with monthly monitoring
- Total Metal / Metalloids: Aluminium (Al), Arsenic (As), Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Selenium (Se), Zinc (Zn), Mercury (Hg), Lead (Pb), Potassium (K), Silver (Ag), Fluoride (Fl), Boron (B), Calcium (Ca), Barium (Ba), Magnesium (Mg), Cadmium (Cd), Sodium (Na)
- Nutrients: Total phosphorous (P), Nitrite, Nitrate, Total Kjeldahl Nitrogen (TKN), Total Nitrogen (Total N)
- Ions: Chloride (Cl), Bicarbonate (CaCO3), Sulphate (SO4)

BCC also proposes to include in the surface water monitoring program a trigger for increased frequency of monitoring metals/metalloids based on recorded pH.

3.2 Item 14

The proponent has stated that there is the potential for mining to be disrupted over time due to excessive volumes of water stored in the open cut voids (HEC 2019, p. 37). Consequently, the proponent has outlined a site water storage strategy which includes discharging excess water to underground goafs and the Hunter River through the HRSTS. Limited information has been provided on the volumes, quality and timing of releases of this excess water. Further information on the quality of the water and potential for interactions with the goaf material should be provided. Monitoring of the water quality of all water subject to controlled discharge should occur prior to discharge.

As discussed in the Surface Water Impact Assessment (Engeny, 2019) the Approved Operations and Proposed Modification exist and operate within a well-regulated system that has been designed to provide for the sustainable management of the State’s water resources. This includes licensing of allowable water take with consideration of environmental flow requirements of watercourses and the needs of other water users; control of water pollution, including management of sustainable salt loads associated with all water sources, including mine water discharges; and guidelines that govern the appropriate design of water management systems for mines to provide for appropriate water quality in accordance with EPL requirements.

All discharges are monitored and must meet the relevant EPL criteria including HRSTS requirements in relation to salinity.

Further to this water is currently pumped to the goafs which are used within the BCC as a water storage as they provide enhanced water conservation (i.e. minimising evaporative losses). These volumes are tracked in the Water Accounting Framework (as per guidelines provided by the Minerals Council of Australia, following the National Water Initiative (2004) and provide an important role in water security at the BCC. Water pumped into the goafs only occurs in areas where these former workings will eventually flood through groundwater inflows. The storage of water in the goafs is not expected to result in any adverse impacts on water quality relative to groundwater inflows to these workings and they remain a groundwater sink.

The Proposed Modification will not require any alteration to the existing regulatory or licensing arrangements for discharges under the EPL or the HRSTS.

4. QUESTION 8

***Avoidance, Mitigation and Monitoring* - Question 8: Are there any additional mitigation, monitoring, management or offsetting measures that should be considered by the decision makers to address the residual impacts of the Proposed Modification on water resources in conditions of consent?**

4.1 Item 46

The proponent has not clearly identified expected discharge quality (particularly in relation to metal contaminants). This means that the appropriateness of the proposed mitigation or monitoring cannot be fully evaluated.

Monitoring of discharges from the BCC are driven by Section 120 of the POEO Act, which makes it an offence to pollute waters or cause harm unless licensed to do so. The EPL and HRSTS regulate discharges from the BCC mine water management system which would otherwise be considered a breach of the POEO Act.

As discussed in Item 14, the Proposed Modification will not require any alteration to the existing regulatory or licensing arrangements for discharges, maintaining existing discharge quality limits. Therefore, there is no change to the discharge quantity or quality relative to existing approved operations.

BCC reuses water within the WMS as a first priority for dust suppression and in the coal handling and preparation plant (CHPP). Discharges only occur when surplus water cannot be managed on-site and discharge opportunities are present. WaterNSW determines when discharges can occur and participants of the HRSTS are notified of events and associated limits.

4.2 Item 48

The IESC notes that monitoring of the water management dams on site does not include any monitoring of metals and metalloids. Metals (both total and dissolved) and metalloids should be monitored especially in the Northern Dam and Surge Dam as this water can be discharged to the Hunter River.

As discussed in Item 13, BCM will expand the existing surface water monitoring program to include monitoring of a broader suite of analytes such as metals and metalloids. The six monthly program will include monitoring of on-site dams.

4.3 Item 49

The IESC recommends the proponent develop a Receiving Environment Management Plan (REMP) that specifies actions to ensure that the downstream environment is not adversely affected by discharges or storage overflows from the proposed mine. The REMP should:

a. include a program of regular and event-based water quality monitoring of discharge water, and of surface water upstream and immediately downstream of the mine or licenced discharge points;

b. provide a TARP, in line with ANZG (2018) guidelines, which uses site-specific data from reference sites;

c. include site-specific guidelines that have been derived from reference sites as outlined in Huynh and Hobbs (2019);

d. integrate with the existing Surface Water Management Plan (SWMP) so that the mitigation and management measures will adequately protect environmental values within and downstream of the project area;

e. include ecohydrological conceptual models that illustrate potential pathways and mechanisms of the effects of altered surface flows on groundwater and alluvial recharge, instream water quality, and surface and groundwater ecosystems. These conceptual models would help the proponent justify strategies proposed to mitigate and manage potential impacts; and,

f. include a mechanism for evaluating the effectiveness of selected mitigation and management measures and adopting new approaches if the current approaches are found ineffective.

The BCC operates in accordance with a range management plans, required by the conditions of the development consent for SSD-4960, which detail management and mitigation measures. Under this management plan framework, the BCC manages water capture, supply, consumption, storage, disposal and hydrological interception in accordance with the WMP and associated sub plans. These plans must be prepared in consultation with NSW regulators and are approved by the NSW DPIE-Planning.

The BCC WMP can be found at the following location: https://www.bulgacoal.com.au/en/publications/management-plans/ManagementPlans/Water-Management-Plan-Approved-by-Commonwealth.pdf

Specific to the above requirements of a Receiving Environment Management Plan (REMP), the BCC WMP includes:

a. A Surface Water Monitoring Program under which regular monthly water quality monitoring is undertaken at various upstream and downstream locations on the creeks affected by the BCC. In addition to the monthly schedule, continuous monitoring is undertaken during discharge events. The monitoring schedule will be expanded to include annual monitoring of a broader set of analytes, including metals and metalloids. Refer to Sections 5.3.1, 9.3.1 of the BCC WMP.

b. A Trigger Action Response Plan (TARP) outlining required management actions in the event site-specific trigger values are exceeded. Refer to Table 31 of the BCC WMP.

c. Site-specific Surface Water Impact Assessment Criteria which defines trigger values for physical and chemical factors, based on background data, in accordance with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC Guidelines) and *Deriving site-specific guideline values for physicochemical parameters and toxicants* (Huynh T and Hobbs D, 2019).

d. An integrated Surface Water Monitoring Program. Refer to Section 9.3 of the BCC WMP.

e. Covered by other NSW state government management plans prepared for BCM.

f. An integrated Surface and Groundwater Response Plan which identifies the appropriate response to exceedances of trigger values. If regular exceedances occur, the response plan requires the Environment and Community Manager to notify and formulate corrective actions in consultation, as required, with any relevant stakeholders. Refer to Section 11 of the BCC WMP.

As identified above, the conditions required by an REMP are addressed as part of the existing NSW management plan framework required by SSD-4960. BCM is committed to continuing with the existing approach to the management of the Proposed Modification in order to continue to meet the SSD-4960 criteria, that is via the BCC WMP.

5. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report.

f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g. This report does not provide legal advice.

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APPENDIX C

HEC Response

HYDRO ENGINEERING & CONSULTING PTY LTD

20 March 2020

Senior Principal Environmental Consultant
Umwelt (Australia) Pty Limited
75 York Street
Teralba, NSW 2284
Via Email
Attention: Bret Jenkins

Bret,

Re: Bulga Optimisation Project Modification 3 (Proposed Modification) – Response to Independent Expert Scientific Committee Submission

Further to our recent correspondence, Hydro Engineering & Consulting Pty Ltd (HEC) has considered the submission of the Independent Expert Scientific Committee (IESC) in regard to the Site Water Balance (SWB) for the above Proposed Modification. The following sections address issues raised in the submission and have been prepared as an addendum to the SWB report (HEC, 2019)[1].

1. Comment 8 – Climate Change Effects

IESC Comment 8:

"*The site water balance modelling was based on the use of a well-accepted rainfall-runoff model (AWBM), and a reasonable level of agreement was obtained between model simulations and monitored storage levels. The site water balance considered three scenarios relating to underground operations: existing approved underground operations, delaying restart of underground operations until 2029 and no further underground operations. These scenarios considered climate variability through the use of 121 "climate realisations" which were based on 20-year periods that were successively shifted forward one year at a time over the full historic period. This approach to investigating the impacts of climate variability does not allow for projected changes in rainfall and temperature associated with climate change (Whetton et al. 2012).*"

HEC Response:

Predicting future climate using global climate models is undertaken by a large number of research organisations around the world. In Australia much of this effort has been conducted and co-ordinated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CSIRO and the Bureau of Meteorology (BoM) have published a comprehensive assessment of climate change effects on Australia and future projections[2]. This is based on an understanding of the climate system, historical trends and model simulations of climate response to future global scenarios.

[1] Hydro Engineering & Consulting Pty Ltd (2019). "Bulga Coal Complex Bulga Optimisation Project Modification 3 Site Water Balance", prepared for Umwelt (Australia) Pty Limited, rev g, August.

[2] CSIRO and BoM (2015a). "Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report". Commonwealth Scientific and Industrial Research Organisation and the Australian Bureau of Meteorology, Australia.

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Simulations have been drawn from an archive of more than 40 global climate models (GCMs) developed by groups around the world. Modelling has been undertaken for four Representative Concentration Pathways (RCPs) used in the Intergovernmental Panel on Climate Change (IPCC) assessments, which represent different future scenarios of greenhouse gas and aerosol emission changes and land-use change.

Predictions of future climate from the various GCMs and RCPs have been used to formulate probability distributions for a range of climate variables including rainfall and potential evapotranspiration. Predictions are made for up to 14 future time periods between 2025 and 2090.

Assessments of likely future concurrent rainfall and evapotranspiration changes have been undertaken using the online Climate Futures Tool[3]. Projected changes from all available GCMs are classified into broad categories of future change defined by these two variables, which are the most relevant available parameters affecting rainfall runoff. The Climate Futures Tool excludes GCMs which were not found to perform satisfactorily over the Australian region. The assessments assumed an emissions scenario of RCP 4.5 (representing a future with a lowering of emissions, achieved by application of some mitigation strategies and technologies, with a carbon dioxide level peaking at around the year 2040). Assessments were performed for 2025, 2030, 2035 and 2040 (with results interpolated in other years through the Project) for the east coast region of the continent. Table 1 presents mean annual changes for these two climate variables.

Table 1 Predicted Mean Change in Annual Rainfall and Evapotranspiration using Climate Futures Tool

Climate Variable	Mean Change From Reference Period by			
	2025	2030	2035	2040
Annual Rainfall	-2.5%	-2.7%	-1.3%	-1.4%
Annual Evapotranspiration	3.1%	3.5%	3.8%	4.0%

The above factors were used in the operational water balance model for the Proposed Modification by applying to the daily rainfall and evaporation data used in the simulations – refer HEC (2019). No specific data was available for evaporation from the Climate Futures Tool; therefore the factors for evapotranspiration were applied to modelled daily pan evaporation.

Other than the application of the rainfall and evapotranspiration factors given in Table 1 (and the resulting calculation of site rainfall runoff), no other changes were made to the operational water balance model. There were no changes to the simulation of Hunter River supply availability and licensed discharge opportunities via the Hunter River Salinity Trading Scheme (HRSTS).

Model predicted average inflows and outflows for the three modelled scenarios relating to underground operations[4] with climate change factors applied, averaged over all 121 realizations and the 21 year simulation period, are shown in Figure 1.

[3] CSIRO and BoM (2015). "Climate Change in Australia", accessed 10th March 2020, http://www.climatechangeinaustralia.gov.au/en/. Commonwealth Scientific and Industrial Research Organisation and the Australian Bureau of Meteorology, Australia.

[4] The three scenarios were: with existing approved underground operations, with underground operations delayed and with no further underground operations.

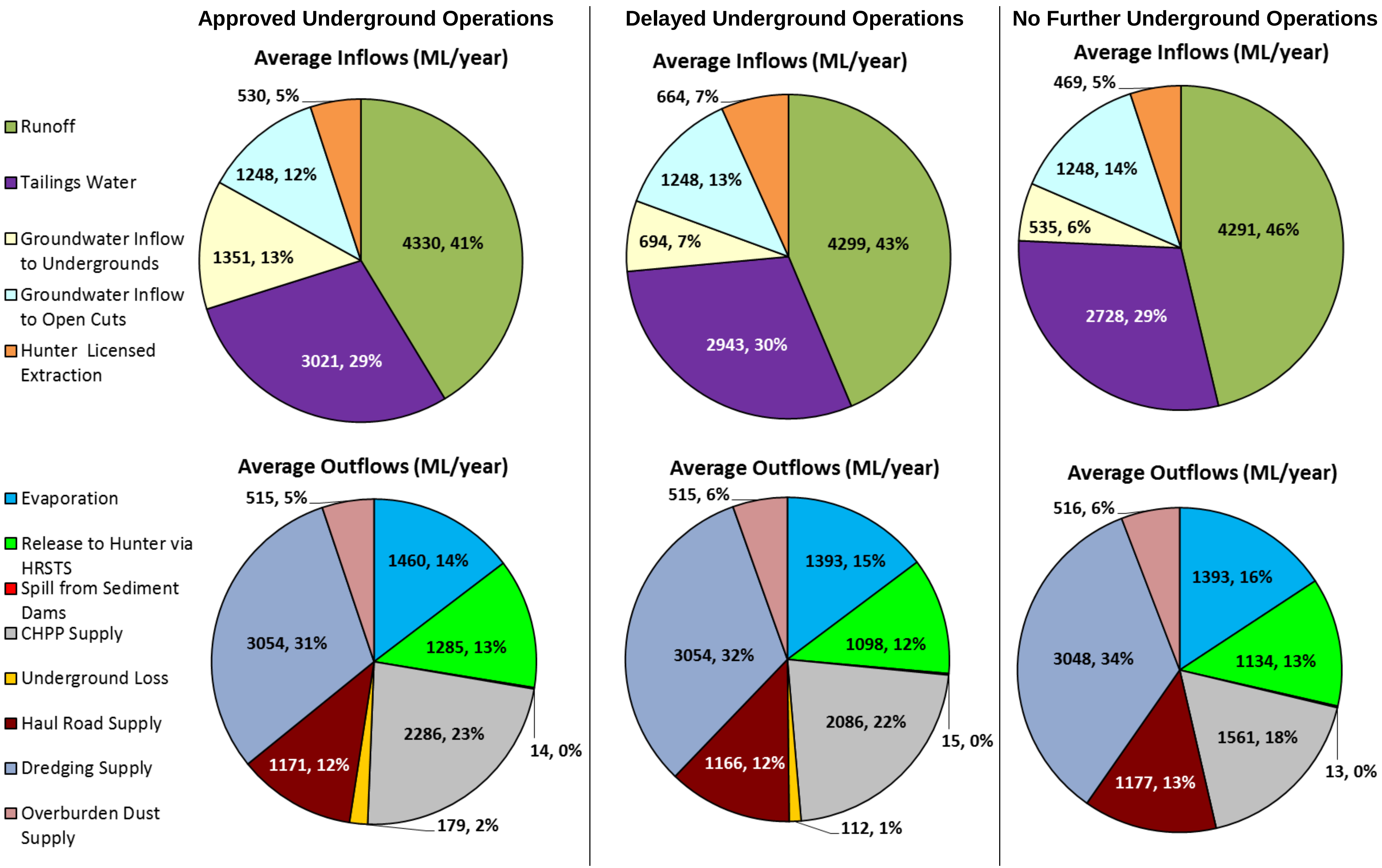

Figure 1 Average Modelled System Inflows and Outflows with Climate Change

The relative proportions of inflows and outflows shown in Figure 1 are similar to those shown in Figure 18 of HEC (2019). Modelled climate change results in a forecast average reduction of approximately 300 ML/year in site runoff with a small increase of between 30 and 70 ML/year in the volume of water sourced from Hunter River Supply (WALs). Overall, this results in less water stored on site and, even with the increased evapotranspiration factors, this results in a decrease in average annual evaporation of between 20 to 30 ML/year. Lower site water inventory also results in approximately 150 to 200 ML/year less licensed HRSTS discharge. A slight increase in the average annual volume supplied for haul road dust suppression is predicted (approximately 30 ML/year) which is due to increased haul road demand associated with the use of the evapotranspiration factors.

Predicted total stored water inventory is shown in Figure 2 to Figure 4 for the three modelled mining cases as probability plots over the simulation period.

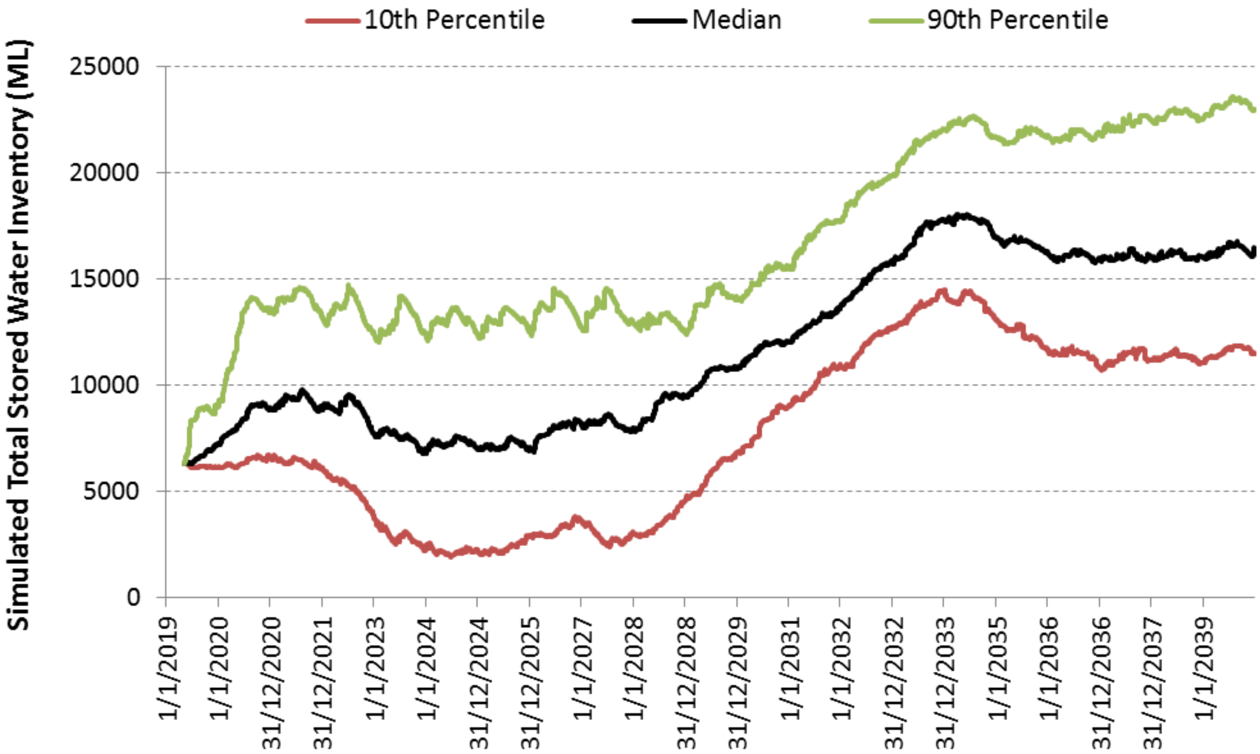

Figure 2 Simulated Total Stored Water Volume with Approved Underground Operations with Climate Change

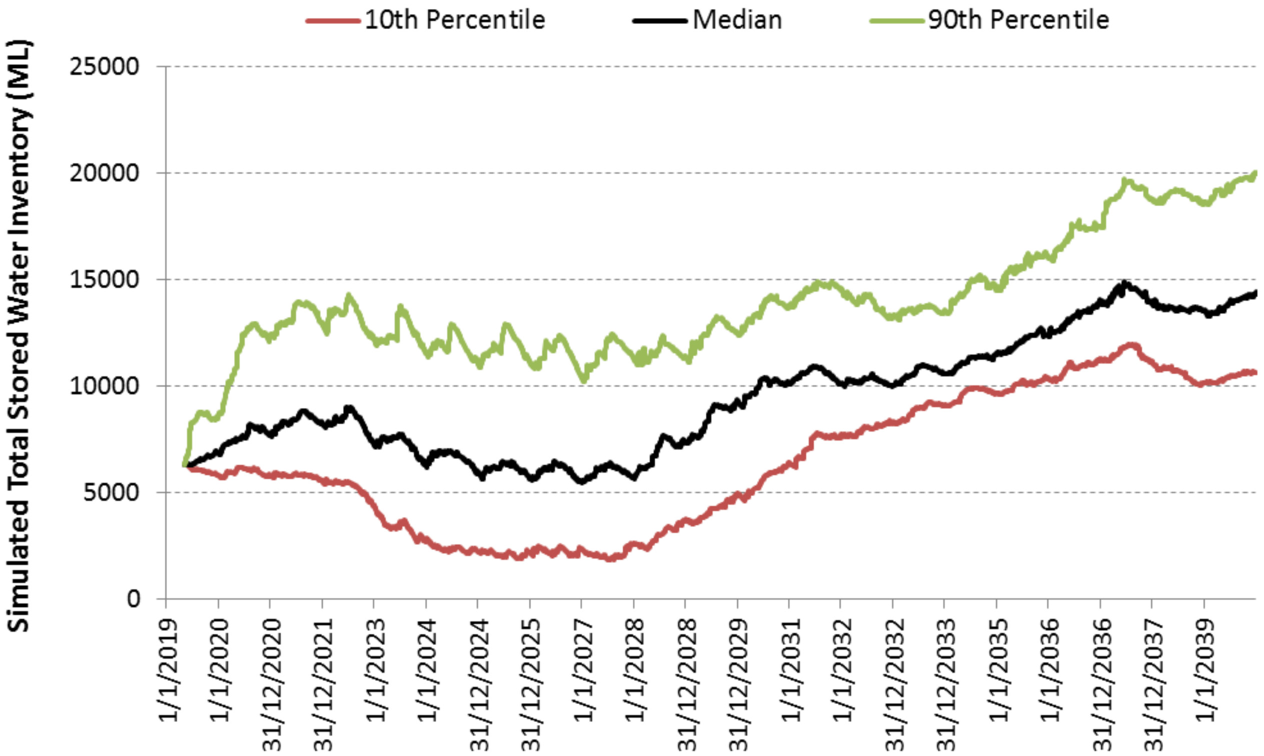

Figure 3 **Simulated Total Stored Water Volume with Delayed Underground Operations with Climate Change**

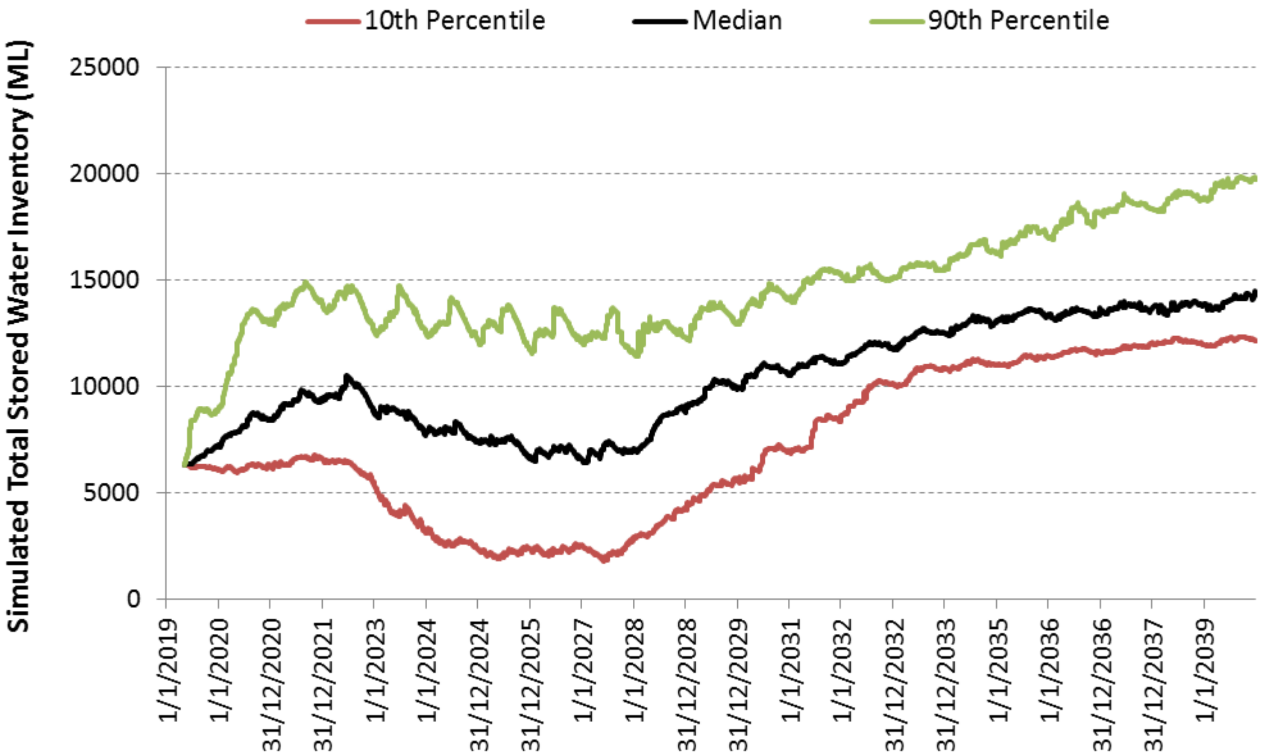

Figure 4 **Simulated Total Stored Water Volume with No Further Underground Operations with Climate Change**

The model results plotted in Figure 2 to Figure 4 show a similar pattern to the model results presented on Figure 19 to Figure 21 of HEC (2019), with lower simulated stored water inventories. There is a decrease in the median total stored water volume at the end of the simulation period of approximately 2,500 ML for the approved underground case, 1,600 ML for the delayed underground case and 1,300 ML for the case with no further underground operations.

The simulated stored water volume in the Bulga East open cut is shown in Figure 5 to Figure 7.

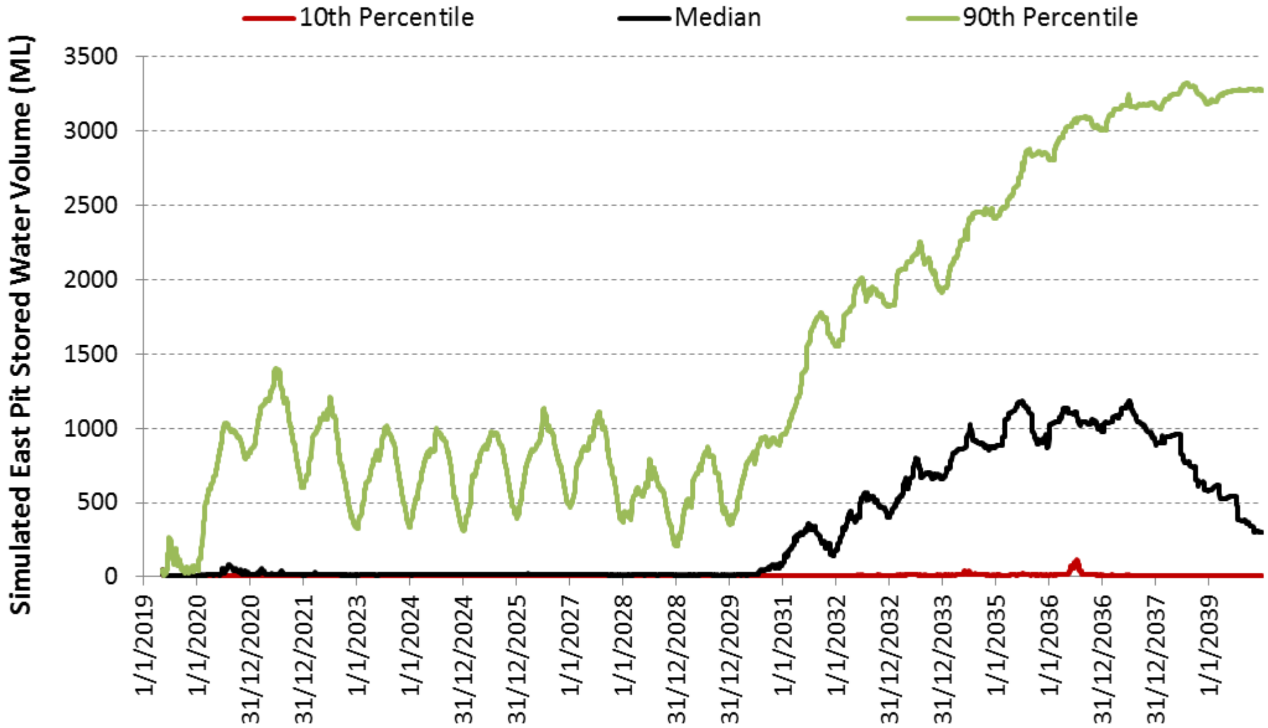

Figure 5 **Simulated Bulga East Open Cut Stored Water Volume with Approved Underground Operations with Climate Change**

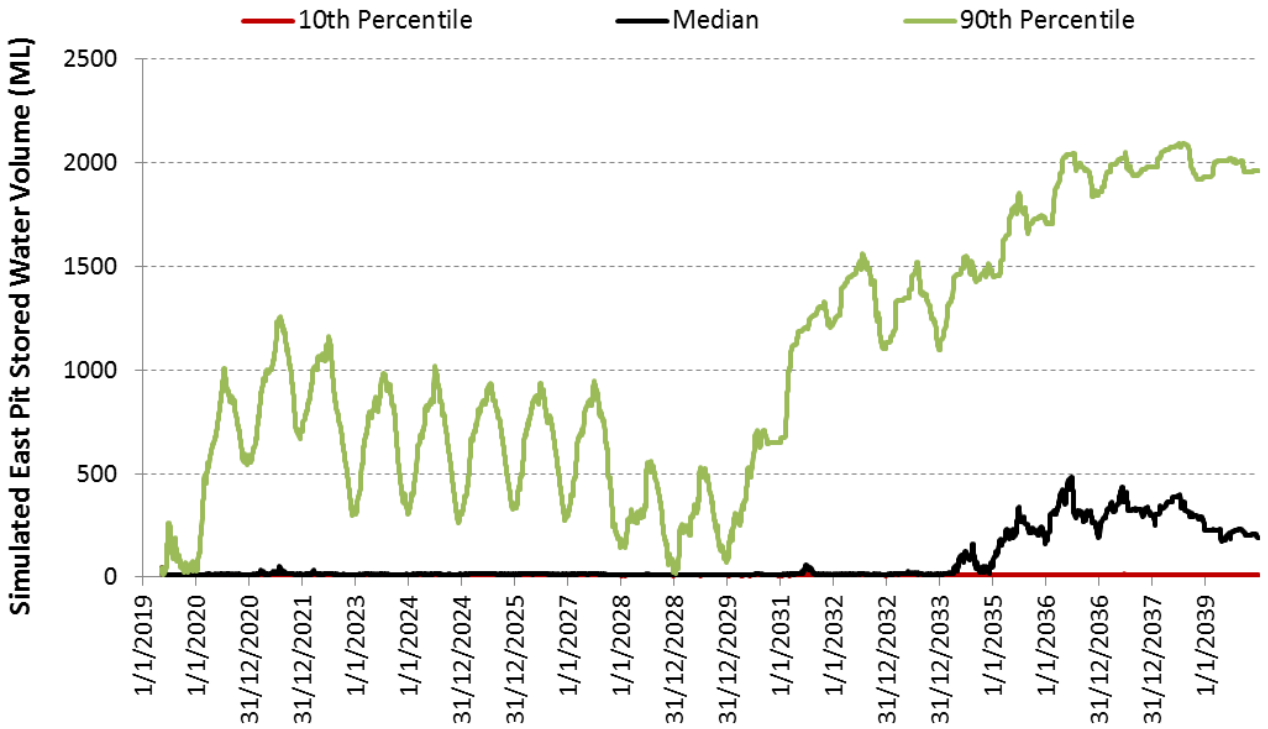

Figure 6 **Simulated Bulga East Open Cut Stored Water Volume with Delayed Underground Operations with Climate Change**

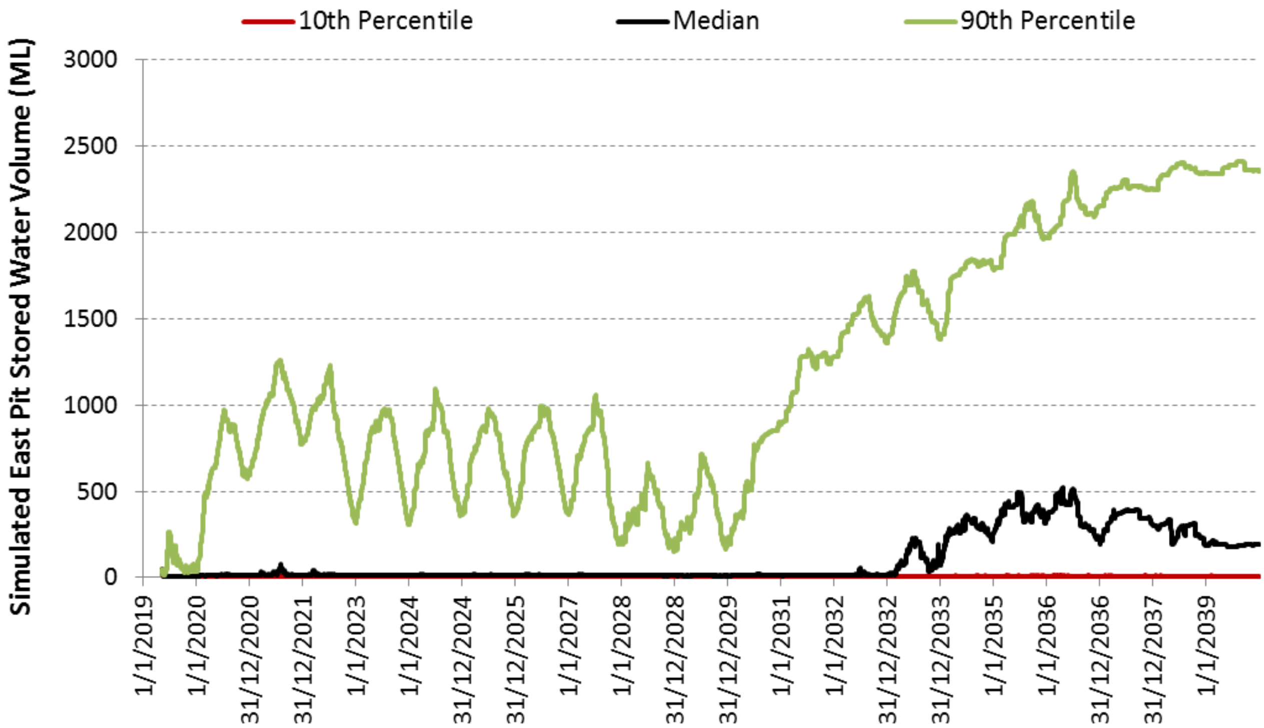

Figure 7 Simulated Bulga East Open Cut Stored Water Volume with No Further Underground Operations with Climate Change

The effect of simulated climate change is a reduction in the volume of water held in the open cut, with, for example, the peak median volume decreasing by approximately 1,000 ML for the approved underground case (comparing Figure 5 to Figure 25 in HEC [2019]).

Predicted average supply reliability is expressed as total water supplied divided by total demand (i.e. a volumetric reliability) over the simulation period. Average supply reliability over all climatic realizations, as well as the lowest single realization reliability (representing a simulated 'worst case' simulation period), for CHPP supply, dredging supply, haul road dust suppression (truckfill) and overburden dust suppression with simulation of climate change are summarised in Table 2. There was negligible shortfall simulated for underground supply.

Table 2 Summary of Modelled Water Supply Reliability with Climate Change

Demand	Volumetric Supply Reliability					
	Average			Lowest		
	Approved Underground Operations	Delayed Underground Operations	No Further Underground Operations	Approved Underground Operations	Delayed Underground Operations	No Further Underground Operations
CHPP	99.9%	99.9%	99.9%	98.8%	98.0%	99.2%
Dredging	99.6%	99.6%	99.4%	93.4%	92.4%	89.5%
Haul Road Dust Suppression	97.5%	97.2%	98.1%	81.4%	79.8%	86.0%
Overburden Dust Suppression	99.4%	99.4%	99.5%	97.8%	97.9%	98.2%

The above indicates a slight reduction in forecast supply reliability compared with the values in Table 5 of HEC (2019). There is a 0.8% reduction in the forecast lowest CHPP supply reliability for the approved underground case but no discernible change in the forecast high average reliability of supply for the CHPP. There is a 1.4% reduction in the forecast lowest haul road dust suppression reliability for the approved underground case and a 0.9% reduction in the forecast average reliability of supply for haul road dust suppression. Modelling with climate change continues to indicate an overall high predicted water supply reliability.

The predicted annual water year (July to June) Hunter River licensed extraction at different probabilities is shown in Figure 8 to Figure 10.

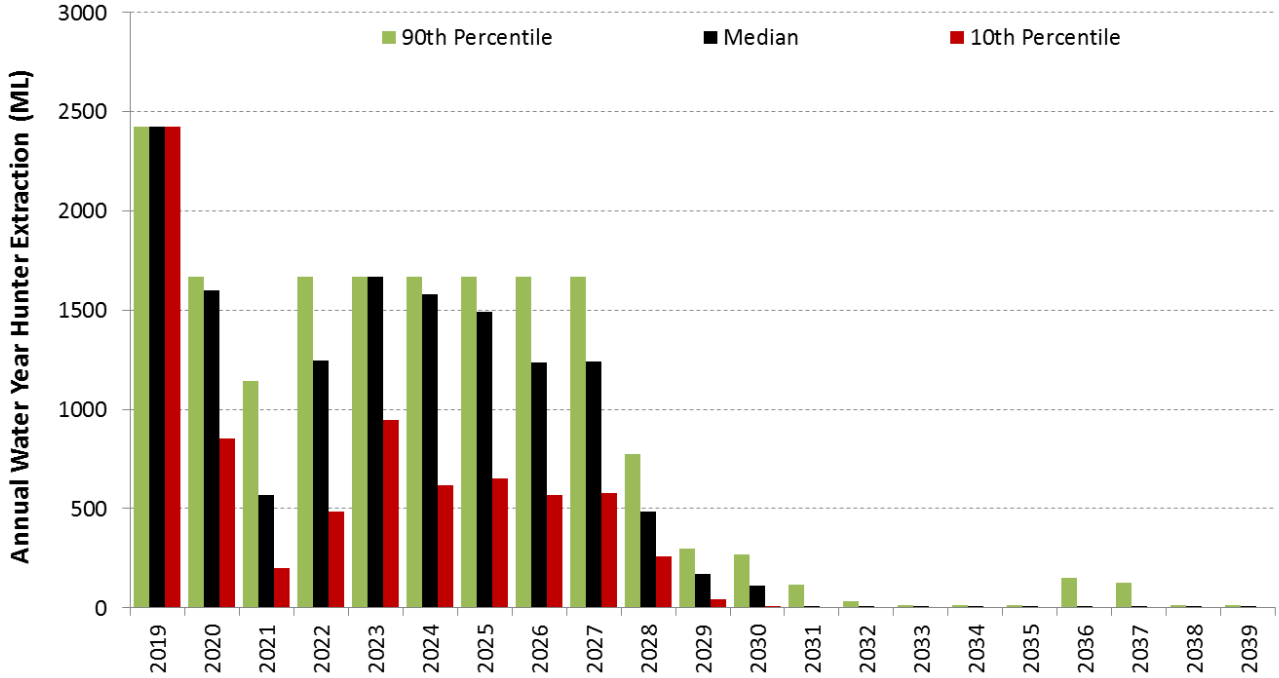

Figure 8 Predicted Annual (Water Year) Hunter River (WAL) Extraction with Approved Underground Operations with Climate Change

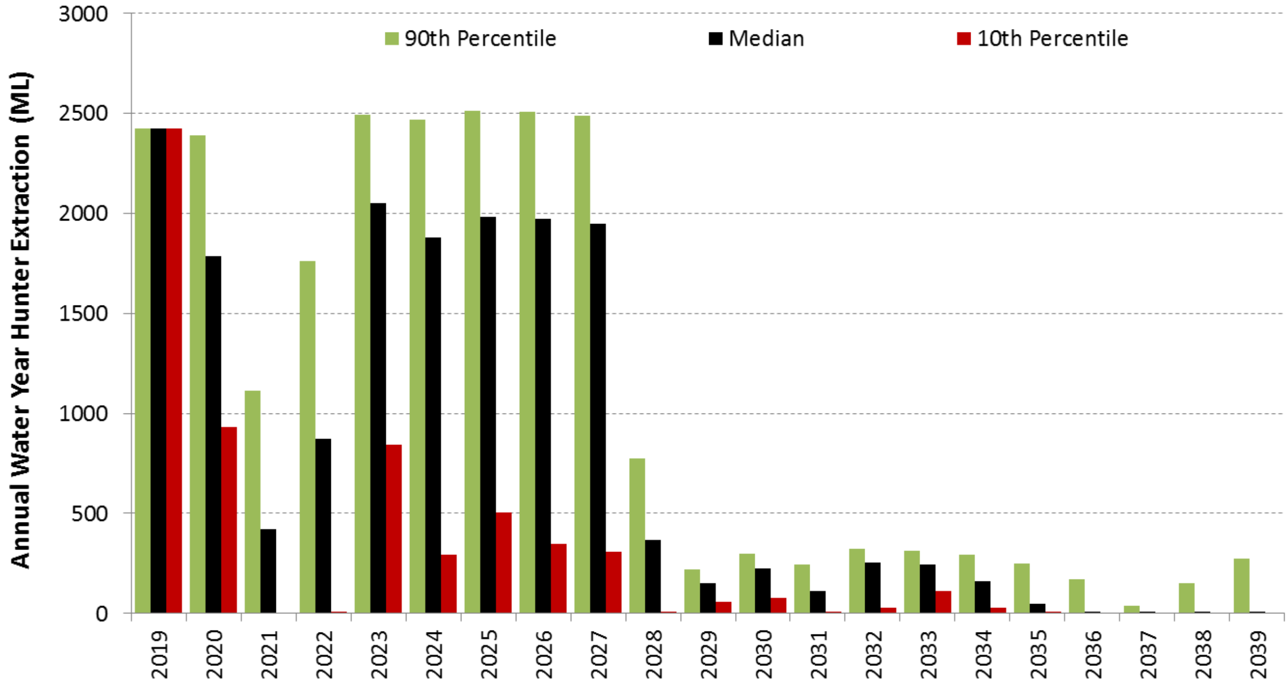

Figure 9 Predicted Annual (Water Year) Hunter River (WAL) Extraction with Delayed Underground Operations with Climate Change

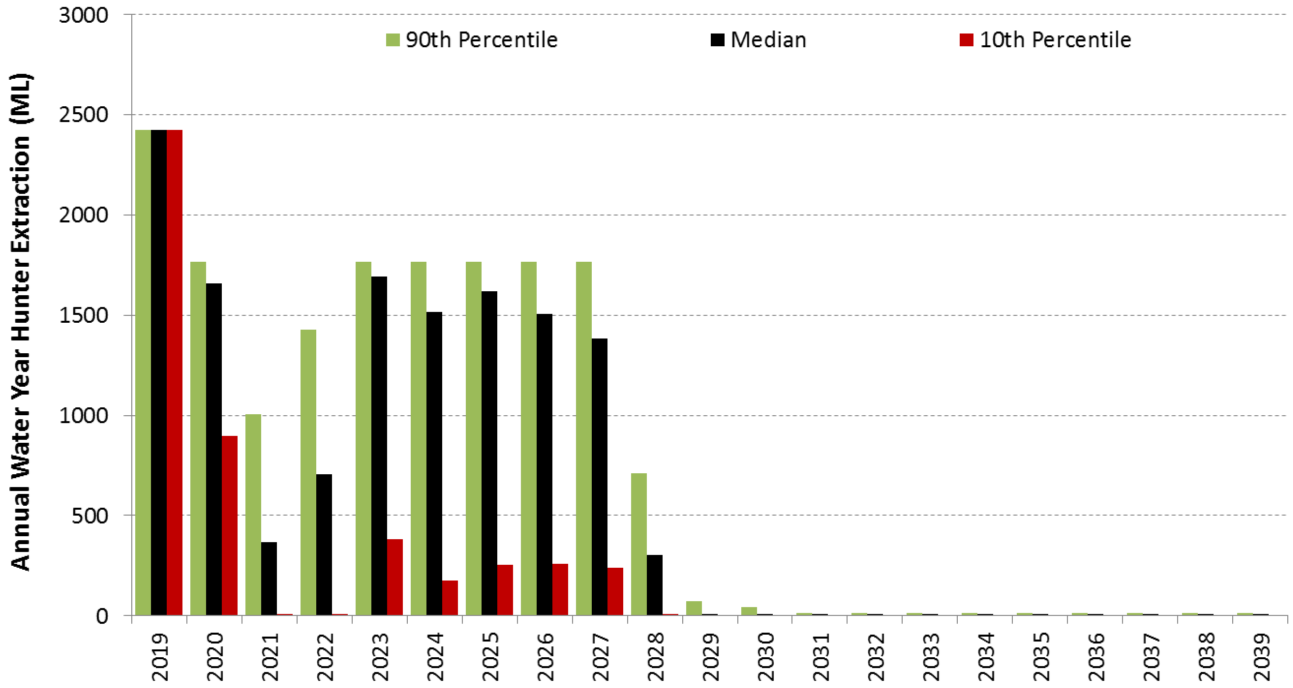

Figure 10 **Predicted Annual (Water Year) Hunter River (WAL) Extraction with No Further Underground Operations with Climate Change**

Patterns of annual extraction are similar to those shown in Figure 28 to Figure 30 of HEC (2019) with generally slightly increased annual volumes (refer also Figure 1).

Model predicted annual (water year) licensed releases in accordance with the HRSTS are summarised in Figure 11 to Figure 13 at different probabilities. Annual patterns are again similar to those shown in Figure 31 to Figure 33 of HEC (2019), with either little change or a slight decrease in volumes due to reduced site runoff as a result of the application of the climate change factors given in Table 1.

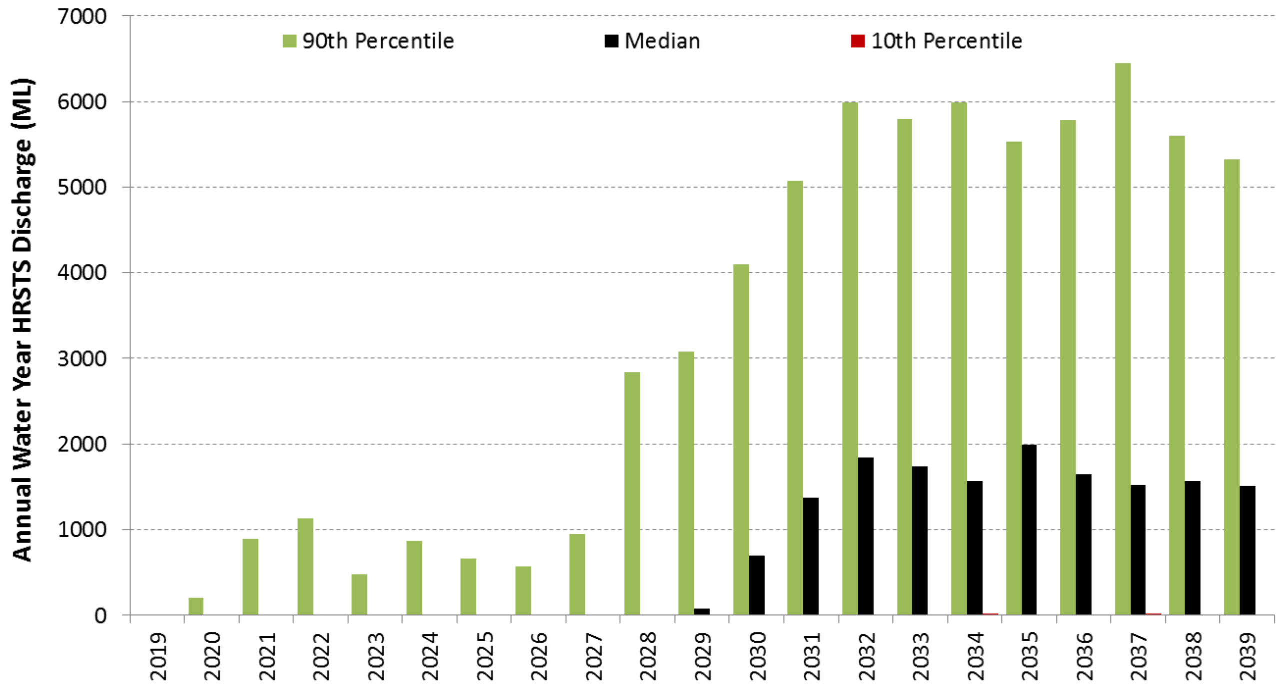

Figure 11 **Predicted Annual (Water Year) HRSTS Licensed Discharge with Approved Underground Operations**

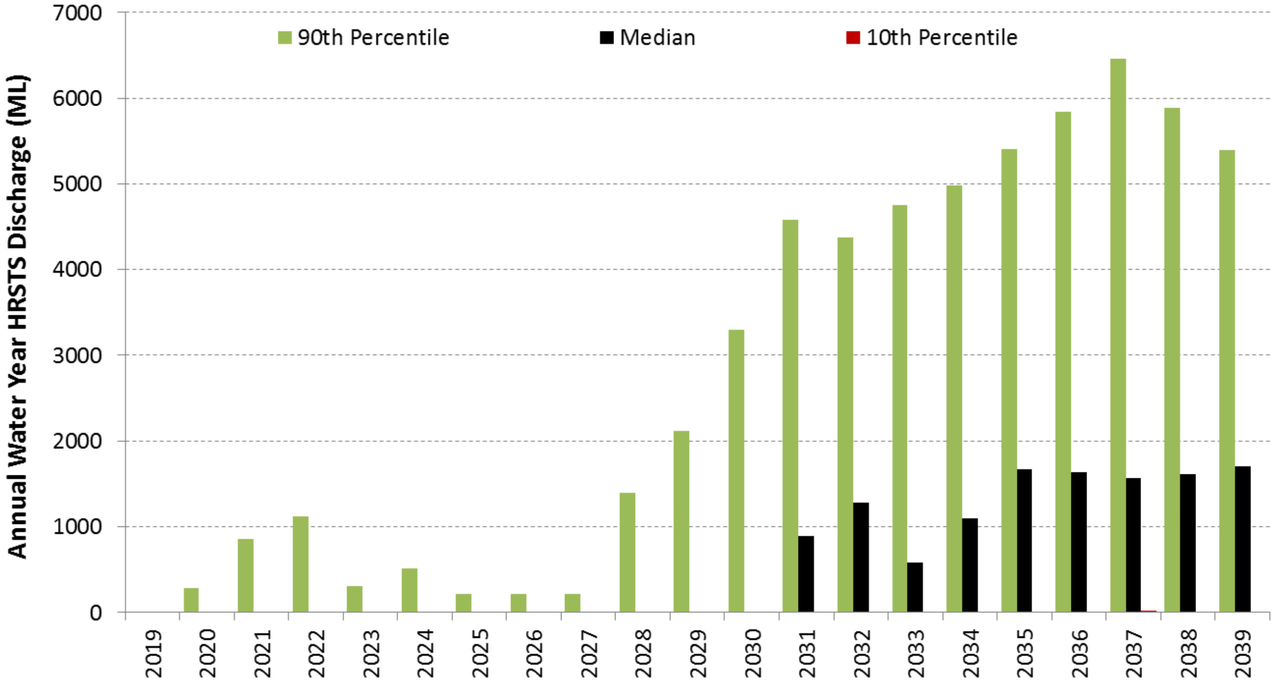

Figure 12 Predicted Annual (Water Year) HRSTS Licensed Discharge with Delayed Underground Operations

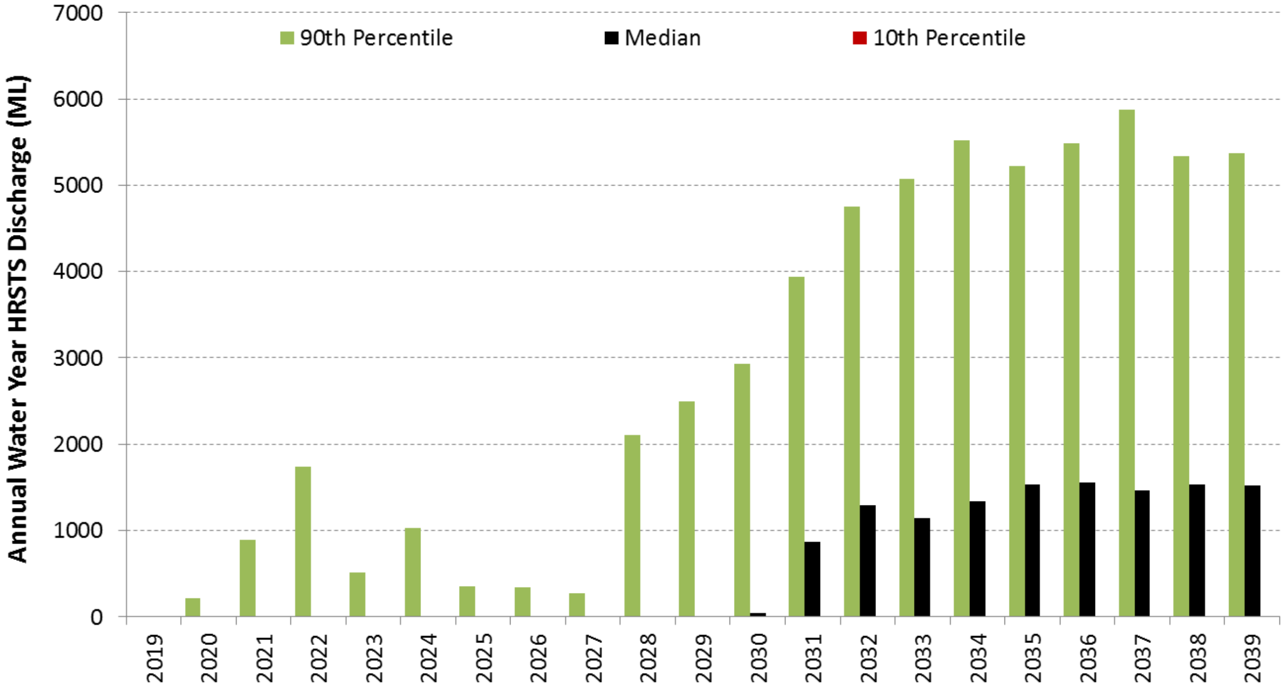

Figure 13 Predicted Annual (Water Year) HRSTS Licensed Discharge with No Further Underground Operations

Patterns of annual release are similar to those shown in Figure 31 to Figure 33 of HEC (2019) with generally slightly decreased annual volumes (refer also Figure 1).

In summary, the application of climate change factors to the calculation of site rainfall runoff in the operational water balance model results in a reduction in forecast site runoff volumes. This results in a predicted reduction in stored water inventory, supply reliability, licensed release and a slight increase in dust suppression demand and volumes sourced from Hunter River WALs. In the overall context of the water balance volumes, the forecast changes are small and within the bounds of historical climatic variability. Model forecasts continue to indicate a high predicted water supply reliability.

2. Comment 11 – Final Void Impacts

<u>IESC Comment 11:</u>

"*The proponent has not adequately modelled potential impacts of the final void in the rehabilitated landscape, including worse-case impacts on surface water. These include long-term impacts on surface water and groundwater quality (particularly salinity). More detail is needed on the range of possible rates of water level recovery (cf. KCB 2019, Figure 4-12, p. 71) to improve assessment of legacy impacts. Further information on the salt balance of the site and salt sources and stores within the final landform should be provided by the proponent (discussed further in Paragraphs 16 and 25).*"

<u>HEC Response:</u>

In terms of "worse-case impacts on surface water", other than the final void (lake) itself there should be no impacts on surface water because the void is not predicted to spill. Per Figure 38 of HEC (2019), final void water balance modelling indicates that the final void water body would reach an equilibrium level well below spill level. Note that Figure 38 of HEC (2019) shows a difference between the equilibrium final void water level and the spill level of approximately 94 m whereas the text below Figure 38 indicates that the equilibrium water level is approximately 120 m below spill level. The reason for this inconsistency is that the plotted spill level on Figure 38 represents the planned lowest spill point through emplaced spoils, whereas the 120 m was calculated based on the depth below the lowest point on the perimeter of the final landform. In the analysis described below the spill level for the final void has been adopted as the planned lowest spill point through emplaced spoils.

In order to further investigate the sensitivity of final void water balance model results to the rates of water level recovery additional final void water balance simulations were undertaken with increased and decreased rates of groundwater flux (inflow and outflow). Updated forecast groundwater flux rates were obtained from KCB[5] and used to develop two groundwater flux versus void water level relationships (in consultation with Umwelt [Australia] Pty Limited). The adopted flux relationships are shown in Figure 14.

[5] File "KCB Groundwater to void inflows 20200306_to HEC.xlsx" supplied via email from B. Jenkins, Umwelt (Australia) Pty Limited, 10 March 2020.

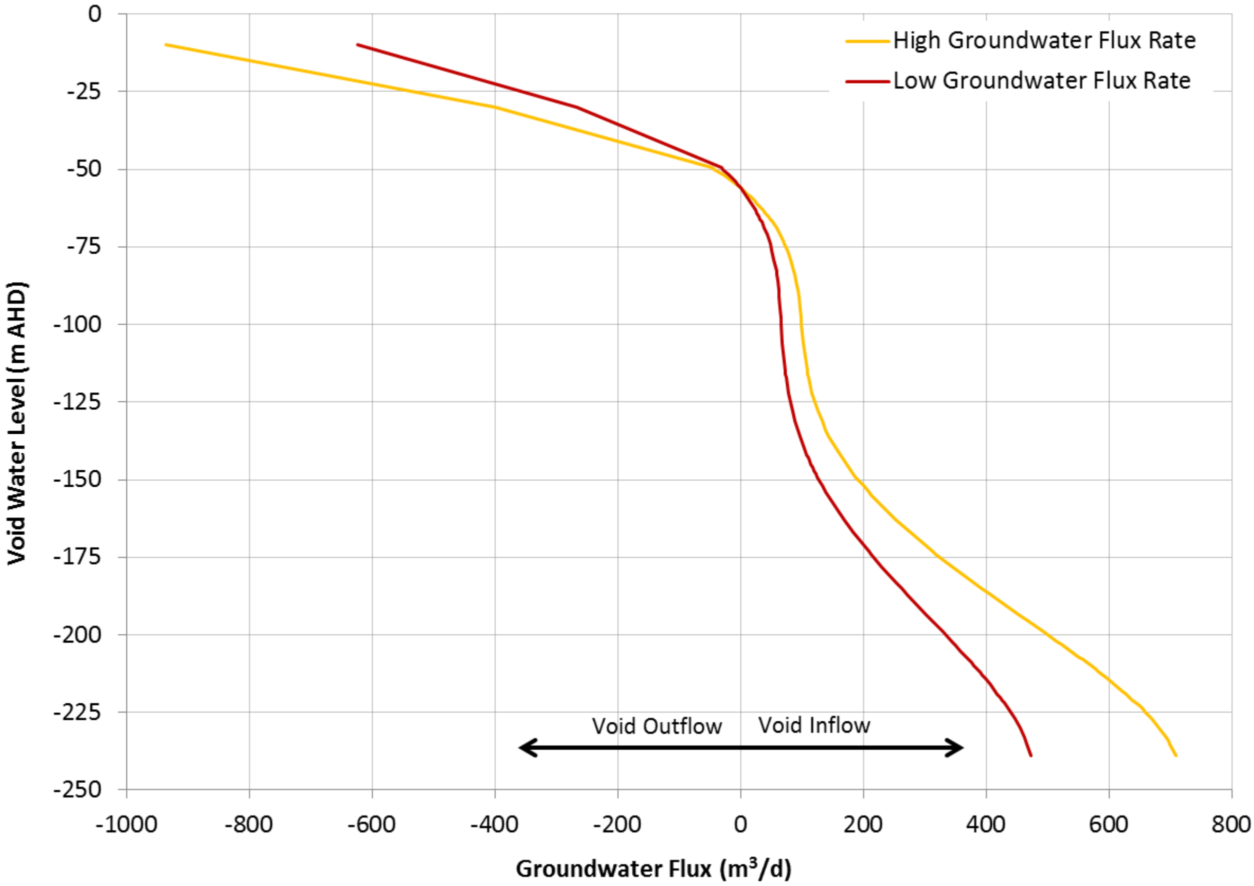

Figure 14 Final Void Modelled Groundwater Flux Rates

Model predicted final void water levels and EC values are shown in Figure 15 and Figure 16.

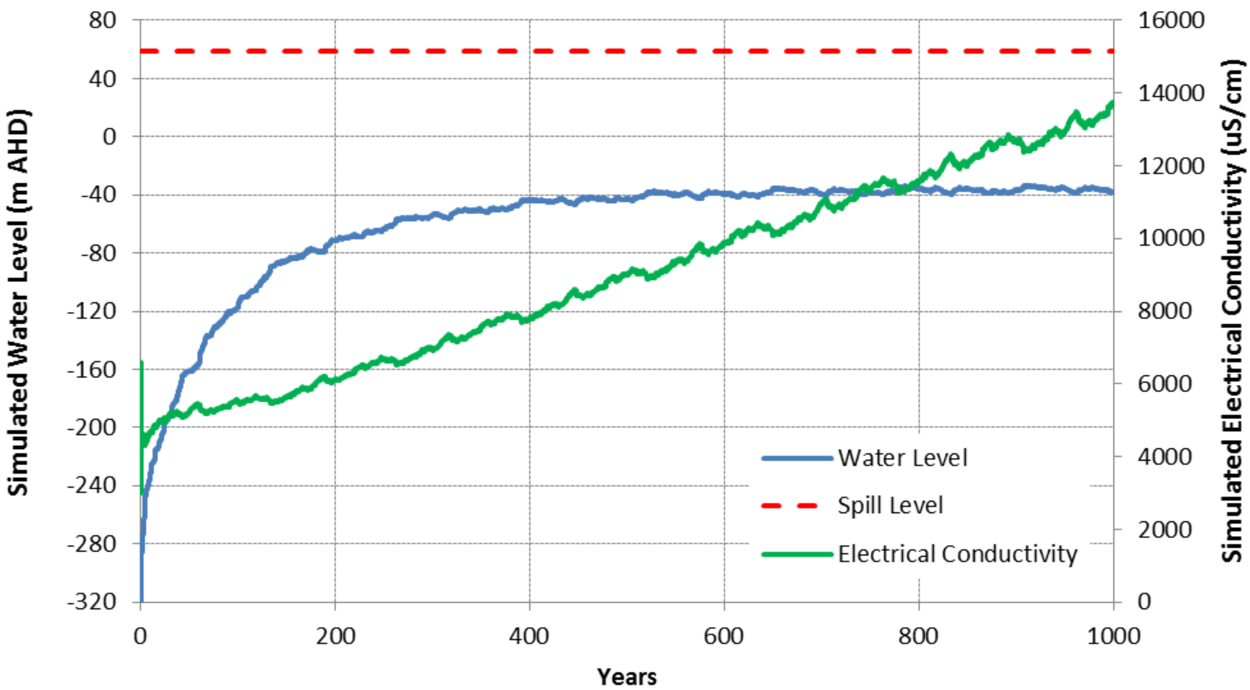

Figure 15 Predicted Final Void Water Levels and EC Values – High Groundwater Flux Rates

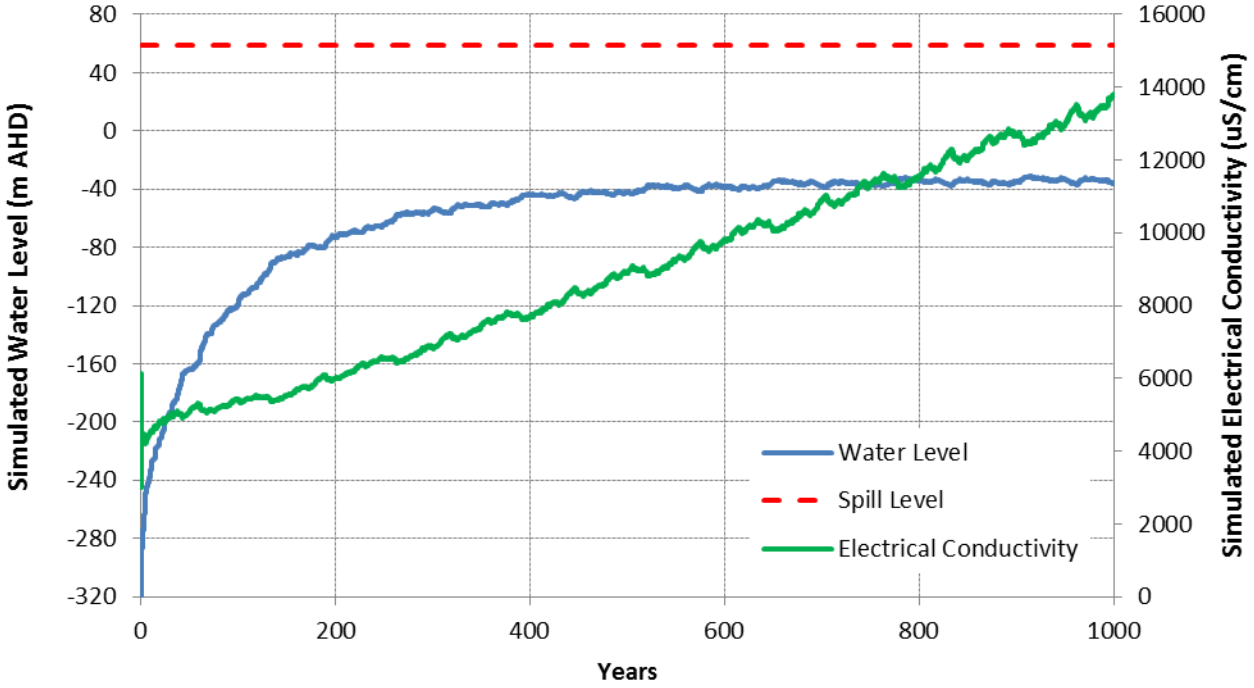

Figure 16 Predicted Final Void Water Levels and EC Values – Low Groundwater Flux Rates

For the high groundwater flux case, the final equilibrium water level averages -36.3 mAHD, while for the low groundwater flux case the final equilibrium water level averages -34.1 mAHD. These levels are both more than 90 m below the final void spill level (adopted as 59 mAHD – the planned lowest spill point through emplaced spoils). Equilibrium water level conditions are forecast to take approximately 600 years to establish. A long term average groundwater outflow rate of 0.3 ML/d is simulated for the high groundwater flux case and a rate of 0.2 ML/d for the low groundwater flux case. Final void salinity is forecast to gradually increase with time. Final void salinity is simulated assuming conservation of mass, with sources of salt comprising inflow from groundwater (when inflow occurs), catchment runoff and spoil seepage. Modelled values of salinity are the same as in the operational water balance model (refer Section 3.2.9 of HEC [2019]) and assume no reduction in salt concentrations with time.

The above model results are reasonably consistent with those presented in HEC (2019) which show an average final equilibrium water level of -35.3 mAHD being reached after approximately 600 years with average groundwater outflow of 0.3 ML/d.

3. Comment 14 – Water Storage in Underground Goafs and Release Via HRSTS

IESC Comment 14:

"*The proponent has stated that there is the potential for mining to be disrupted over time due to excessive volumes of water stored in the open cut voids (HEC 2019, p. 37). Consequently, the proponent has outlined a site water storage strategy which includes discharging excess water to underground goafs and the Hunter River through the HRSTS. Limited information has been provided on the volumes, quality and timing of releases of this excess water. Further information on the quality of the water and potential for interactions with the goaf material should be provided. Monitoring of the water quality of all water subject to controlled discharge should occur prior to discharge*."

HEC Response:

The ability to discharge from the Northern Dam and the Surge Dam to the Hunter River is already part of the existing Project Approval, licensed under EPL 563 and managed in accordance with the HRSTS. The Proposed Modification is seeking approval for the continued ability to discharge under the same arrangement in accordance with the HRSTS.

The volumes of water proposed to be released in accordance with the HRSTS and the provisions of Environment Protection Licence (EPL) 563 are summarised in Figure 31 to Figure 33 of HEC (2019) and above in Figure 11 to Figure 13. Timing of releases would be in accordance with high or flood flow events in the Hunter River as prescribed by the HRSTS as well as the need to discharge from the site water management system (refer Section 3.2.12 of HEC [2019]). Storage of water within underground goafs is in line with the existing Project Approval and water is transferred into and recovered from the Beltana goaf. No releases are proposed from the underground goaf water storages. Releases would predominantly occur from the Northern Dam. Forecast salinity in the Northern Dam for the mine case of no further underground operations is shown in Figure 17.

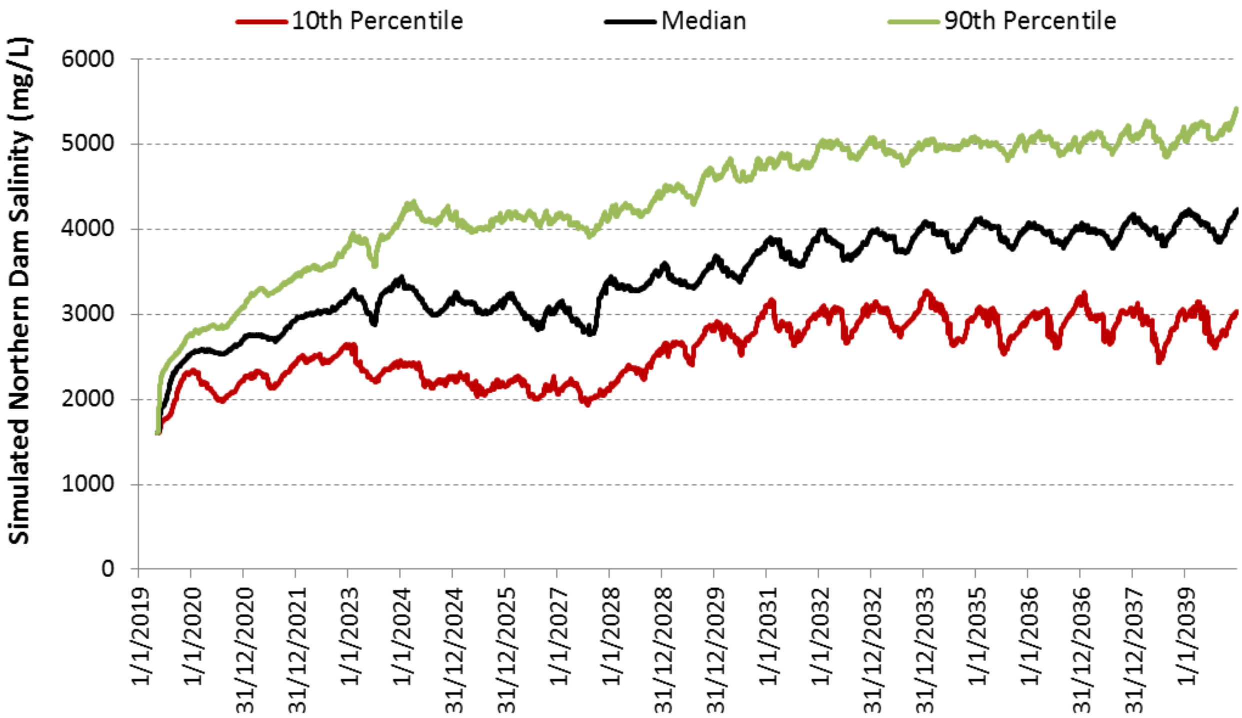

Figure 17 Simulated Northern Dam Stored Water Salinity with No Further Underground Operations

Controlled releases during high Hunter River flows would be made allowing for the salinity of the water that was to be released and the number of HRSTS credits held by Bulga Coal Management Pty Ltd (BCM) at the time. Release waters are subject to continuous monitoring of flow rate, electrical conductivity (EC), turbidity, pH and temperature with information available online[6].

4. Comment 15 – Controlled and Uncontrolled Discharges

IESC Comment 15:

"*The proponent has highlighted that, under the new water management system, there will be discharges from the Northern Dam and Surge Dam (HEC 2019, pp. 12-14). As noted in Paragraph 7, the potential impacts from controlled and uncontrolled discharges (spills from dams overtopping*

[6] https://realtimedata.waternsw.com.au/

during high rainfall events) are not discussed. Any impacts from discharge into the Hunter River will be cumulative with existing impacts from agriculture and mining, and these potential impacts should be assessed in the context of current and future monitoring. The IESC notes that the HRSTS is intended to manage impacts from salinity but not other contaminants. The proponent should provide a detailed assessment of all potential impacts from discharges, including from metal contaminants and cumulative impacts. This assessment should include expected quantity, quality, frequency and timing of discharges, together with assessment of the likely impacts and any proposed mitigation measures (such as water treatment). As discharges may present an ongoing local erosion risk, the potential impacts of this on downstream water quality also require consideration."

HEC Response: - Controlled Discharge

Controlled discharge from the Northern Dam and Surge Dam has previously been approved, is licensed under EPL 563 and managed in accordance with the HRSTS. The Proposed Modification will continue to discharge under EPL 563 and in accordance with the HRSTS.

Controlled discharge from the Northern Dam and Surge Dam via the HRSTS will comprise a very small component of the flow in the Hunter River (as governed by the discharge rules of the HRSTS) and dilution will be substantial. Water balance model results (HEC, 2019) and above Figure 11 to Figure 13 provide forecast annual release volumes. With reference to Figure 31 in HEC (2019) forecast median annual controlled discharge volume varies from zero to 2,003 ML. This compares with a median annual flow recorded in the Hunter River at Singleton[7] of 419,616 ML, meaning the forecast maximum median discharge represents less than 0.5% of the recorded median annual river flow. Similarly Figure 31 in HEC (2019) indicates a 90th percentile annual controlled discharge volume of between 257 ML and 6,614 ML. This compares with a 90th percentile annual flow recorded in the Hunter River at Singleton of 1,653,443 ML, meaning the forecast 90th percentile discharge represents between 0.02% and 0.4% of the recorded 90th percentile annual river flow.

It is recognised that the above analysis does not allow for the fact that controlled discharge does not occur on each day and that there are substantial periods of river flow when controlled discharge does not occur. Therefore simulated controlled daily discharge volumes were sourced from the water balance model (refer HEC [2019]) in order to calculate the percentage of flow in the Hunter River at Singleton that these forecast discharges would represent for each discharge day – i.e. the forecast discharge dilution.

A modelled mine life realization for the no further underground operations case corresponding to the median overall total controlled discharge volume was selected for illustrative purposes. For each simulated day, the controlled discharge volume was compared with the flow rate for the Hunter River at Singleton. Discharge was found to occur only on 2.9% of days on average. For the 20½ year simulation period, on average the controlled discharge volumes equated to 1.2% of river flow on those (rare) discharge days. On a single day selected from the model output with a 'typical' (median) discharge volume, the discharge equated to 0.4% of river flow.

The above illustrates that any contaminants present in the Northern Dam and Surge Dam at the time of controlled discharge would be highly diluted by flow in the Hunter River.

HEC Response: - Uncontrolled Discharge

The risk of uncontrolled discharge from the Northern Dam and Surge dam is extremely low. Both are operated with significant freeboard volume (more than 500 ML for the Northern Dam and 200 ML for the Surge Dam). Small volumes of spill are modelled from these two dams late in the Project life as a result of the June 2007 recorded high rainfall event (the 'Pasha Bulker' event), with

[7] Recorded data at GS210001 - https://realtimedata.waternsw.com.au/ downloaded 12 March 2020.

71 ML and 4 ML forecast spill from the Northern and Surge Dams respectively, for the approved underground mine case (this case gives the highest spill volumes of the three cases simulated). In the context of flow in the Hunter River during such a flood (e.g. approximately 563,000 ML recorded at the Singleton gauge in June 2007) such small volumes are trivial and would have no discernible impact on water quality in the Hunter River.

5. Comment 16 – Final Void Salinity and Water Level

<u>IESC Comment 16:</u>

"*The proponent needs to include analysis of the evolution of salinity and water level in the final void. This information is key for understanding the potential risks posed by the void should it spill or leach. The analysis should use relevant predictions from the project's surface water and groundwater modelling.*"

<u>HEC Response:</u>

The predicted rise in water level and change in salinity in the final void is simulated and reported in Section 4.0 of HEC (2019) and Section 2 above. This shows the water level rising slowly to equilibrium over several hundred years but remaining well below the void spill level at equilibrium. The salinity is forecast to slowly rise with time, reaching an EC value of approximately 13,000 µS/cm after 1,000 years.

6. Comments 24 and 25 – Salt Balance

<u>IESC Comment 24:</u>

"*The proponent has not explicitly modelled changes to the catchment salt balances. This is presumably because they are generally predicting small changes in groundwater discharge to surface waters which are expected to result in no changes to water quality. Planned discharges to surface water are managed under the HRSTS and, as such, are unlikely to have a considerable impact on the catchment salt balance.*"

<u>IESC Comment 25:</u>

"*If the additional uncertainty analyses recommended in the response to this question suggest that fluxes to surface waters may be likely to be large enough to impact water quality, then the catchment salt balance should be calculated and discussed to inform potential management.*"

<u>HEC Response:</u>

Salt balance modelling has been included in the water balance model for the Proposed Modification as detailed in HEC (2019). Model forecasts of the salinity within the two dams (from which discharge under the HRSTS can occur) have been undertaken (refer Figure 17), together with discharge volumes. The volume of water discharged will be subject to the provisions of the HRSTS which is designed to control discharges so that the resulting mixture of river and discharge water can be kept fresh to meet water quality standards. The salinity of waters discharged from these two dams will be highly diluted by flow in the Hunter River – refer response to Comment 15 (Section 4).

Please contact the undersigned if you have any queries.

Yours faithfully,

Tony Marszalek
Director

APPENDIX D

Additional Information on Warkworth Sands Woodland of the Hunter Valley Ecological Community

Our Ref: 4100/BJ/KD/161118

16 November 2018

Mark Jenkins
EPBC Assessment Officer
Northern NSW Assessment Section
Department of the Environment and Energy

E| Mark.Jenkins@environment.gov.au

Dear Mark

Re: EPBC 2018/8300 – Bulga Optimisation Project Modification Referral – Additional Information

As per your correspondence (email) dated 1 November 2018, the Department of the Environment and Energy (DoEE) have requested additional information in relation to the potential for increased cumulative impacts on the Warkworth Sands Woodland of the Hunter Valley Ecological Community (WSWEC) which is listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

As noted by DoEE, there is EPBC listed WSWEC within the Referral Area, however, the Proposed Modification is not anticipated to have any direct or indirect impacts on the community. The extent of mapped WSWEC in relation to the existing operations and Proposed Modification are shown on **Figure 1**.

Under the original Environmental Impact Statement (EIS) for the Bulga Optimisation Project (Umwelt 2013), it was proposed that 7.4 hectares (ha) of the WSW would be cleared. As part of the Response to Submissions and Amended Project Application Report (RTSAMA) (Umwelt 2014) the clearance of 7.4 ha of WSW was removed from the Project and has not been undertaken. In addition, a Biodiversity Conservation Area (BOA) was proposed under the RTSAMA and has been established for the management and preservation of the WSWEC within the Referral Area.

Occurrences of Warkworth Sands Woodland EC

The distribution of the WSWEC is described in the Approved Conservation Advice for the WSWEC pursuant to the EPBC Act (s266B) as:

> *The ecological community is only known to occur on aeolian sands – on old dune formations and swales between the dunes and on sand sheets ('veneers'); all part of the Warkworth Land System (Story et al., 1963; Kovac and Lawrie, 1991).*
>
> *Warkworth Sands Woodland mostly occupies linear sand dunes, which are between one and six metres high, typically resting on a river terrace, on the undulating valley floor. As well as these deeper sand deposits, the ecological community also occurs on shallow veneers of sand, separated from the main sand deposit by areas of clay soils developed on Permian sediments.*

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As identified in **Figure 1**, the location of the WSWEC within the Referral Area is adjacent to the currently approved Bulga mine and the Mount Thorley (Yancoal) open cut mines on aeolian sand deposits on the undulating valley floor. These aeolian sand sheet deposits range from being located in close proximity to Wollombi Brook, to more elevated rolling valley floor topography in proximity to the mine.

<u>Warkworth Sands Woodland BOA Condition Monitoring</u>

Bulga Mine has implemented a BOA for the ongoing protection of WSWEC as shown on **Figure 1,** consistent with requirements of the NSW Development Consent (SSD 4960) and EPBC Approval (EPBC 2012/6637).

Ecological monitoring of the BOA has occurred annually since 2015, and has reported positive results against the key performance indicators contained in the approved Biodiversity Offset Management Plan (BOMP). Results indicate that in the remnant woodland area species diversity is being maintained, or changing in response to varying climatic conditions and that natural regeneration of the Derived Native Grassland is occurring in the natural regeneration zones. A copy of the 2017 WSW BOA monitoring report is provided in **Attachment 1** - *Flora and Fauna Monitoring at Wollombi Brook BOA, Singleton LGA: 2017 Results* (Bell et al, 2018).

<u>Relationship between Proposed Actions (Referral) and WSWEC</u>

As shown in **Figure 1**, the WSWEC BOA is located immediately adjacent to the northern end of the current approved Bulga mine and in close proximity to Yancoal's Mount Thorley mine. The Proposed Modification, which is the subject of the Referral, relates to an extension of mining at the southern end of the Bulga mine, approximately 5 km south east of the WSWEC BOA.

Cross sections have been provided as **Figure 2** and **Figure 3** to show the relationship between the geology, previously mined areas and the proposed additional mining areas that form this Referral. The additional proposed mining areas are shown in the cross sections in green. These areas have been previously mined and are currently used for the storage of tailings, water and access to the Bulga underground mine. The Proposed Modification proposes to relocate the tailings, dewater the pits and mine deeper by open cut methods down to the Bayswater Seam.

As shown in the sections the alluvium/regolith on which the WSWEC is located has been mined in the areas adjacent by current approved open cut operations. The alluvium has also been undermined by previous underground mining operations, the Beltana Underground (shown in white) on the attached figures. Longwall mining occurred in the Lower Whybrow Seam at a depth of approximately 75m below the surface at the location of the alluvium, and was mined between 2003 and 2011. Numerous paired piezometers are located within the alluvium and Permian coal measures within the area undermined. These have shown no significant impact on water levels in the alluvium from the longwall operations. This monitoring data was summarised and supplied to DoEE in the letter report prepared by KCB dated 4 September 2018.

Schematic hydrogeological cross-sections across the Bulga Surface Operations are shown in **Figure 2** and **Figure 3**. The cross-sections show the extent of mining that has been undertaken. **Figure 3** transect runs through a section of the proposed new mining area, in the Deep and Vaux pits, at some distance from the WSWEC BOA. The blue surface line is the modelled bore pressure surface. The Lower Whybrow seam is the target seam as part of the Proposed Modification. Ecological monitoring and borehole monitoring data suggest little measurable impact on groundwater regime of the WSWEC BOA due to mining.

WSWEC Summary

It is predicted that the influence of the proposed actions on the WSWEC will be limited and the proposed actions that are subject to the current referral will represent negligible incremental impact on the WSWEC due to:

- the proposed actions represent a relatively minor increase in the area of mining in the local context comprising the Bulga Optimisation Project, Bulga Underground Operations and the Mount Thorley and Warkworth Mines
- borehole monitoring in proximity to the WSWEC has shown no significant impact on water levels in the alluvium from mining to-date
- ecological condition monitoring of the WSWEC BOA since 2015, and has reported positive results against the key performance indicators contained in the approved BOMP
- the proposed actions involve mining further away from the WSWEC than current approved mining operations at a distance of approximately 5km from the WSWEC
- the proposed mining area is contained within the footprint of the current operation and will not result in a measurable change to the groundwater regime in proximity to the WSWEC
- it is targeting deeper seams than the Lower Whybrow that has been mined directly underneath the alluvium as part of the previous Beltana underground operations.

Land Ownership Information

In discussions with Greg Newton (Bulga Modification 3 Project Approval Manager) on 13 November 2018, DoEE requested additional information on current land ownership status within and adjacent to the Referral Area. Please find **Figure 4** attached showing current landownership within and surrounding the Referral Area, including the adjacent Singleton Military Training Area (SMTA) (Commonwealth Land) and Crown Land. A small parcel of the SMTA is licenced to the Bulga Coal Management for ongoing approved land uses.

If you have any questions or require additional information, please don't hesitate to contact Kirsty Davies or myself on 02 4950 5322.

Yours sincerely

Bret Jenkins
Senior Principal Environmental Consultant

FIGURES

umwelt

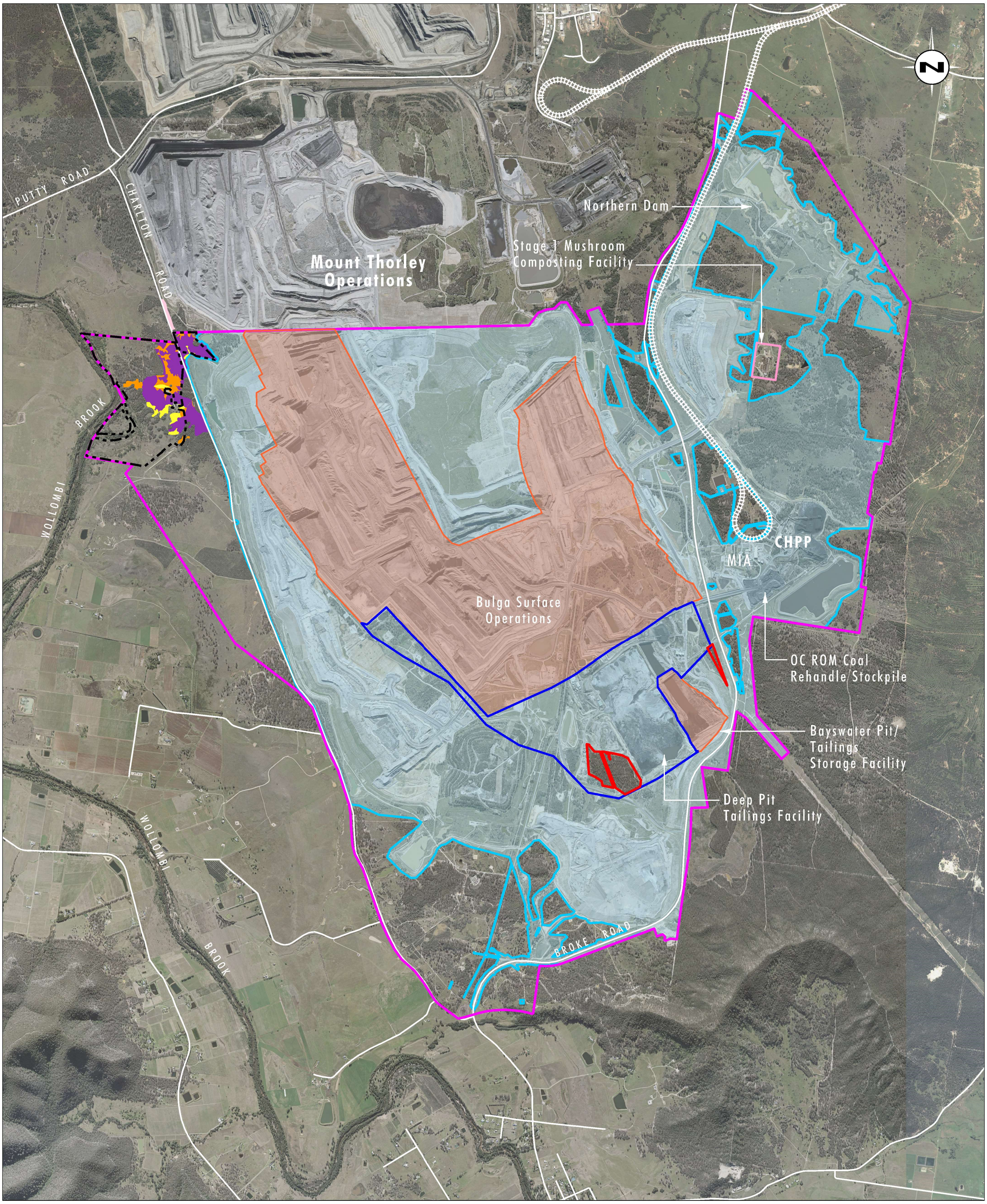

Image Source: Bulga (2017)
Data Source: Bulga (2017)

0 1 2 3km
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Legend

- Project Area
- Modification Additional Disturbance Area
- Current Disturbance Area
- Modification Additional Coal Extraction Area
- BOP Approved Mining Area
- Warkworth Sands Woodland EEC (Peake, 2006)
- Warkworth Sands Woodland EEC (Umwelt, 2013)
- Warkworth Sands DNG (Umwelt, 2013)
- Warkworth Sands Disturbed Grassland (Umwelt, 2013)
- Rail Line
- Wollombi Brook Conservation Area

FIGURE 1

Proposed Action

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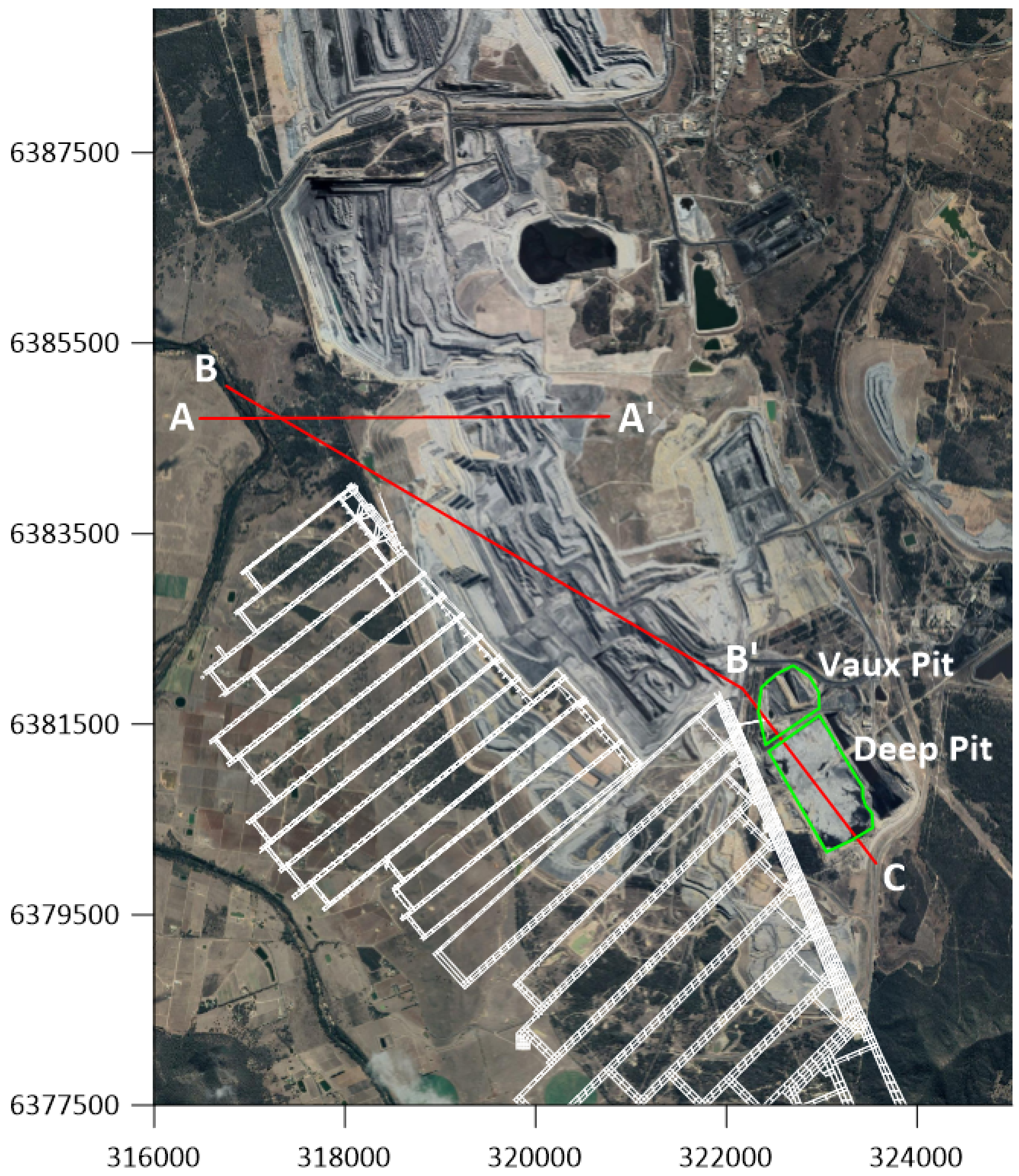
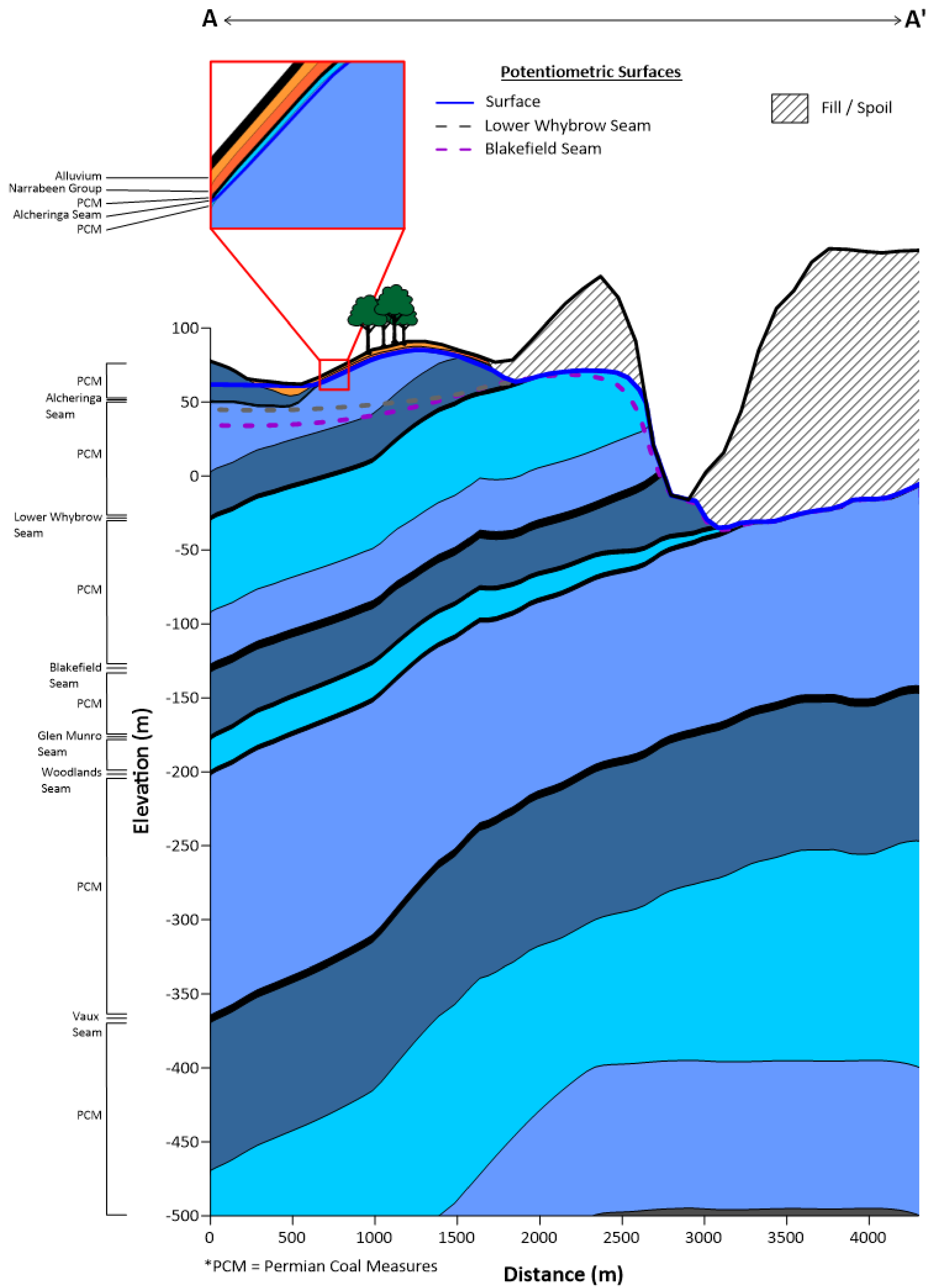
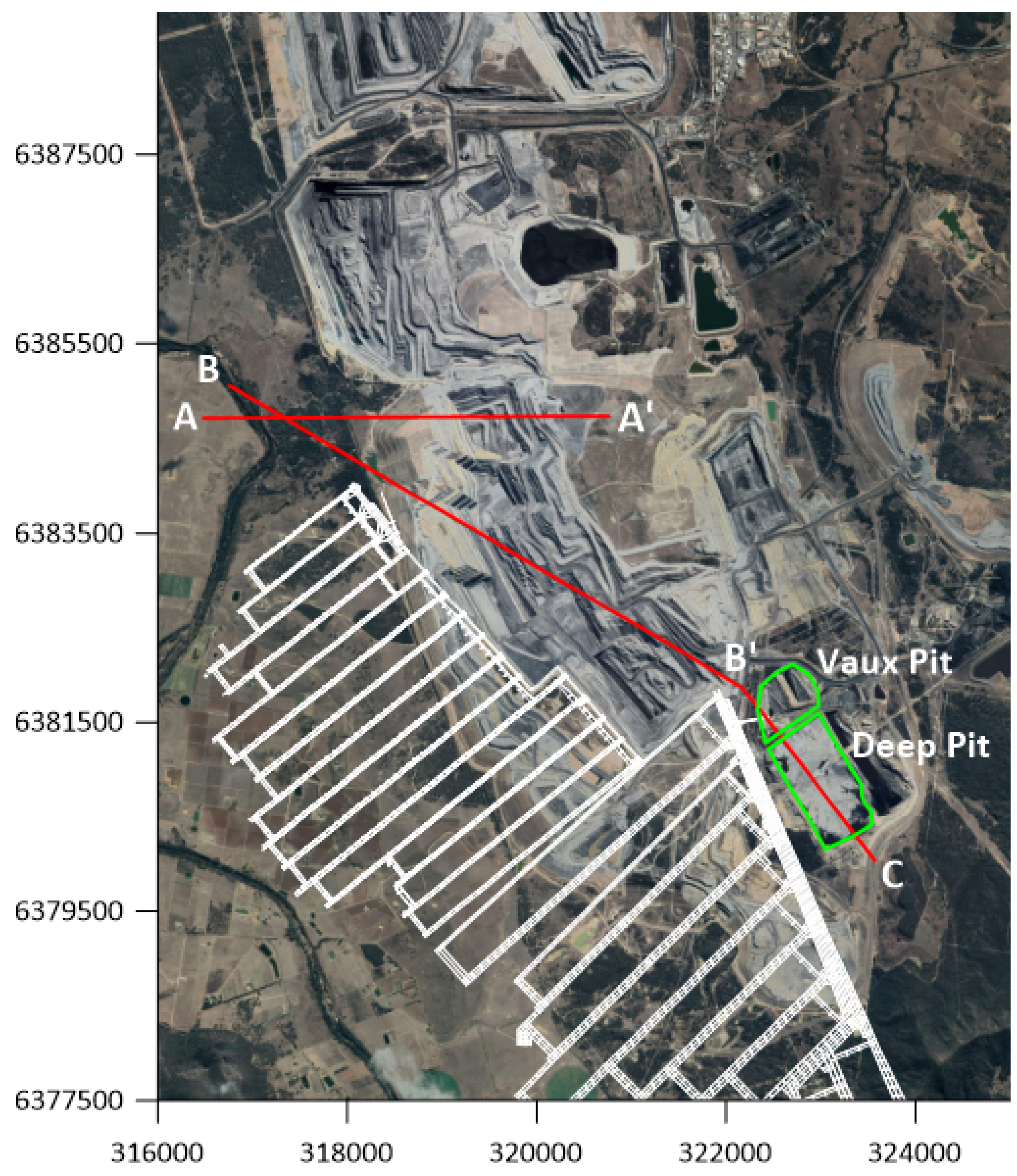
20181115 15.27



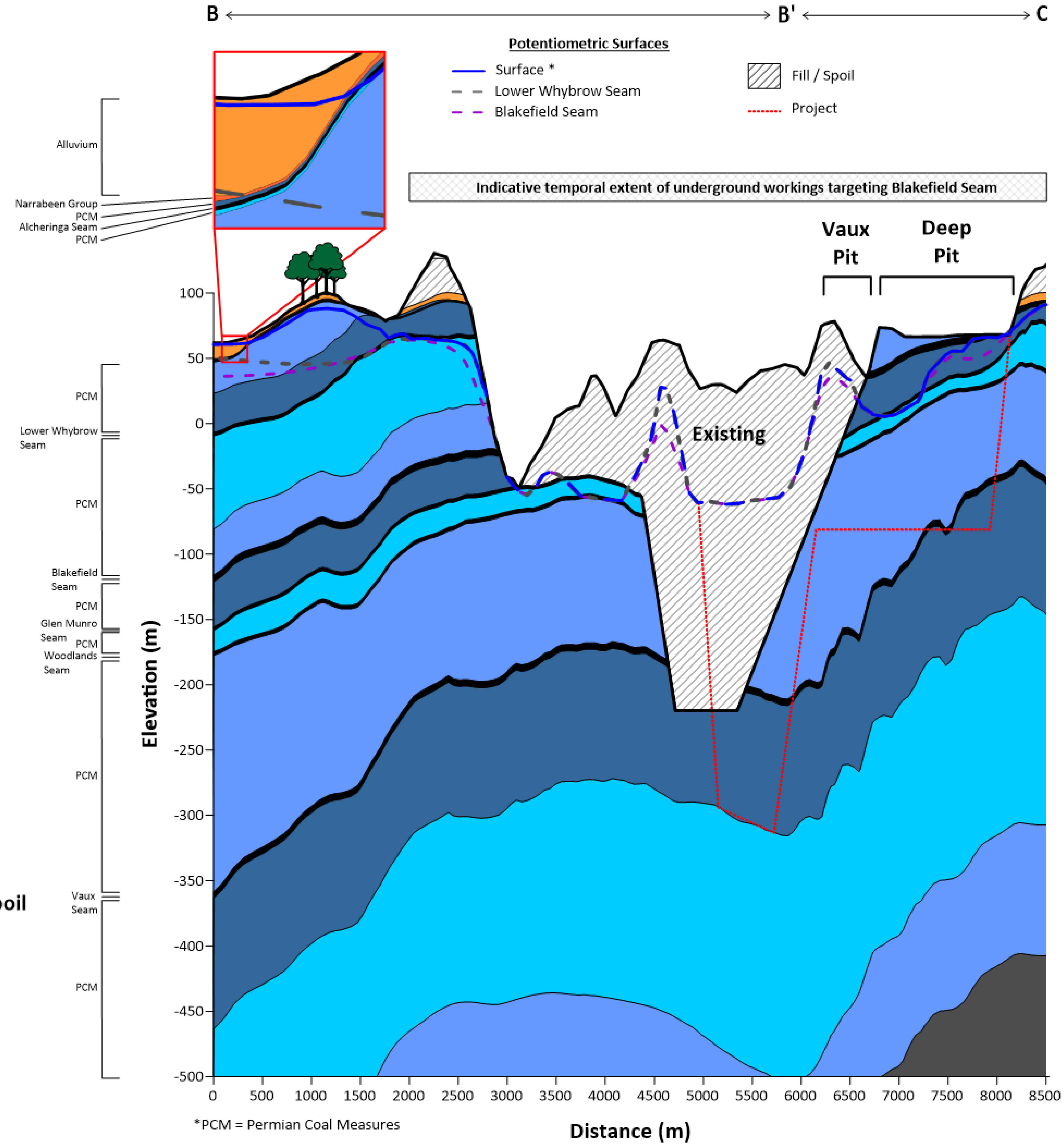


Schematic hydrogeological cross-section across the Bulga Coal Project - A-A'



Schematic hydrogeological cross-section across the Bulga Coal Project - B-B'-C

*** Piezometric data shown as a dashed line inside placed spoil is taken from numerical model output for a slightly different geometry, thus does not directly conform with the major geometric features shown.**



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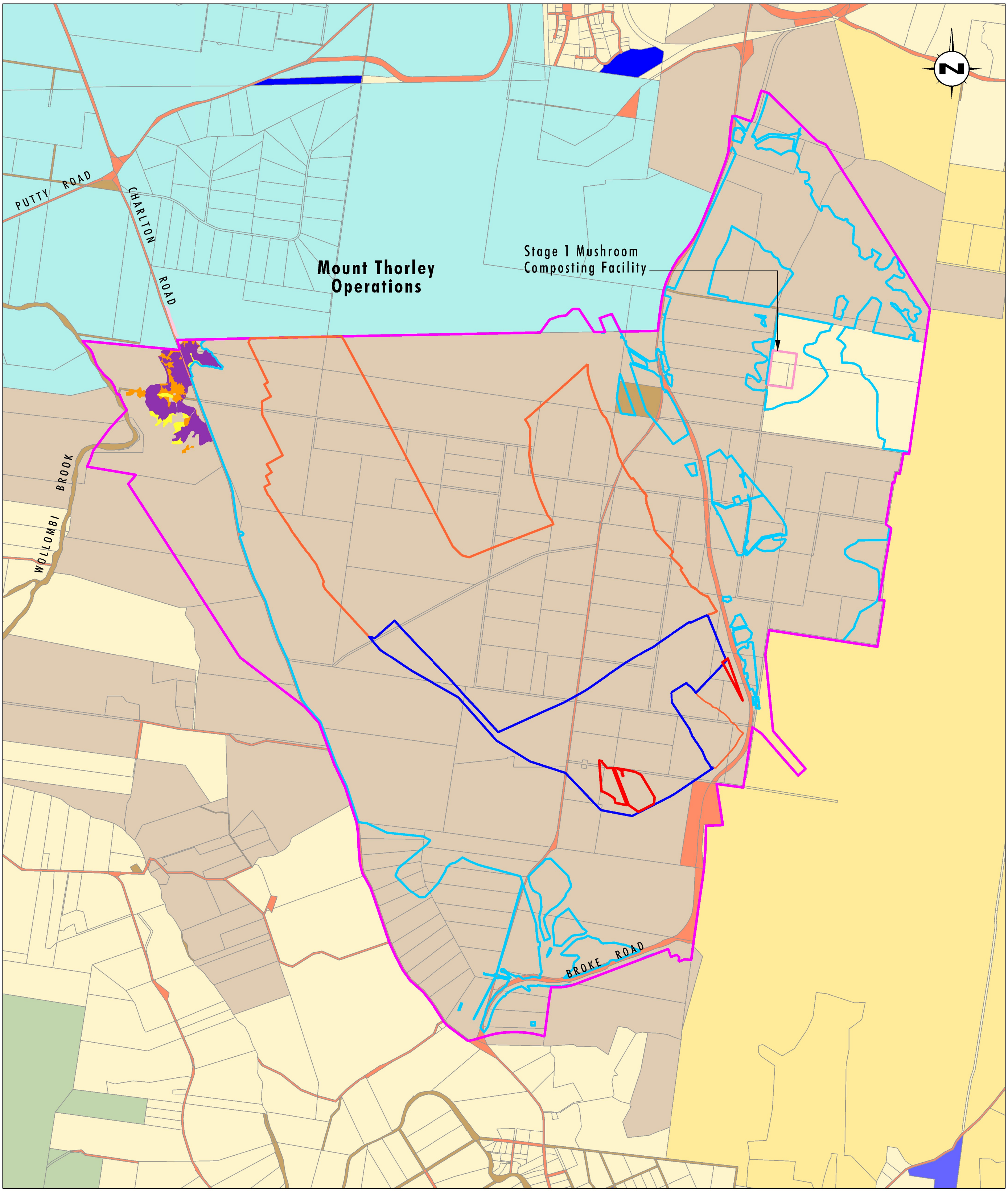

Image Source: Bulga (2017)
Data Source: Bulga (2017)

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Legend

- Project Area
- Modification Additional Disturbance Area
- Current Disturbance Area
- Modification Additional Coal Extraction Area
- BOP Approved Mining Area
- Warkworth Sands Woodland EEC (Peake, 2006)
- Warkworth Sands Woodland EEC (Umwelt, 2013)
- Warkworth Sands DNG (Umwelt, 2013)
- Warkworth Sands Disturbed Grassland (Umwelt, 2013)
- AGL Energy
- Crown Land
- Defence
- Glencore
- Private
- Singleton Council
- Yancoal
- National Park
- Local Government/NSW Government

FIGURE 4

Land Ownership

File Name (A4): 4100_107.dgn
20181115 10.18

ATTACHMENT 1

2018

Flora and Fauna Monitoring at *Wollombi Brook BOA*, Singleton LGA: 2017 Results

April 2018

Report to

Bulga Surface Operations, Glencore

Stephen Bell, Michael Murray &

Ryan Sims

Eastcoast Flora Survey
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Cover image: Resprouting *Allocasuarina luehmannii* in ecological thinning trial area, *Wollombi Brook BOA*.

Report produced for:

Bulga Coal Surface Operations
Bulga Joint Venture
Broke Road
Singleton NSW 2333

Project Manager: Tom Scott (Environment & Community Advisor)

Summary

Flora and fauna monitoring has been undertaken on the 65ha *Wollombi Brook Biodiversity Offset Area (BOA)*, located on Charlton Road between Broke and Bulga in the central Hunter Valley. *Wollombi Brook BOA* was established as an environmental offset for land disturbance associated with the Bulga Surface Operations near Singleton. This report presents the findings of monitoring undertaken during 2017 (Year 3).

Flora – Monitoring of vegetation at *Wollombi Brook* in 2017, accomplished primarily through the collection of replicated quantitative data, has now been undertaken for three consecutive years. Data on species diversity, threatened taxa, weed prevalence and distribution, canopy and shrub composition and structure, and ground cover attributes have been documented and graphed, and have been compared and illustrated against 2015 and 2016 results.

Based on data collected from six transects, the following key points summarise the floristics and structure within five management units sampled from 2015 to 2017: Ironbark, Apple, Grassland (Ironbark), Grassland (Apple), and Shrubland (Apple). In the absence of better alternatives on-site, Ironbark and Apple management units have been collectively categorized into 'benchmark' data, while Grassland (Ironbark), Grassland (Apple), and Shrubland (Apple) management units are considered 'regenerating'.

- mean overall species diversity is 36.6 species per management unit, ranging from 29 in Shrubland (Apple) MU to 43 in Ironbark MU. Weed species range from 14% of all species in Shrubland (Apple) to 46.9% in Grassland (Apple), with only slight changes on 2016 data;
- basal area of canopy species was not measured in 2017, however based on 2016 data this attribute ranges from 16 cm^2 in Grassland (Ironbark) to 30,062 cm^2 in the Apple MU, with all but the Apple and Shrubland (Apple) MUs;
- mean DBH of canopy species was not measured in 2017, however based on 2016 data this attribute ranges from 0.75 cm in Grassland (Ironbark) to 11.56 cm in the Apple MU;
- canopy stem density reduced across all MUs in 2017, ranging from a low in Grassland MUs (0 and 60 stems/ha) to considerably higher numbers in Shrubland (500 stems/ha), Apple (1340 stems/ha) and Ironbark (1680 stems/ha). Dramatic decreases are likely related to water stress on young plants following drought conditions, coupled with grazing by resident macropods and rabbits;
- woody shrubs are generally absent, with the exception of the Apple (700 stems/ha) and Shrubland (12,400 stems/ha) MUs, but both showing a decrease on 2016 data;
- similarly the total number of *Acacia* stems is very low across all MUs, with only 220 stems/ha evident in the Apple MU, and 40 stems/ha for the Grassland (Apple) MU;
- percentage cover of weed species ranges from minimal in Ironbark, Apple, Grassland (Ironbark) and Shrubland MUs (all <2% cover) to moderate in the Grassland (Apple) MU (19.3% cover). All MUs showed a decrease from 2016 data, likely attributable to the dry conditions;
- the invasive exotic species *Melinis repens, Panicum coloratum* var. *coloratum, Richardia brasiliensis* and *Richardia stellaris* are common in several transects, and may require management in future years to restrict spread;
- monitoring of the ecological thinning trial of native invasive woody shrubs *Leptospermum polyanthum* and *Allocasuarina luehmannii* has shown only minor change in floristic composition after 16 months, but species such as *Hibbertia* are visibly more prevalent;

- estimated leaf litter cover increased in 2017, ranging from 46.3% in Shrubland (Apple) to 84.5% in Ironbark. Dramatic increases from earlier years are likely a reflection of the dry climatic conditions and canopy leaf shedding as a result of this;
- estimated bare ground also increased in 2017, but remains at <10% cover, again a likely reflection of dry climatic conditions and limited growth of ground layer species.

Fauna – A total of 59 bird species were recorded at *Wollombi Brook* by census survey in 2017 (*n =* 52 in 2016 and 48 in 2015). Total bird species diversity, based on surveys over the period 2015 - 2017 monitoring period, combined with previous records of the Bulga Coal operation, is 115. In 2017, three threatened bird species were recorded, the Grey-crowned Babbler, Speckled Warbler and Varied Sittella. All three species have previously been recorded at *Wollombi Brook BOA.* Bird activity across each of the monitoring sites was lower in 2017 to previous years, possibly attributed to low rainfall and reduced nectar and pollen loads in eucalypt trees. Winter flowering was considered lower in abundance across the *Wollombi Brook BOA* in 2017, compared to previous monitoring years. However, mistletoe was relatively abundant in winter 2017.

Echolocation calls recorded the presence of 8 bat species in 2017, with a total of 138 calls suitable for identification. The most commonly recorded species was the threatened Eastern Freetail-bat *Micronomus norfolkensis*. Despite the survey effort and timing, microbat activity (as defined by echolocation call recordings) is very low for this offset.

Frog activity was very low in 2017, due to the extended dry period with below average rainfall experienced. One small farm dam, which usually records relatively high frog activity, was dry in 2017. No frogs were recorded around this dam during surveys in 2017.

Six threatened species were recorded in *Wollombi Brook BOA* in 2017. All six species have previously been recorded within the offset during previous monitoring surveys.

Management Issues - Issues arising from the 2017 monitoring include continuing to address the spread of exotic invasive grasses (*Eragrostis curvula, Melinis repens, Panicum coloratum var. coloratum*) and herbs (*Richardia brasiliensis, Richardia stellaris*); continued monitoring of the ecological thinning trial of native invasive shrubs; repair of the vandalized fence allowing access to the BOA off the existing crown road reserve; and consideration given to thinning of regenerating Ironbark and Apple species to ultimately promote healthier and structurally sound woodland. In addition, Feral Pigs were noted in abundance during all visits to *Wollombi Brook BOA* in 2017, with extensive areas of soil disturbance by diggings. Monitoring of revegetation and regeneration areas will identify if Feral Pigs cause damage to habitat augmentation works within the BOA. Increased controls may be required if identified as a significant impact.

Feral pig activity was noted during visits to *Wollombi Brook BOA* in 2017. Damage to topsoil is localised, and may require periodic trapping to reduce overall numbers. Monitoring of revegetation and regeneration areas will identify if Feral Pigs cause damage to habitat augmentation works within *Wollombi Brook BOA.* Increased controls may be required if identified as a significant impact. Presence of other introduced pest species including wild dogs / dingo and Fox, based on monitoring by remote cameras, but are not considered abundant to warrant additional management actions to those already outlined in the BOMP.

Table of Contents

1. Background

Bulga Surface Operations own and manage four biodiversity offset areas (BOA's) in the central and upper Hunter Valley: Condran BOA, Reedy Valley BOA, Broke Road BOA and Wollombi Brook Conservation Area BOA (*Wollombi Brook*). These properties were purchased by Glencore as environmental offsets to compensate for lands lost to the Bulga Surface Operation mine south of Singleton. A Biodiversity Offset Management Plan (BOMP) for *Wollombi Brook* has been prepared to guide ongoing management with the aim of maintaining and enhancing its biodiversity values (Glencore undated). The BOMP broadly focuses on managing woodland for conservation and assisting Derived Native Grassland (DNG) areas to return to woodland condition.

The objectives for the BOMP include:

- Identify and describe the area of land that will be required to be managed in accordance with the BOMP;
- Provide clear and concise instructions for the management of the *Wollombi Brook* in accordance with the biodiversity management targets;
- Provide a working schedule for the implementation of BOMP activities;
- Describe the monitoring, performance evaluation and reporting procedures.

Wollombi Brook provides key ecological values, including:

- Warkworth Sands Woodland and Central Hunter Grey Box – Ironbark Woodland EEC's;
- Habitat for 13 species of threatened fauna, and potential for 2 nationally threatened birds, the Regent Honeyeater and Swift Parrot.

Biodiversity management targets for *Wollombi Brook* are specified in Section 2.4 of the BOMP, including:

- Establish boundary fencing and signage and removal of stock grazing activities;
- Commence establishment of woodland vegetation (primarily Central Hunter Grey Box – Ironbark Woodland and Warkworth Sands Woodland EEC's in areas of DNG through assisted natural regeneration;
- Manage weed and pest species;
- Establish a monitoring program to assess the success of ongoing management and improvement strategies.

Preliminary targets include the establishment of an additional 10 hectares of Warkworth Sands Woodland in areas of existing DNG, through assisted natural regeneration, and 16 hectares of Central Hunter Grey Box – Ironbark Woodland in areas of existing DNG. The BOMP specifies that systematic ecological monitoring will be undertaken annually for the first five years of management (2015-2019), and then every three years thereafter for 15 years (until 2034).

This report outlines the results of flora and fauna monitoring (Year 3) undertaken at *Wollombi Brook* for the 2017 period.

2. Study Area

Wollombi Brook BOA comprises 65ha of offset lands, located in the north western corner of the Bulga Coal Complex adjacent to Charlton Road (Figure 1). This land currently supports a mosaic of cleared, grassed and regenerating forest/woodland vegetation, consistent with past use as a grazing property. Umwelt (2013) have surveyed and mapped the vegetation and habitats across the BOA, describing five forest/woodland communities, five grassland communities, and one shrubland community. The bulk of vegetated land comprises the Warkworth Sands Woodland or Central Hunter Grey Box – Ironbark Woodland EECs, or grasslands and shrublands associated with them. Wollombi Brook runs along the western boundary. Boundary fencing demarcates the limits of the BOA and excludes grazing by stock and unauthorised personnel.

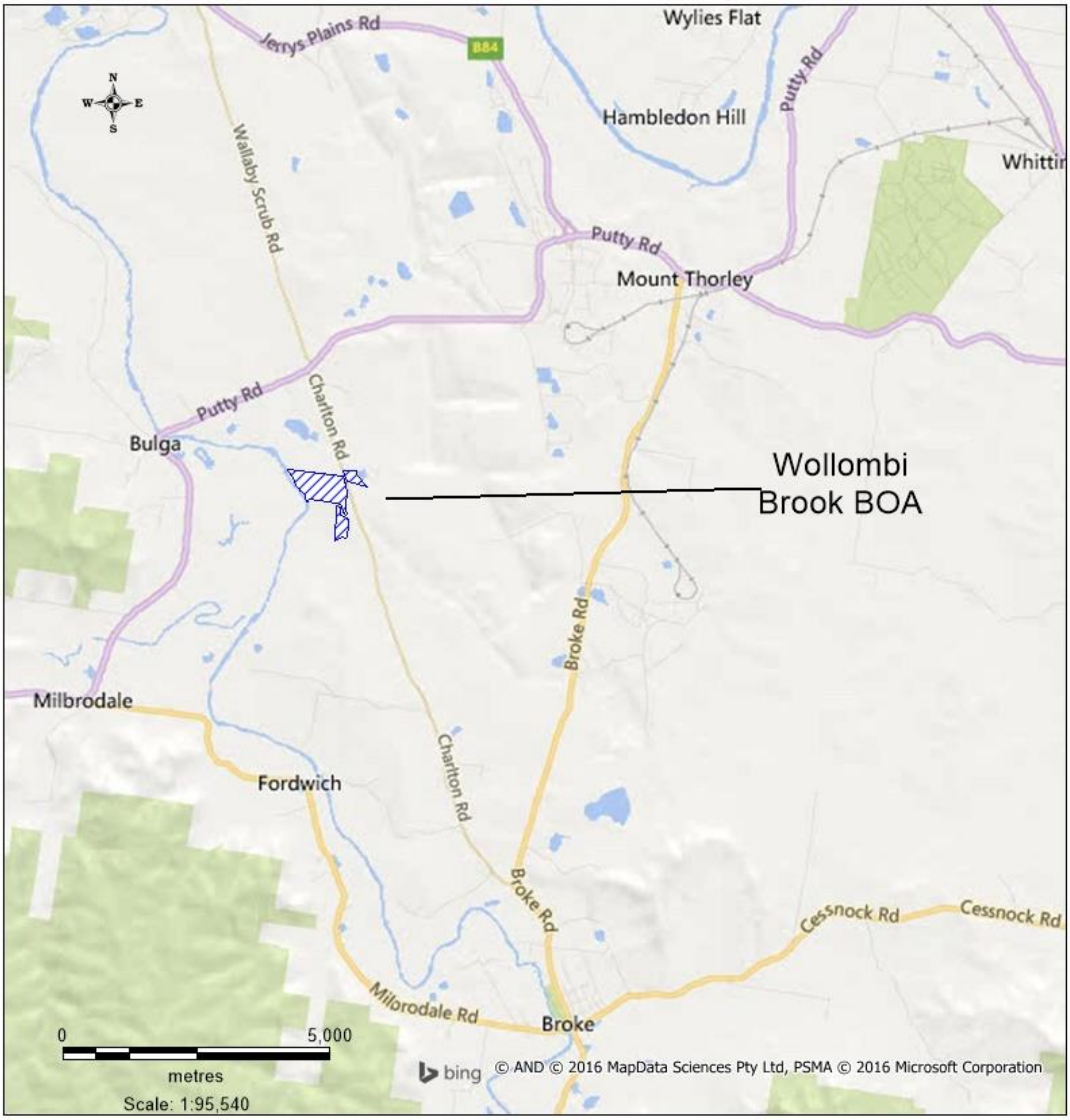


Figure 1 Location of the *Wollombi Brook* biodiversity offset property.

3. Methods

The BOMP specifies that ecological monitoring is to incorporate techniques which:

- are relatively simple to measure, can be replicated with limited subjectivity, and are reproducible;
- are targeted towards recording information that provides a good indication of the status of the biodiversity values of the BOA;
- allow for floristic composition and structure to be monitored over time using basic statistical analysis;
- allow for comparison to reference (control) sites; and
- are cost effective.

Monitoring of vegetation to meet these requirements follows techniques outlined in Bell (2013), which provides a framework to improve the quality of data collected and analysed as part of revegetation and offset strategies in the Hunter Valley coal mining industry. Flora monitoring for Year 3 in 2017 was undertaken primarily by Ryan Sims, under the guidance of Stephen Bell, while fauna monitoring was completed by Michael Murray.

3.1 Property Condition

Assessment of vegetation condition was made following inspections of the BOA in November 2017 and January 2018, and during fauna monitoring in June, August and November 2017. This included collating observations on fence condition, weed presence, evidence of feral animals, and recently eroded or degraded areas. Reconnaissance of the property involved inspection on foot with a hand-held GPS unit, recording the locations of management issues evident in relation to fences, weeds, feral animals and erosion.

3.2 Flora Monitoring

3.2.1 Survey Design

Permanent transect-pairs were established across remnant woodland and grassland boundaries in 2015 to effectively monitor the vegetation, each comprising two 50m transects positioned end-to-end. Grassland regeneration was assessed through the surveying of one of these 50m transects ('regenerating') within representative areas of Native Grassland (or Shrubland). Each transect comprised ten primary quadrats 5x5m in size, positioned along alternate sides of the 50m transect (Figure 2). Within each primary quadrat, data on species diversity, and age and structure of the shrub strata was collected (Table 1). Canopy data was collected across the full 50x10m transect (ie: the ten primary quadrats + the complimentary ten secondary quadrats, totaling 20 quadrats). Each 50m transect collected quantitative data over a 250m^2 area (or 0.025ha) for most attributes, but 500m^2 (0.05ha) for canopy data. Replicated transects within adjacent remnant woodland/forest ('controls') on site comprised the complimentary 50m transect of each pair. In effect, transect pairs (ie: 100m transects of 20 primary quadrats) were positioned end-to-end across grassland-woodland boundaries so that restoration progress can be tracked over successive monitoring seasons.

For Year 3, Biometric floristic and habitat data was also included in the monitoring program (see Section 3.2.7), with 20 x 20m quadrats positioned as shown in Figure 2. Additionally, from Year 3 the collection of detailed structural data on canopy species will no longer be collected annually but once every three years. This change was brought about following the collection of two years of such data (and more at other offset sites), which showed insignificant changes year-to-year.

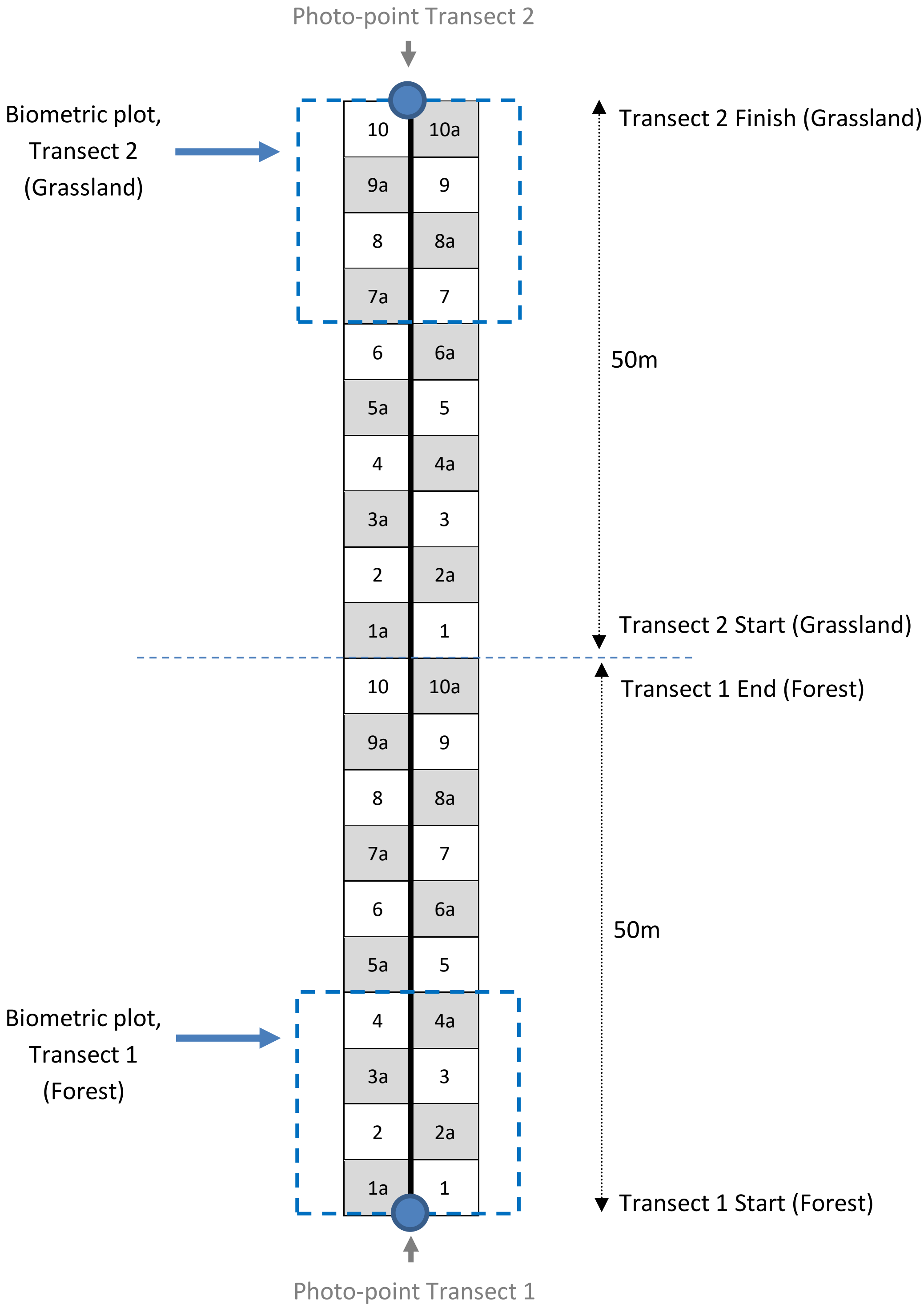


Figure 2 **Schematic representation of transact-pair (Forest & Grassland) layout for vegetation monitoring (units = m).** Each small grid (quadrat) is 5 x 5m in size along a 50m transect; primary quadrats are numbered 1-10, secondary quadrats 1a-10a. Biometric plots are 20 x 20m, and photo-points capture photographs at the four cardinal compass points.

Table 1 Strategy for monitoring of vegetation at *Wollombi Brook BOA*.

Activity	Attribute Measured
1. Descriptive	• general description of vegetation • general observations of problem areas or evidence of key or significant species
2. Quadrats (5m x 5m)	• positioned alternately along a 50m transect (Figure 2) • count the number & record identity of all species, including grass • count the number of stems of all woody shrubs, recording wattles separately • count the number of stems of all trees • measure DBH all trees >1.6m high • estimate percentage cover of bare ground & litter; weed species
3. Photography	• photograph transects & quadrats; other areas of interest requiring attention

Three transect-pairs were established in 2015 within regenerating and control areas (six 50m transects in total), incorporating 60 primary quadrats (Figure 3, Table 2). Transect locations were selected following a thorough reconnaissance of the *Wollombi Brook BOA*, using the mapping of Umwelt (2013) as a guide, and concentrated on listed threatened ecological communities. Final transect locations were chosen based on consistency of floristic communities, size and proportion of remnant forest stands and their proximity to neighbouring stands, and the likely original composition (parent community) of grassland areas. Two transect-pairs (WOL01 & WOL03) were positioned within the Warkworth Sands Woodland of Umwelt (2013); one in remnant open woodland adjoining former grazing lands (WOL01), and a second in old regrowth and regenerating shrubland (WOL03). A third transect-pair (WOL02) was positioned at the Grassland-Ironbark interface within Central Hunter Grey Box – Ironbark Woodland. Other previously identified vegetation communities (Central Hunter Bulloak Regeneration, Central Hunter Swamp Oak Forest, Exotic Grassland, Grassland on Alluvial Sand, Hunter Valley River Oak Forest) were not a requirement of vegetation monitoring.

In terms of landscape Management Units (MU), two transects were located in an Apple MU (WOL01F & WOL03F), one in an Ironbark MU (WOL02F), two in a Grassland MU (WOL01G, Apple Grassland; WOL02G, Ironbark Grassland), and one in an Apple Shrubland MU (WOL03G). Figure 4 shows views of each transect, while images of all component quadrats as assessed in Year 3 are included in Appendices A8.1-8.6.

Transect start and end positions were marked in the field by metal star pickets (visible in Figure 4), while quadrat central corners were marked by in-ground metal pegs and galvanized washers with flagging tape (Figure 5). These can be relocated in subsequent years through use of a small metal detector, and (unlike light-weight posts) have the advantage of avoiding accidental removal or dislodgement by wildlife.

3.2.2 Species Composition: Management Units

Collectively, the ten 5x5m primary quadrats comprising each 50m transect allowed for the analysis of species diversity over 250m^2 (0.025ha), and between different management units (2 in grassland, 3 in forest, 1 in shrubland). Species-presence data, as collected in each quadrat, was converted to an absolute abundance measure for each 50m transect, by tallying the number of quadrats where each species was recorded. On this scale, the maximum abundance value is 10, while the minimum is 1. All six transects were then subjected to multivariate analysis of abundance data using *Primer* (Clarke & Gorley 2005). Non-metric Multi Dimensional Scaling (nMDS) and cluster analysis was run across the six transects to compare grassland and forest sites. nMDS is a method of graphically depicting in 2-dimensional space the floristic relationships apparent between different sampling units, with closer positioning of quadrats indicating higher similarities, while quadrats aligning further apart support lower similarities. Significance testing of returned groups was undertaken using the SIMPROF module in *Primer*.

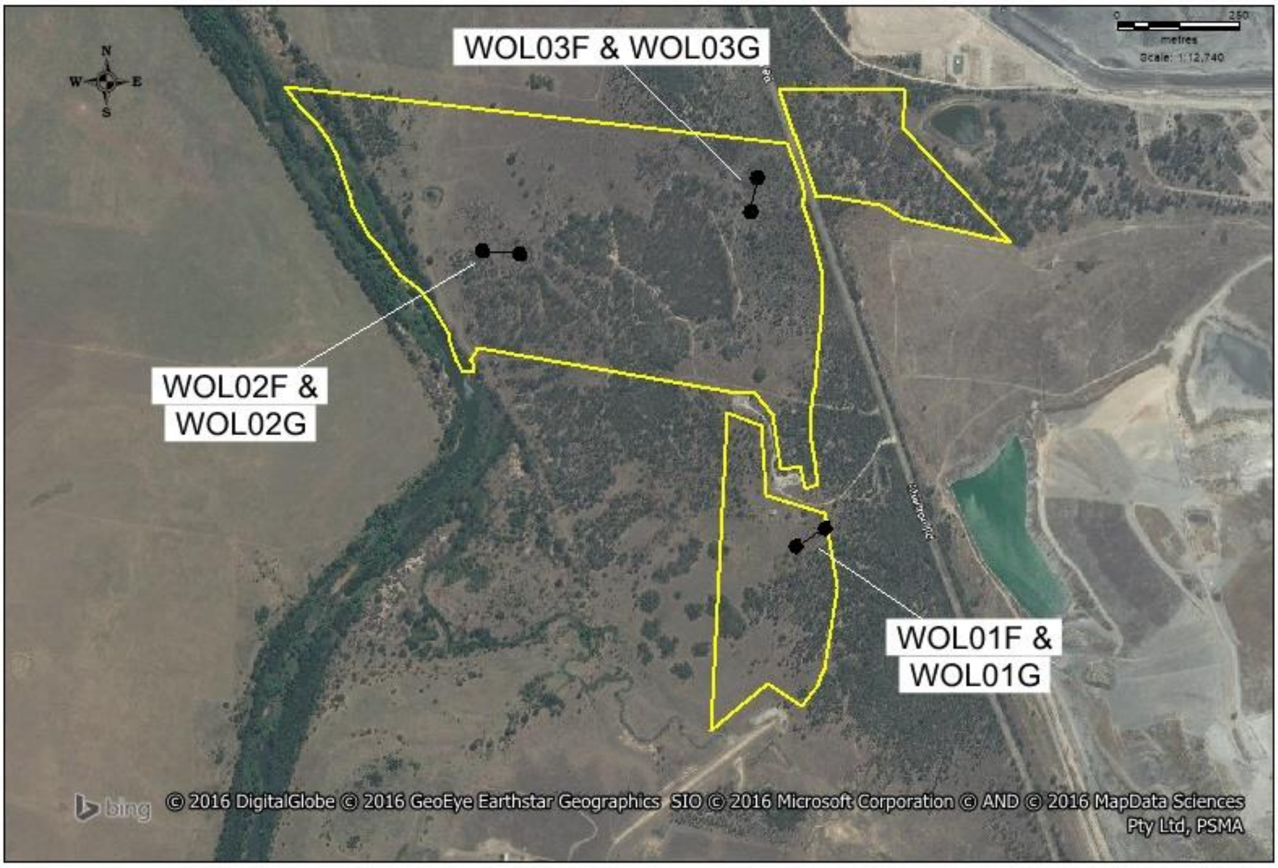


Figure 3 Location of three monitoring transect-pairs at *Wollombi Brook*.

Table 2 Location of transects within management units at *Wollombi Brook BOA*.

Management Unit	Transect No.	Transect Location (MGA, zone 56)	
		Start	Finish
Grassland (Apple)	WOL01G	317883 6384171	317844 6384146
Grassland (Ironbark)	WOL02G	317226 6384748	317177 6384750
Shrubland (Apple)	WOL03G	317753 6384877	317745 6384833
Apple	WOL01F	317925 6384198	317883 6384171
	WOL03F	317761 6384926	317753 6384877
Ironbark	WOL02F	317276 6384746	317226 6384748

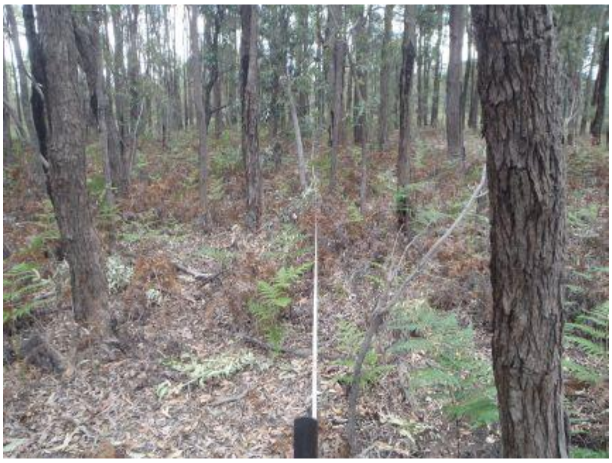
Transect WOL01G

Transect WOL01F

Transect WOL02G

Transect WOL02F

Transect WOL03G



Transect WOL03F

Figure 4 Fifty metre transects established at the *Wollombi Brook* offset. Grassland MUs (left hand side); Apple MU (top right & bottom right); Ironbark MU (right centre). Photographed November 2015.

Figure 5 Method of marking quadrat corners to avoid accidental dislodgement by wildlife.

3.2.3 Species Composition: Regenerating Grassland

Analysis of species diversity for each 100m transect-pair was undertaken through multivariate analysis of species-presence in component primary quadrats. Using *Primer*, nMDS and cluster analysis was run across the 20 quadrats in each transect-pair to enable comparisons between regenerating grassland (50m of 10 primary quadrats) and baseline forest (50m of 10 primary quadrats). Such analysis also allowed for comparative assessment of those quadrats lying at the interface between forest and grassland, specifically to determine if positive regeneration was occurring.

3.2.4 Canopy Composition & Structure

Since 2015, the identity and number of all canopy species (*Allocasuarina luehmannii, Angophora floribunda, Banksia integrifolia* subsp*. integrifolia, Eucalyptus crebra*) have been recorded for each primary and secondary quadrat along transects (ie: 20 quadrats per 50m transect), and through mathematical extrapolation used to estimate tree densities for forest, grassland and shrubland areas. The diameter-at-breast-height (DBH) of all canopy species greater than 1.6m in height within each quadrat was also measured, so that the age structure of existing forest vegetation could be established. For multiple-stemmed trees, all stems were measured but only the largest was included in age structure calculations. Canopy specimens less than 1 cm in diameter were not measured, but were tallied and included in the lowest age class (0-1cm DBH). For calculations, these individuals were automatically applied a DBH value of 0.16 cm (a circumference of ~0.5 cm). In the absence of better quality forests on the BOA, this data is considered 'baseline' and can be used to compare the progress of regeneration grasslands.

As noted in Section 3.2.1, the collection of detailed canopy data is no longer undertaken annually as *reward-for-effort* does not justify its collection. For completeness and reference, however, canopy data from the 2016 report have been retained in the current work.

3.2.5 Shrub Composition & Structure

A count was made of the number of stems of all woody shrubs present in quadrats, and densities calculated for each transect and management unit. It was to be expected that grassland areas would support the lowest density of woody shrub species, given their history of clearing and grazing. Densities of pioneering wattle species (*Acacia*) were also assessed separately, as these species play an important early role in grassland restoration and health.

3.2.6 Leaf Litter & Bare Ground

For each quadrat, qualitative (visual) assessments were made of the percentage cover of leaf litter and bare ground, and examined collectively by management unit.

3.2.7 Biometric Data Collection & Standardised Photopoints

At the request of Bulga Coal, the collection of standard Biometric floristic and habitat data was added to the monitoring program for Year 3. This data (habitat-based) was collected along the same 50m transects as the existing information, with additional floristic data collected from 20 x 20m quadrats positioned at the distant end (of the transect-pair) and partially overlapping 50m transects (see Figure 2 in Section 3.2.1). Biometric data was collected on the same days as other monitoring data. Standardised photo-point monitoring was also undertaken, using the existing transect star pickets as a reference point (see Figure 2) and photographing at the four cardinal points of the compass (N, S, E, W).

3.3 Fauna Monitoring

The *Wollombi Brook BOA* BOMP specifies six fauna monitoring sites for diurnal birds, nocturnal spotlight searches, Anabat recordings for microbats and habitat assessment for *EPBC Act* listed species. Additional fauna to be monitored at selected sites include larger terrestrial fauna by remote IR field cameras installed at three sites in 2017.

A summary of survey effort at each fauna monitoring site is presented in Table 3, while the fauna survey schedule is shown in Table 4. Locations of fauna monitoring sites are presented in Figure 6.

Table 3 Summary of fauna survey effort in 2017, *Wollombi Brook BOA*.

Wollombi Brook (65 ha)	No. Sites	Remnant Woodland	DNG* Regeneration	DNG* Revegetation
Flora Monitoring Plots	4	2	2	
Fauna Monitoring Sites	6	WB01, WB02, WB03	WB04, WB05, WB06	
Winter Birds	6	2 x 20 minute census	2 x 20 minute census	
Diurnal Birds (Spring)	6	2 x 20 minute census	2 x 20 minute census	
Nocturnal Spotlight	6	2 x 30 minute census	2 x 30 minute census	
Anabat Survey	6	2 nights	2 nights	
Motion Detection Camera	3	3 sites x 153 nights		
Habitat Assessment (EPBC Act Species)	4	1 transect	1 transect	

Table 4 Summary of fauna survey schedule in 2017, *Wollombi Brook BOA*.

Wollombi Brook (65 ha)	WB01	WBO2	WB03	WB04	WB05	WB06
Habitat Type	**DNG Regen**	**Remnant Wood**	**Remnant Wood**	**Remnant Wood**	**DNG Regen**	**DNG Regen**
x GDA 94	**317848.4**	**317140.3**	**317780.5**	**317607.3**	**317512.0**	**317881.7**
Y GDA94	**6384062.6**	**6384589.0**	**6384872.5**	**6384684.1**	**6384019.2**	**6385047.9**
Winter Birds 1	12/06/2017					
Winter Birds 2	11/08/2017					
Diurnal Birds (Spring)	6/11/2017					
Nocturnal Spotlight	7/11/2017					
Anabat Survey	7/11/2017					
Motion Detection Camera	12/6 – 7/08/17	7/8 – 7/11/17	12/6 – 7/8/17			
Habitat Assessment (EPBC Act Species)	2 transects					

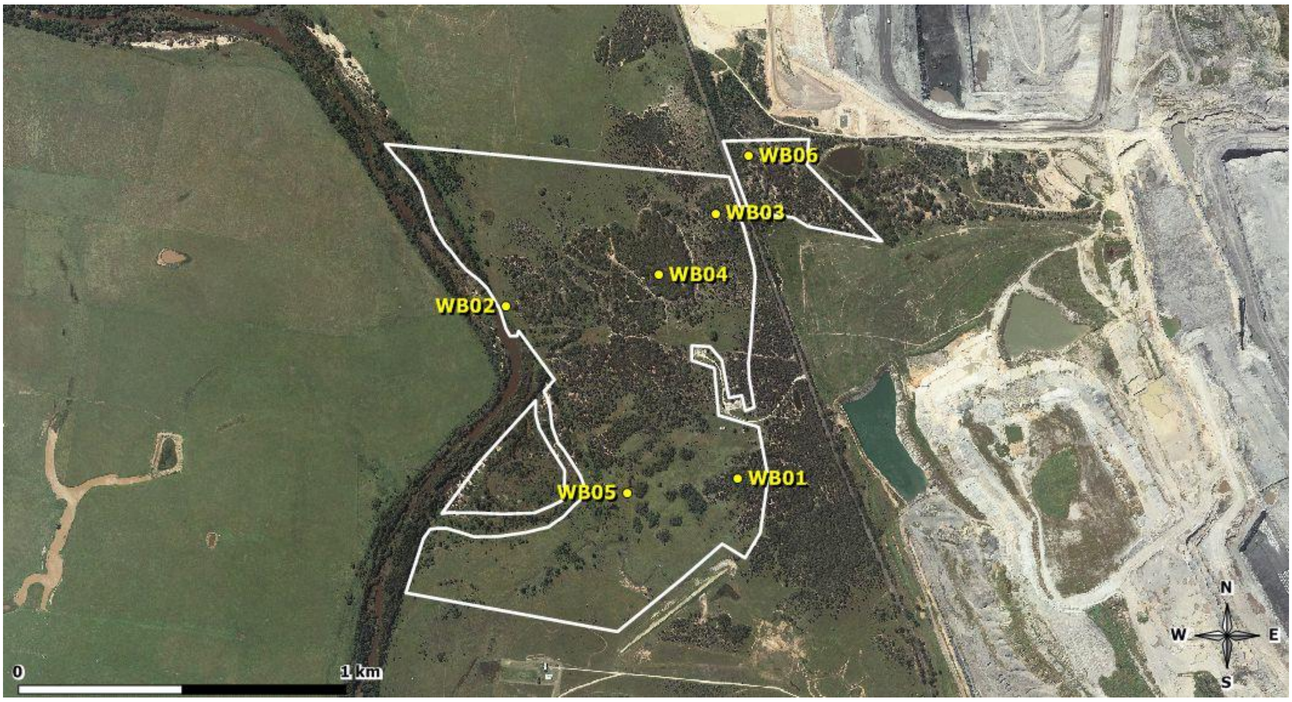


Figure 6 Location of fauna monitoring sites, *Wollombi Brook BOA*.

3.3.1 Birds

Two survey methodologies to census for bird species were adopted for the fauna monitoring program:

Opportunistic Sightings - Opportunistic sightings of bird species were recorded whilst undertaking other field duties. This includes direct observations of bird species and identification of their characteristic calls.

Diurnal Census - Sample plot counts employ a standard 40 minute search within a 1 hectare area (i.e. 100m x 100m, 50m x 200m, etc.) at each of the fauna monitoring sites. Replicate counts of all bird species observed or heard were conducted in winter, and one survey in spring 2017 as per the requirements of the BOMP. All bird species and individuals seen or heard are recorded, being scored as on-site if detected within plot, or off-site if recorded in adjacent vegetation types or flying overhead.

Heterogeneity within the bird community at *Wollombi Brook* has been analysed using Simpson's Index of Diversity (S.I.) between each of the fauna monitoring sites. This Index is sensitive to samples with low species diversity and abundance and is therefore suitable for the more common and abundant fauna groups, such as birds. This analysis was applied to bird census data collected from the 2013 to 2017 monitoring surveys.

The calculation of the S.I. is determined by the following equation:

$$d_s. = \frac{\sum n_i (n_i - 1)}{N^*(N-1)}$$

where $d_s.$ = diversity index

n_i = number of individuals of species i

N = total number of individuals of n_i, n_2, etc.

The Index ranges in value from 0 (low diversity) to a maximum of infinity ∞ (high diversity).

3.3.2 Mammals

Larger Terrestrial Mammals - Infra-red motion detection digital cameras were installed at fauna monitoring site (WB01, WB02, WB03) to photograph fauna. The cameras were installed on 12 June 2017 and retrieved on 7 November 2017, a total of 153 consecutive nights. Photographs recorded were analysed for species identification.

Micro-chiropteran Bats - Surveys for micro-chiropteran (insectivorous) bat species was conducted with one *Titley SD2* detector set at each site for 1 night. Anabat detectors were set on the evening of 7 November 2017. Echolocation calls of micro-chiropteran bats were recorded by the SD2 detector and stored onto a digital storage card. This technique enables sampling of bat activity for the duration of the night, providing a more comprehensive recording of bat species utilising each site. All recorded calls were down loaded for computer analysis using *AnalookW v.4.1* software.

3.3.3 Opportunistic Searches

Opportunistic fauna sightings, such as reptiles and frogs, were conducted whilst undertaking other field duties.

3.3.4 Habitat Condition for Regent Honeyeater, Swift Parrot and Large-eared Pied Bat

The BOMP outlines the requirement for assessment of habitat condition for the threatened Regent Honeyeater, Swift Parrot and Large-eared Pied Bat. For the Regent Honeyeater and Swift Parrot, both species could potentially forage on the *Wollombi Brook BOA* in specific vegetation communities, particularly in winter flowering eucalypts for pollen and nectar, but also generally in remnant woodland for lerps and foliage insects.

Habitat condition will be measured by the presence, abundance and duration of flowering of eucalypts and other trees species. The extent of woodland communities has been mapped and extent calculated. Ongoing monitoring will assess the extent of additional habitat augmentation undertaken by revegetation and regeneration of important woodland communities for both species.

Abundance and duration of flowering of eucalypts will be measured by the following parameters:

- presence of flowers in canopy (present / absent) during each bird census per annum;
- intensity of flowering (low, medium or high) based on visual assessment of crown abundance of flowers;
- duration of flowering. The duration of flowering, if present, is noted from records of presence in each bird census conducted per annum. Bird census monitoring commences in early winter and is completed by end of Spring, effectively monitoring 5-6 months per annum.

For the Large-eared Pied Bat, it's occurrence at *Wollombi Brook BOA* is restricted to foraging in the aerial space above and within the offset. The species roosts in caves or similar structures, none of which is present at *Wollombi Brook BOA*. Hence, monitoring for the species is restricted to presence only, as detected by Anabat surveys conducted in late Spring.

3.4 Ecological Thinning Trial

An ecological thinning trial was undertaken in mid-2016 which aimed to address observed thickening of the vegetation following the change in land use to conservation. In particular, dense growth of the tall shrub *Leptospermum polyanthum* was present within regenerating Warkworth Sands Woodland, and the small tree *Allocasuarina luehmanii* had become established in regenerating Central Hunter Grey Box – Ironbark Woodland. Baseline surveys using 10 x 10m quadrats (control & treatment) and a replicated experimental design were undertaken in July 2016 prior to thinning, as documented in Bell (2016). Re-survey of these twelve quadrats was undertaken in November 2016 as part of the annual monitoring program, and again in November 2017, 16 months post-thinning. An updated comparative analysis tracking the response to thinning is presented in this report, using *Primer* (Clarke & Gorley 2005) to examine the floristic relationships within and between monitoring plots.

3.5 Weather Conditions

3.5.1 Flora Survey

In grassy woodland environments such as the upper Hunter Valley, rainfall received in the months prior to flora survey can be influential in the diversity and abundance of herbs, forbs and grasses recorded. For forbs and herbs, adequate rainfall during the preceding weeks rather than months is crucial. Consequently, the comparison of species diversity and abundance of vegetation from year to year requires a cautious interpretation. As an indication of the rainfall variability from year to year, Figure 7 shows rainfall recorded at Bulga (3.5km to the west) between 2015 and 2017 (Bureau of Meteorology 2018). Compared to the long term average (57 years), 2017 was a very dry year, with only the months of March and October receiving higher than average falls. Drought conditions such as this limit the ability for many herbs, grasses and forbs to emerge and flower, and hence overall floristic diversity recorded during surveys is typically low.

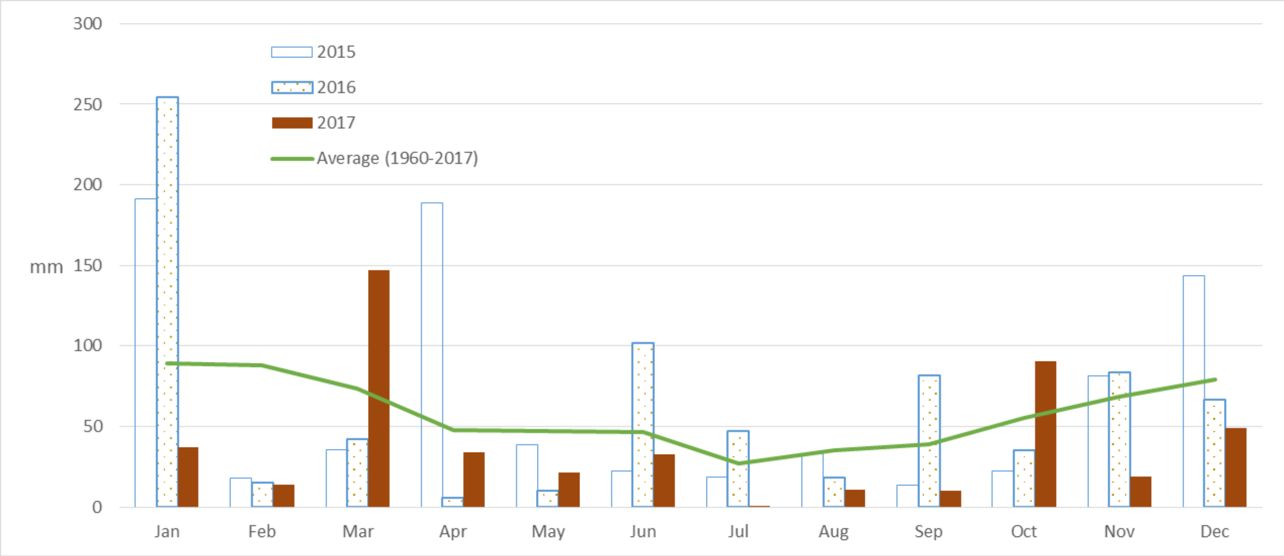


Figure 7 Rainfall received at Bulga 2015 to 2017, showing long-term average (Bureau of Meteorology 2018).

3.5.2 Fauna Survey

Weather conditions were fine during fauna fieldwork in the winter and spring 2017 surveys. Rainfall was recorded in June and November 2017 but the totals were very low, 2.2mm and 2.6 mm respectively. A summary of weather conditions collected from Singleton Defence weather station (Bureau of Meteorology 2018) is summarised below in Table 5.

Table 5 Weather conditions during 2017 fauna survey period, *Broke Road BOA*.

Date	Min. Temp °C	Max. Temp °C	Rel. Hum. 9am	Rel. Hum 3pm	Wind Speed (km/hr) and Direction		Cloud Cover	Rainfall (mm) 24 hrs
					9 am	3 pm		
12/06/2017	10.3	20.1	88%	63%	Calm	NNE - 6	6/8	2.2mm
11/08/2017	10.9	28.0	23%	18%	NW - 22	NW - 33	1/8	0.0
6/11/2017	15.6	22.0	81%	81%	SW - 6	NW - 7	8/8	2.6mm
7/11/2017	15.0	22.5	No data	No data	No data	No data	4/8	0.0

Data Courtesy of Bureau of Meteorology (www.bom.gov.au)

Note: *Cloud cover* refers to the extent of cloud cover in the sky expressed on a proportional scale from 1 – 8. For example, a cloudless sky would score 0 / 8, whilst a fully overcast day would score 8 / 8.

4. Results

4.1 Property Inspections

Due to the ongoing drought conditions experienced in 2017 (see Section 3.5), flora monitoring programs were delayed as far as possible in the hope that conditions would improve. As a consequence, field surveys were not undertaken until January-February 2018 for the Year 3 program, but little improvement in environmental conditions was seen.

Following field inspections, most inspected fences remain in good condition. However, a major breach has occurred off the crown road reserve, where cut fencing has allowed apparently regular unauthorized access into the BOA (Figure 8). Additionally, the main portion of the BOA was subject to an ecological thinning trial in mid-2016 (Section 3.4), and as a consequence some new temporary trails were pushed through transect WOL03G, resulting in the loss of some vegetation and the incursion of some herbaceous weeds. These areas are now regenerating well.

Figure 8 Vandalized fence and illegal access into the *Wollombi Brook BOA* during 2017.

4.1.1 Invasive Weeds

Four potentially invasive exotic species and two native woody invasive shrubs will require continued monitoring and active management in coming years. Section 6 outlines some possible management strategies to address these species.

***Melinis repens* (Red Natal Grass)** – this exotic grass species is common in sandy environments, and within *Wollombi Brook* occurs principally in and around the Warkworth Sands Woodland (including transect-pairs WOL01 & WOL03). Control of this species over wide areas is problematic, as re-emergence from seed stock or from nearby infested areas ensures ongoing infestation.

***Panicum coloratum* var. *coloratum* (Coolah Grass)** – another exotic grass which has likely been sown during past grazing activities, and remains within grassland areas at *Wollombi Brook*. It appears most prevalent in and around transect WOL01G, where a high number of other exotic grasses are present. Depending on the variety, this species has the potential to spread by stolons or seed, and will require monitoring in future years if excessive spread becomes evident.

***Richardia brasiliensis* & *Richardia stellaris* (Mexican Clovers)** – exotic low, prostrate perennials present primarily within the regenerating Warkworth Sands Woodland at *Wollombi Brook,* but also across most other areas. This species may pose a threat to regenerating woodlands through suppression of native seedling emergence.

***Leptospermum polyanthum* (Ti-tree)** – this native species has become invasive within regenerating Warkworth Sands Woodland in and around transect WOL03G. Although native, it is not endemic to this EEC, and an ecological thinning experiment involving the trial removal of this species was undertaken in mid-2016. Continual monitoring of this trial (see Section 4.4) will determine if wider thinning of this species should occur in coming years to improve the returning regeneration of Warkworth Sands Woodland.

***Allocasuarina luehmannii* (Bulloak)** – as identified in the BOMP, this native tall shrub or small tree is present across much of Wollombi Brook, and is particularly dense in some areas. The ecological thinning experiment undertaken in mid-2016 also involved the trial removal of this species, and continual monitoring (Section 4.4) will determine if wider thinning of this species should occur in coming years.

4.1.3 Feral Animals

Feral animal presence, as determined by remote camera monitoring, detected three species, the Fox *Vulpes vulpes*¸ Dog *Canis lupus familiaris* and Brown Hare *Lepus capensis*. The three species were detected by camera on three of the 153 monitoring days. Evidence of Pig diggings were widespread within the *Wollombi Brook BOA*, and a number of individuals were observed in the June 2017 survey.

4.1.4 Erosion

No areas of active erosion were noted during field inspections in Year 3.

4.2 Flora

4.2.1 Species Composition: Management Units

Non-metric Multi Dimensionsal Scaling (nMDS) of the six 50m transects sampled in 2017 showed four significant floristic groups at 44% similarity ($p<0.01$), with negligible stress (Figure 9). Unlike previously, all transects have grouped in close proximity to their respective pairs, most likely a reflection of the lower species abundance and diversity observed due to drought conditions. The Ironbark pair (WOL02) remains significantly different to the Apple pairs (WOL01, WOL03), but for all pairs the distinction between forest and grassland (or shrubland) is unclear.

4.2.2 Species Composition: Regenerating Grassland

In total, 95 plant species (the same as in 2015, but a decrease down from 104 in 2016) were recorded across the 60 sample quadrats in both forest and grassland in 2017 (Appendix A8.7), including 33 weed species (35%, down 3% from 2016). Within management units, native species diversity was highest in Forest transects and lowest in Grassland transects, although not significantly (Figure 10). Weed species diversity was only slightly higher in Grassland and Shrubland than Forest MUs, although a larger discrepancy was evident in the Ironbark

MU. As in previous years, regenerating Warkworth Sands Woodland supported approximately equal numbers of natives and weeds in transect-pair WOL03, but this was not evident in transect-pair WOL01 which has experienced a more dramatic and prolonged grazing disturbance regime.

Non-metric Multi-Dimensional Scaling (nMDS) of quadrat species-presence data for each 100m transect-pair revealed clear 'forest' and 'grassland' groups, with quadrats at the interface of these two structural types comprising informal (yet significant) associations. It may be expected that these two groups will become progressively closer in 2-dimensional space with continued monitoring in subsequent years, as plant composition changes and regeneration of grassland areas proceeds.

For WOL01, five significant groups (P<0.01 at 54% similarity) are evident in the data (Figure 11). Previous years have differentiated only three significant groups, but evidently the dry conditions experienced during Year 3 have impacted on species abundance at the local scale. All Grassland quadrats fall within two large clusters, but Forest quadrats are dispersed across all five clusters. As in 2016, the single quadrat 09F was almost devoid of vegetation due to dense leaf litter from a nearby Rough-barked Apple tree, and consequently was significantly floristically different to all others.

A similar pattern is evident for WOL02 (Figure 12). There are three significant splits in this dataset (p<0.01 at 60% similarity), differentiating all Grassland quadrats in one, but splitting the Forest quadrats into two sub-groups. The bulk of Forest quadrats aggregate together, but two quadrats in the middle of the transect (3F & 05F) significantly split from all others. This change in distribution of Forest quadrats from 2015 and 2016 data may be a reflection of the dry conditions prevailing in 2017.

Figure 9 nMDS chart of 6 transects within management units, 2017. Stress = 0.01, p<0.01 at 44% similarity.

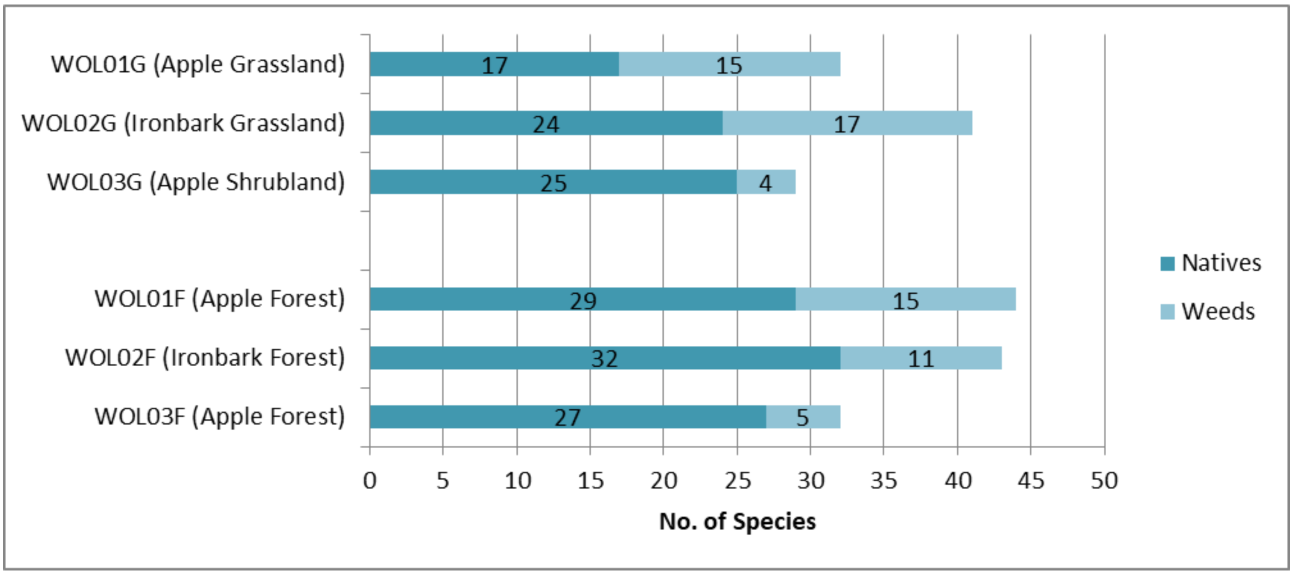


Figure 10 Overall species diversity for all transects at Year 3, showing native and weed species.

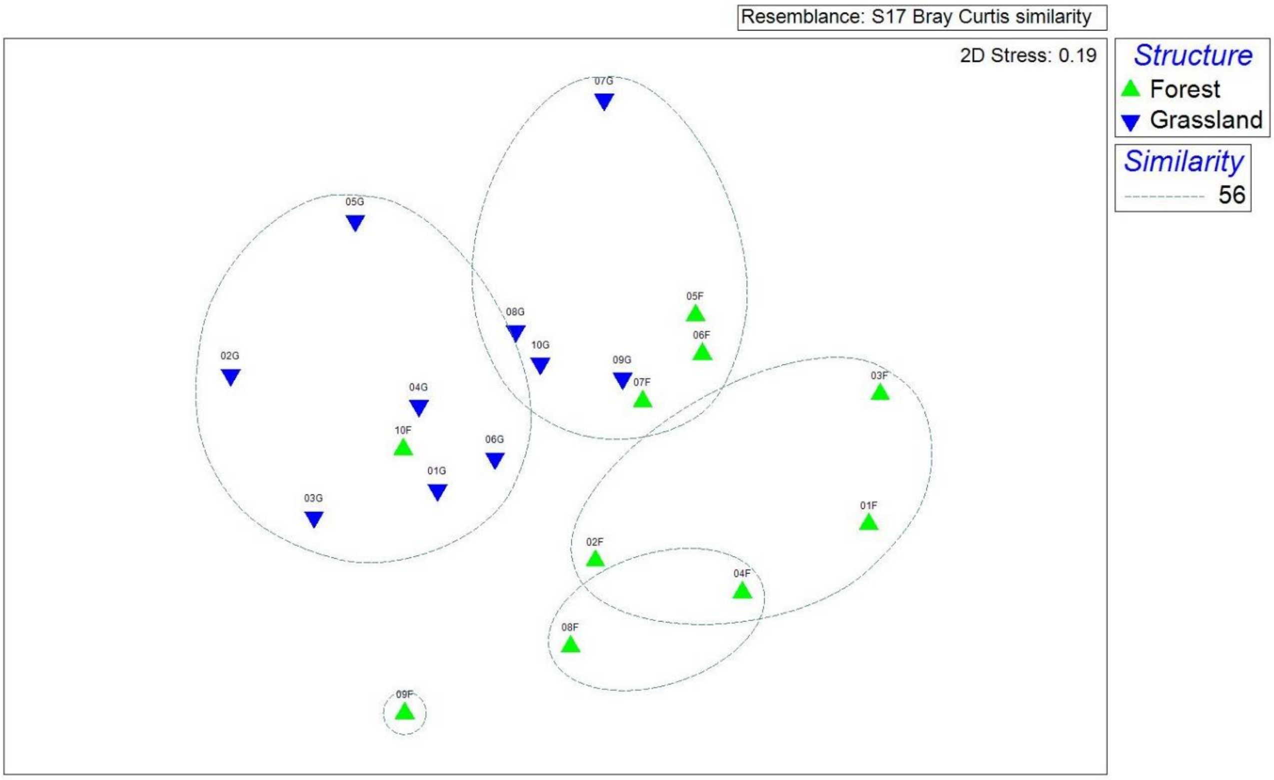


Figure 11 nMDS chart of 20 quadrats comprising Transect WOL01 (Apple-Grassland MU), 2017 data. Stress = 0.19, $p<0.01$ at 56% similarity.

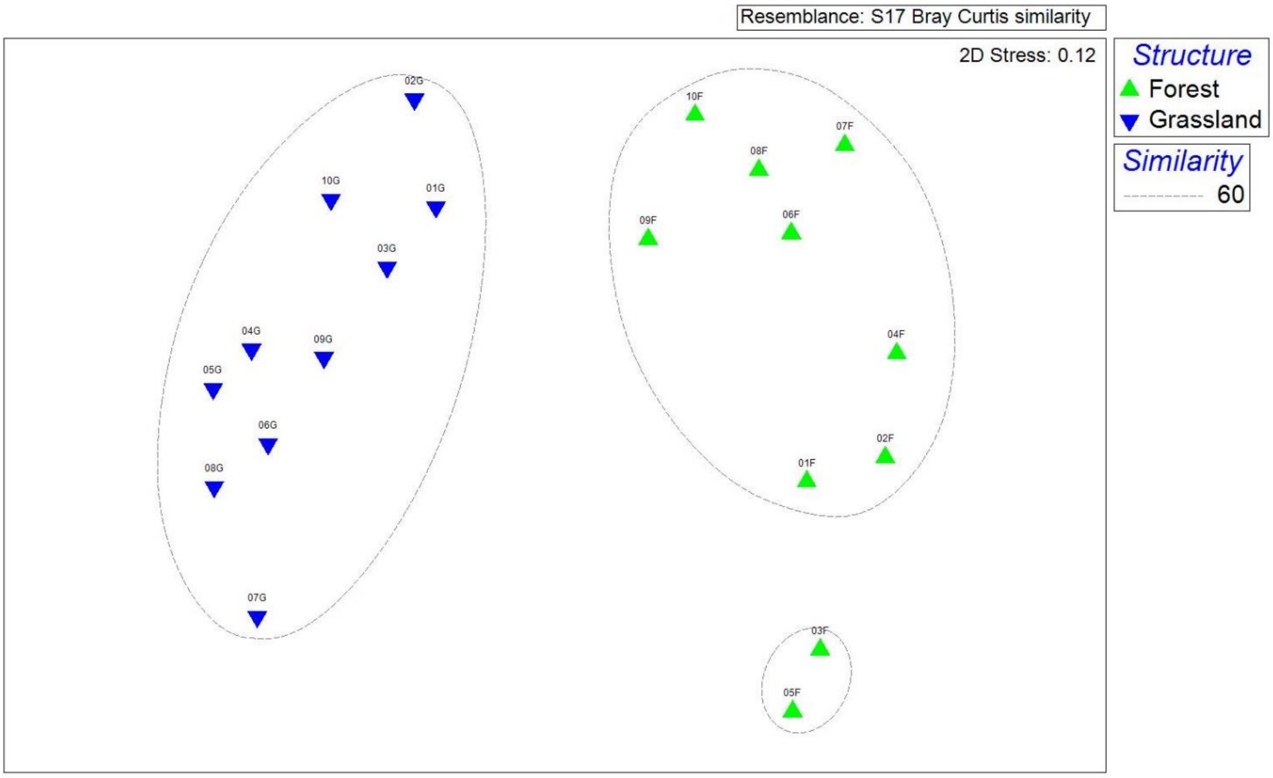


Figure 12 nMDS chart of 20 quadrats comprising Transect WOL02 (Ironbark-Grassland MU), 2017 data. Stress = 0.12, p<0.01 at 60% similarity.

Results returned for WOL03 showed three significant groups (p<0.01 at 46% similarity) (Figure 13). As in 2015 and 2016, the first of these differentiated eight of the ten Forest quadrats (01F-08F), while the second comprised nine Shrubland quadrats in addition to the remaining 09F and 10F. One notable difference from previous years, however, is that quadrat 01G clustered separately to all others; this quadrat likely reflects floristic changes arising from localized disturbance following creation of a new access trail during the thinning experiment in 2016. The developing shrubland within this transect includes much diversity, yet floristics are similar at the Forest-Shrubland interface.

4.2.3 Natives vs Weeds

Visually assessed, the cover abundance of weed species during Year 3 was at its lowest. This is almost certainly due to the later survey time and the drought conditions prevailing over much of the year, which have restricted the growth of annual species. Weed species were negligent across all but the Grassland (Apple) MU, but even here their expression was well tempered compared to previous years. Figure 14 shows the relative proportion (estimated % cover) of weed species across Ironbark, Apple, Grassland and Shrubland units. Currently, there is minimal weed presence within Forest MUs (Ironbark & Apple) and the Shrubland (Apple) MU. The majority of weed cover in grassland areas was explainable by the dominance of exotic grass and herb species (eg: Red Natal Grass, Mexican Clover, Blue Heliotrope, Carpet Grass, Couch). Mexican Clover (*Richardia brasiliensis*) and Blue Heliotrope (*Heliotrope amplexicaule*) are particularly abundant across remnant sand environments, and pose a threat to the ongoing integrity of Warkworth Sands Woodland.

The invasive woody native *Leptospermum polyanthum* has invaded former Warkworth Sands Woodland which now supports a regenerated shrubland, and will require ongoing monitoring following the 2016 thinning trial (see Section 4.4). Despite widely-held opinions that Common Couch (*Cynodon dactylon*) is a native species, this taxon is considered a naturalized exotic species within the Hunter Valley (and potentially elsewhere in Australia: see historical discussions in Langdon 1954), and is unlikely to have naturally occurred prior to European settlement. Within the BOA, this species is dominant in some grasslands occurring on sand and clay, and is considered introduced.

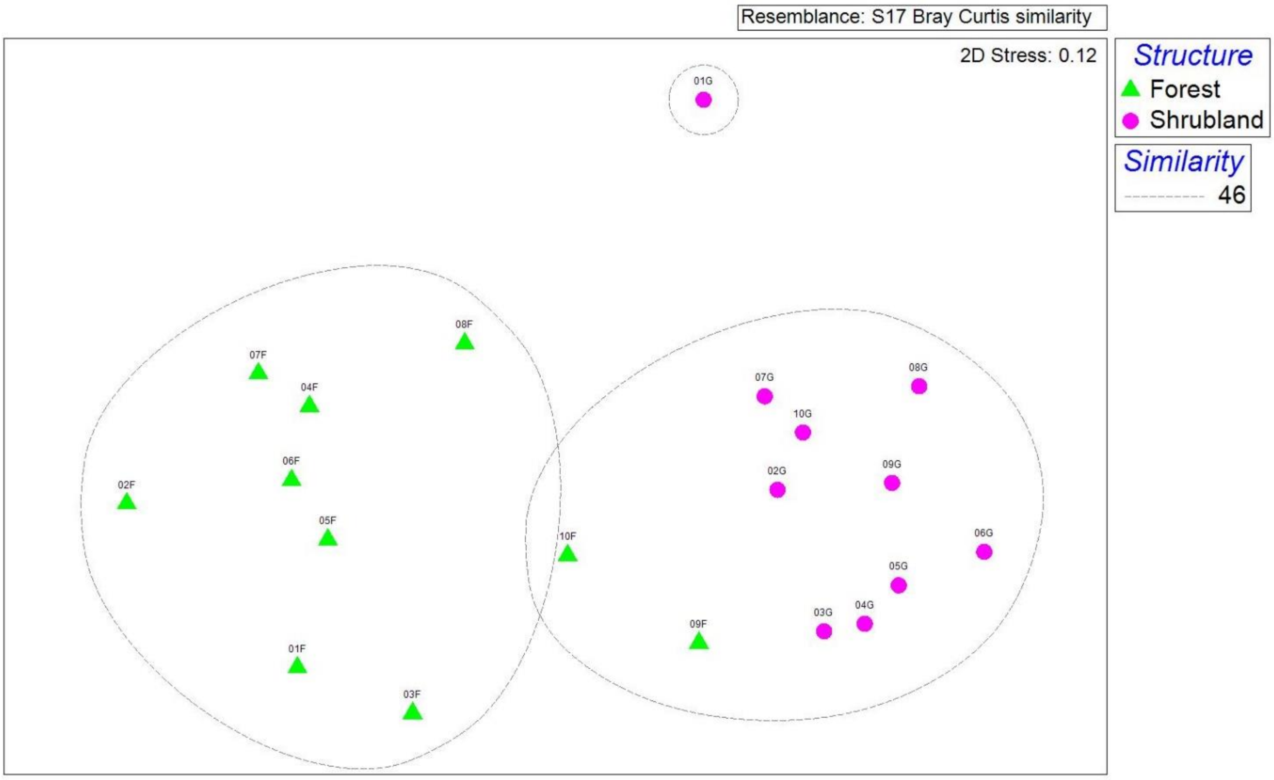


Figure 13 nMDS chart of 20 quadrats comprising Transect WOL03 (Apple-Shrubland MU), 2017 data. Stress = 0.12, p<0.01 at 46% similarity.

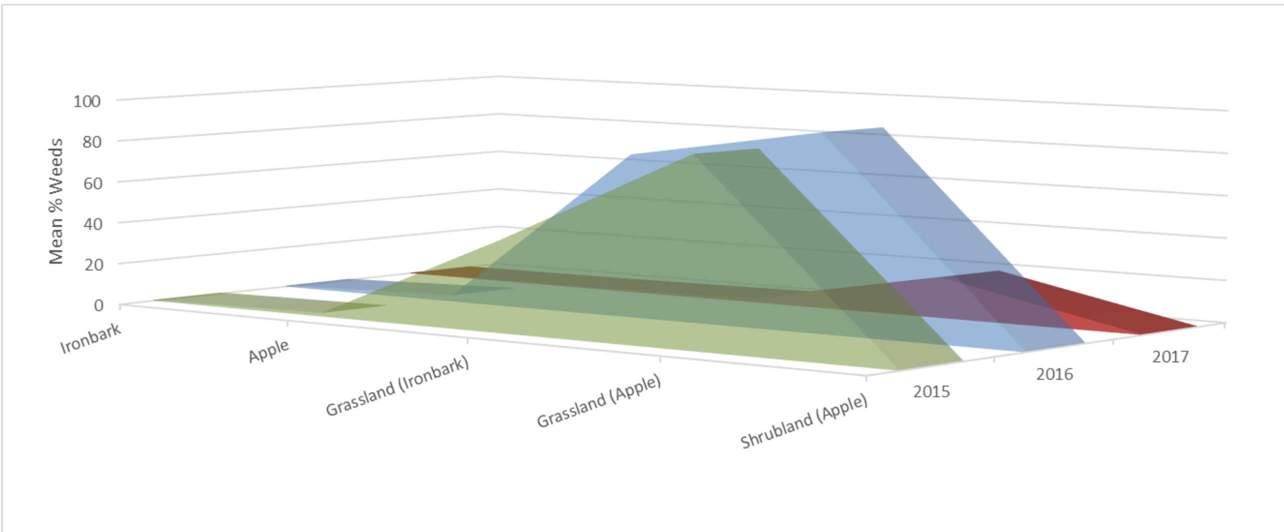


Figure 14 Change in relative proportion of weed species within management units from 2015 to 2017, expressed as estimated % cover, for Ironbark MU (n=10), Apple MU (n=20), Grassland (Ironbark) MU (n=10), Grassland (Apple) MU (n=10), and Shrubland (Apple) (n=10).

Assessment of weeds across 100m transect-pairs revealed differing results for the two MUs, with little divergence from 2015 and 2016 results (Figures 15-17). The dry conditions in 2017 meant that overall there were fewer species of native and exotic origin, and the most obvious change was the greater proportion of weed species evident in the Ironbark MU (WOL02). The two transect-pairs within the Apple MU (WOL01 & WOL03) continue to show only slightly increased weed presence in Grassland compared to Forest. For WOL01 weeds comprise a significant amount of the diversity present, while in WOL03 weeds are minimal. The cessation of cattle grazing will have a major impact on the prevalence of weed species in the first few years of regeneration, and their presence should be continually monitored. Based on this data, native species are more diverse in Forest rather than Grassland MUs. However, transect-pair WOL03 monitors advanced regenerating shrubland (not grassland), and in this situation native diversity is higher here than in the much older regenerated Forest. As has been observed at other Hunter Valley locations, it is expected that weed presence across all MUs will increase initially following cattle removal, but then over time reduce in prominence as native species dominate and provide shading.

No threatened plant species were recorded within monitoring transects. The rare Hunter endemic *Grevillea montana* remains common in and around WOL03. Several other regionally significant species are also present, particularly in the remnant and regenerating Warkworth Sands Woodland. These include the semi-arid species *Perotis rara, Lomandra leucocephala* subsp. *leucocephala* and *Podolepis canescens*. New records of the western grass *Aristida contorta* were also made within transect WOL03 in Warkworth Sands Woodland during Year 3.

4.2.4 Canopy Composition & Structure

Canopy Composition & Density - Four canopy species (*Allocasuarina luehmannii, Angophora floribunda, Banksia integrifolia* subsp. *integrifolia* & *Eucalyptus crebra*) are present within monitoring quadrats. The density of these species within survey areas is likely to be higher than would have naturally occurred, due to previous clearing of the *Wollombi Brook* BOA. Some temporary loss of vegetation was sustained within transect WOL03G as a result of the ecological thinning trial conducted near there in mid-2016, but it is expected that these areas will quickly return to a regenerating state provided vehicles remain excluded from these temporary trails.

Based on the 60 sample quadrats examined at *Wollombi Brook*, Figure 18 shows the change in extrapolated number of stems per hectare for canopy species within sampled Grassland ('regenerating'), Ironbark and Apple management units (both considered 'baseline') over three years. Regenerating grasslands clearly fall well short of current-day baselines. Increases in density from 2015 were seen in all but the Shrubland (Apple) transect (WOL03G), which was impacted upon by two temporary trails. The >1000 stems/ha shown for Shrubland (Apple) largely reflects the density of *Banksia integrifolia* and *Allocasuarina luehmannii* individuals that were present in this transect, rather than *Angophora floribunda* individuals. Under dryer conditions in 2017, all transects suffered a loss of young canopy seedlings, particularly *Banksia* and *Allocasuarina,* some of which may be attributed to browsing by macropods.

Canopy Age Structure & Basal Tree Area - Data on canopy age structure and basal tree area have not been collected during the Year 3 monitoring program, given the existence of such data collected in 2015 and 2016. Re-assessment of this attribute is scheduled for Year 5 (2019). Discussion in the following paragraphs refers directly to the most recent measuring of canopy in 2016, and is compared against 2015 (baseline) data.

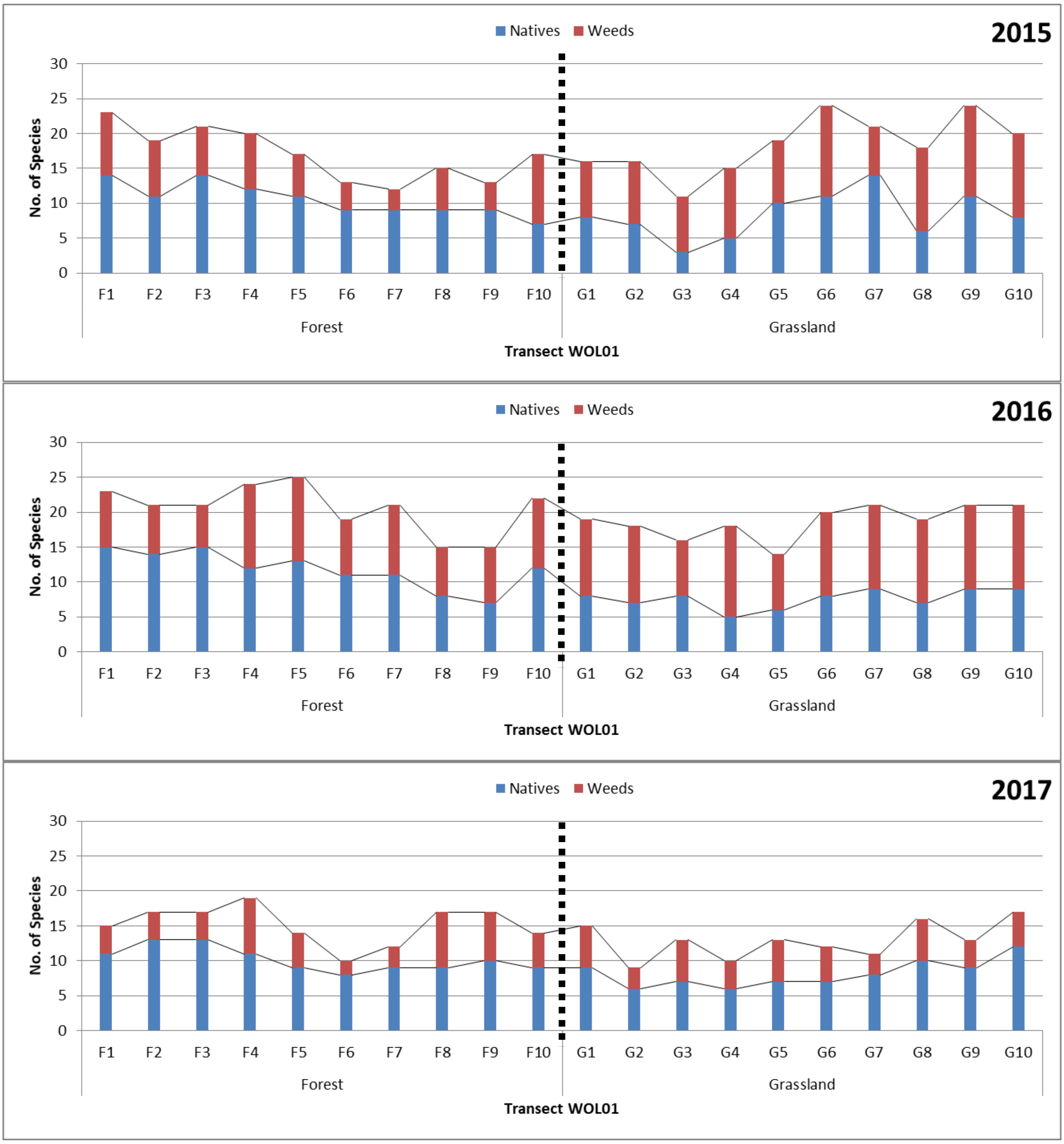


Figure 15 Change in the proportion and number of native and weed species along transect WOL01 for 2015 (top), 2016 (middle) and 2017 (bottom), as represented by 20 contiguous 5 x 5m quadrats. F = forest quadrat; G = Grassland quadrat.

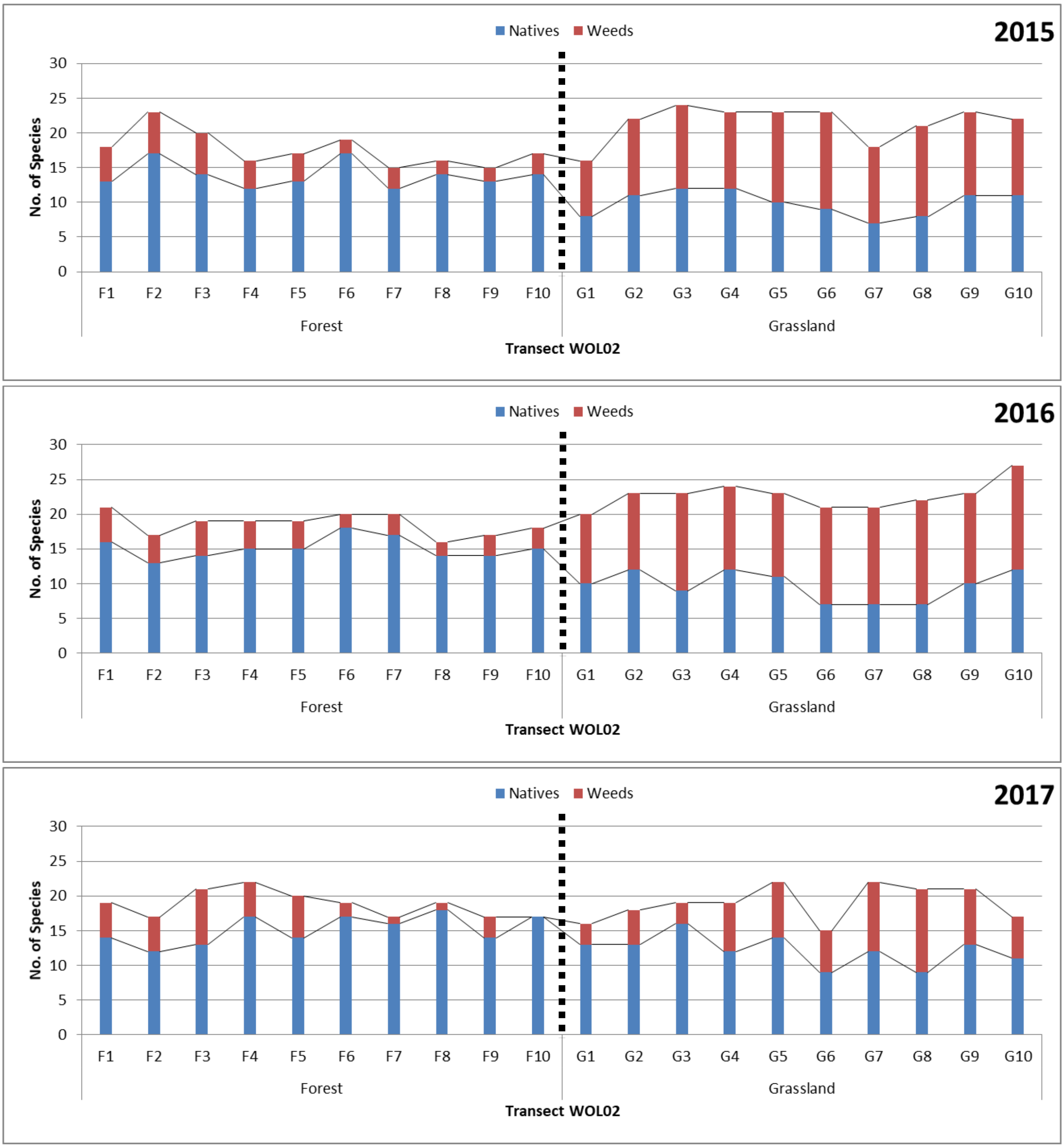


Figure 16 Change in the proportion and number of native and weed species along transect WOL02 for 2015 (top), 2016 (middle) and 2017 (bottom), as represented by 20 contiguous 5 x 5m quadrats. F = forest quadrat; G = Grassland quadrat.

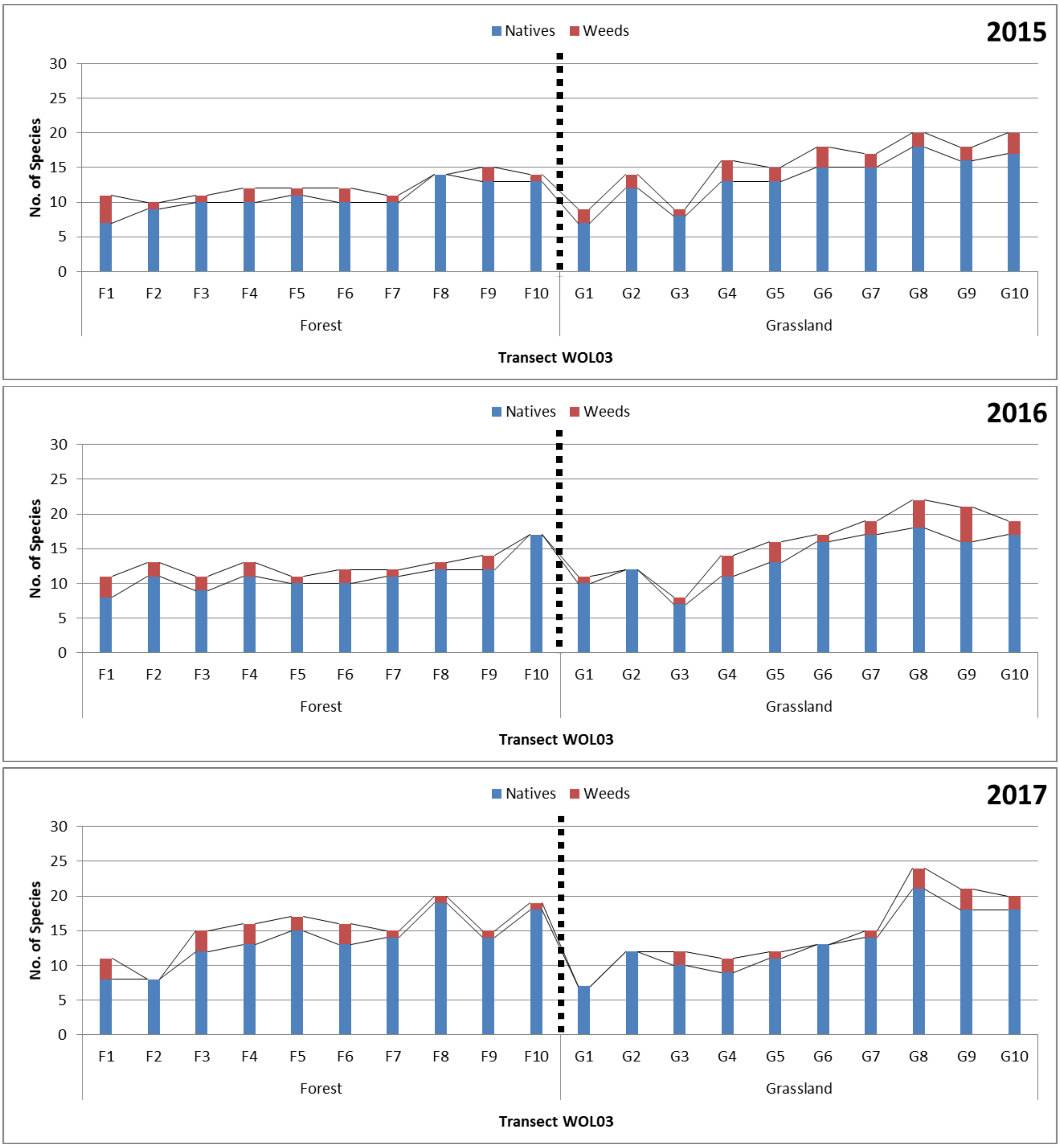


Figure 17 Change in the proportion and number of native and weed species along transect WOL03 for 2015 (top), 2016 (middle) and 2017 (bottom), as represented by 20 contiguous 5 x 5m quadrats. F = forest quadrat; G = Grassland quadrat.

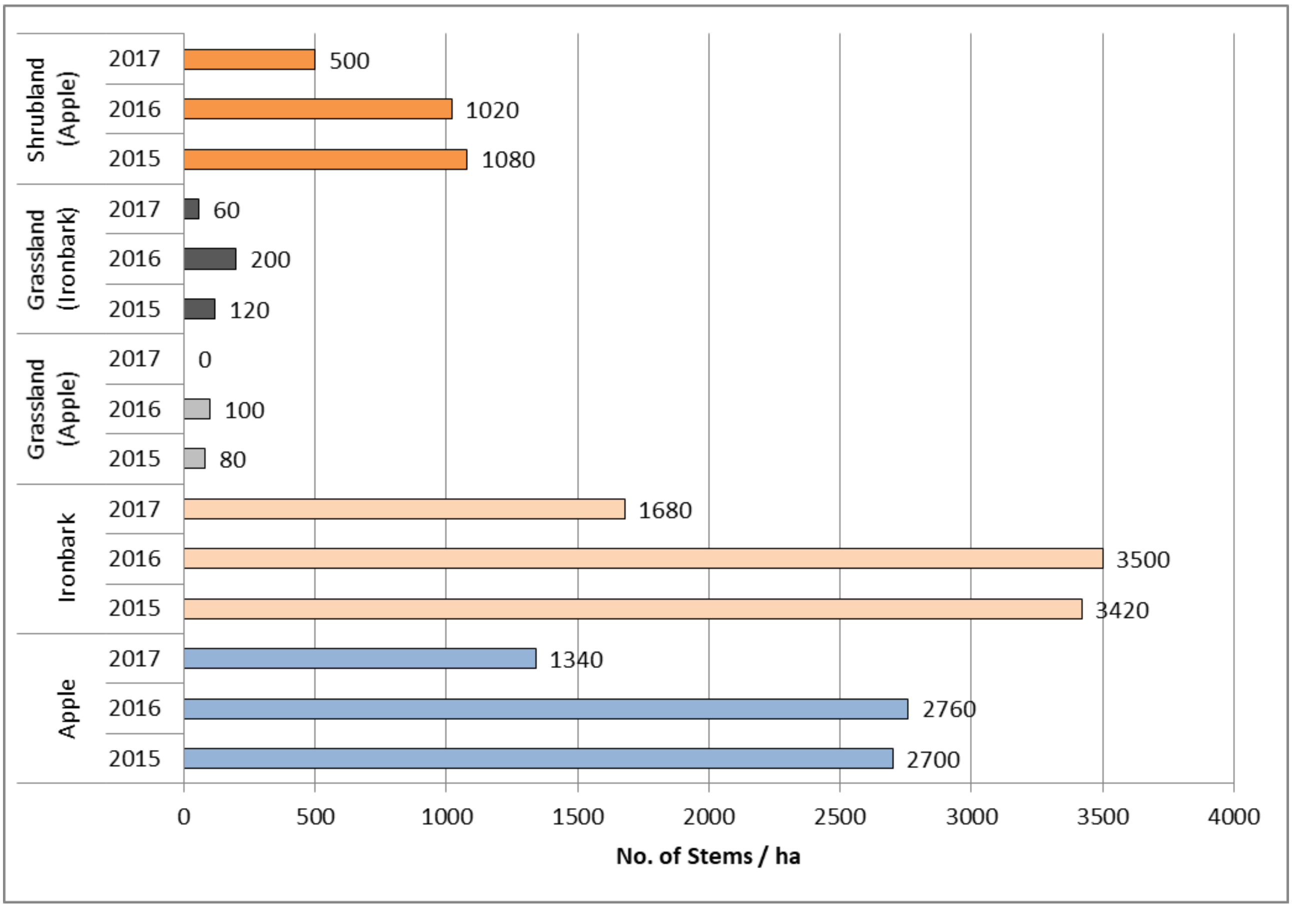


Figure 18 Change in number of canopy stems per hectare for Shrubland (Apple) (n=10), Grassland (Ironbark) (n=10), Grassland (Apple) (n=20), Ironbark (n=10) and Apple (n=10) management units, 2015 to 2017.

Canopy Age Structure - Forest vegetation at *Wollombi Brook* is representative of a regenerating class following previous clearing disturbances. Figures 19 - 23 illustrate this through age distribution charts for all management units (Ironbark, Apple, Grassland & Shrubland MUs), 2015 to 2016. Ironbark (which supported the most individual canopy specimens) and Apple Forests show a range of age classes, with most individuals between 1 and 15 cm DBH. Both MUs show an increase in the 0-1 cm DBH class, indicative of a regenerating forest. No individuals within the Ironbark MU are greater than 20cm DBH, which suggests that hollow-dependent fauna are likely to be rare or absent in forests of this age.

Grassland MUs support very few canopy species at present, but it is expected that this number will increase over time. There has been a slight increase in the number of stems in the 0-1 cm DBH class from 2015 to 2016 data. In 2015, the Shrubland (Apple) MU showed a high number of very young individuals, which were attributed directly to the numerous seedlings of *Banksia integrifolia* that were present along this transect, but in 2016 this number has decreased. Observations made in 2017 suggest that a further decline in these individuals has occurred as most have succumbed to drought conditions.

Basal Tree Area - Figure 24 shows the basal tree area (2016) and mean DBH (2015-2016) for all four management units. For all but the Apple MU, mean DBH values are well above the total basal area of canopy individuals, suggesting that all developing forests are of a young age. The very high basal area for the Apple MU reflects the high density of *Angophora floribunda* evident in transect WOL03F, yet these trees had a mean DBH of under 12 cm. Over time, as new canopy seedlings germinate and develop, it is expected that mean DBH values will drop quickly in the short term, but increases in total basal area will take considerable longer to occur.

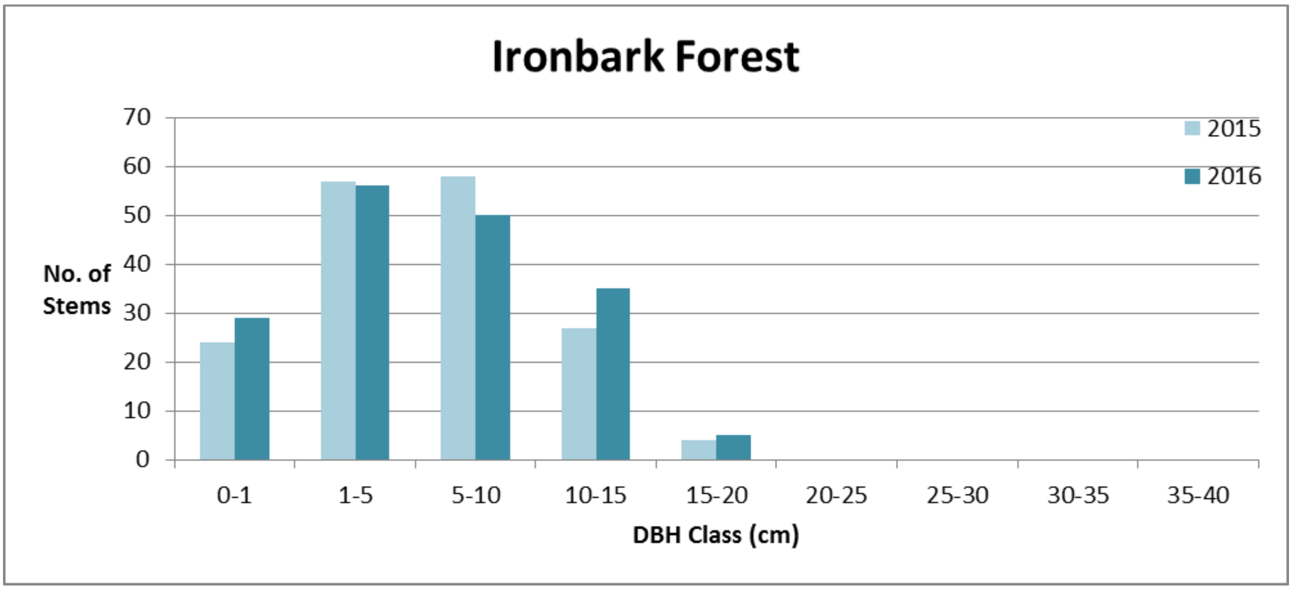


Figure 19 Change in age class distribution of canopy stems for Ironbark MU across 20 quadrats, 2015 (n=170) to 2016 (n=175). Note that DBH of canopy specimens was not measured in 2017.

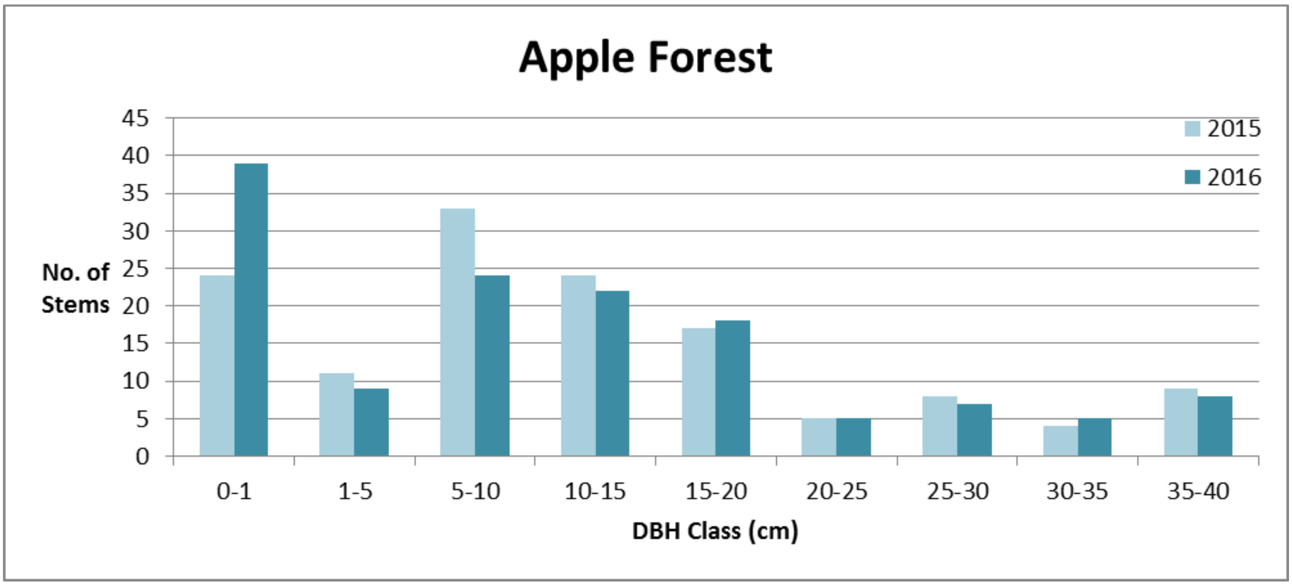


Figure 20 Change in age class distribution of canopy stems for Apple MU across 40 quadrats, 2015 (n=135) to 2016 (n=137). Note that DBH of canopy specimens was not measured in 2017.

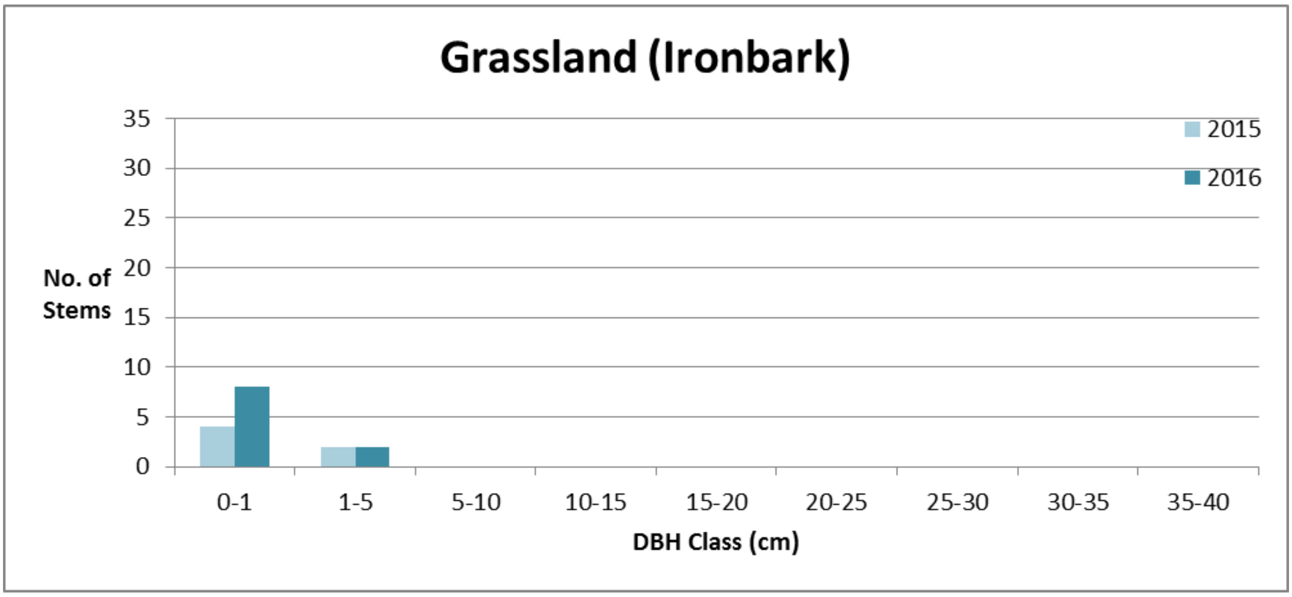


Figure 21 Change in age class distribution of canopy stems for Grassland (Ironbark) MU across 20 quadrats, 2015 (n=6) to 2016 (n=10). Note that DBH of canopy specimens was not measured in 2017.

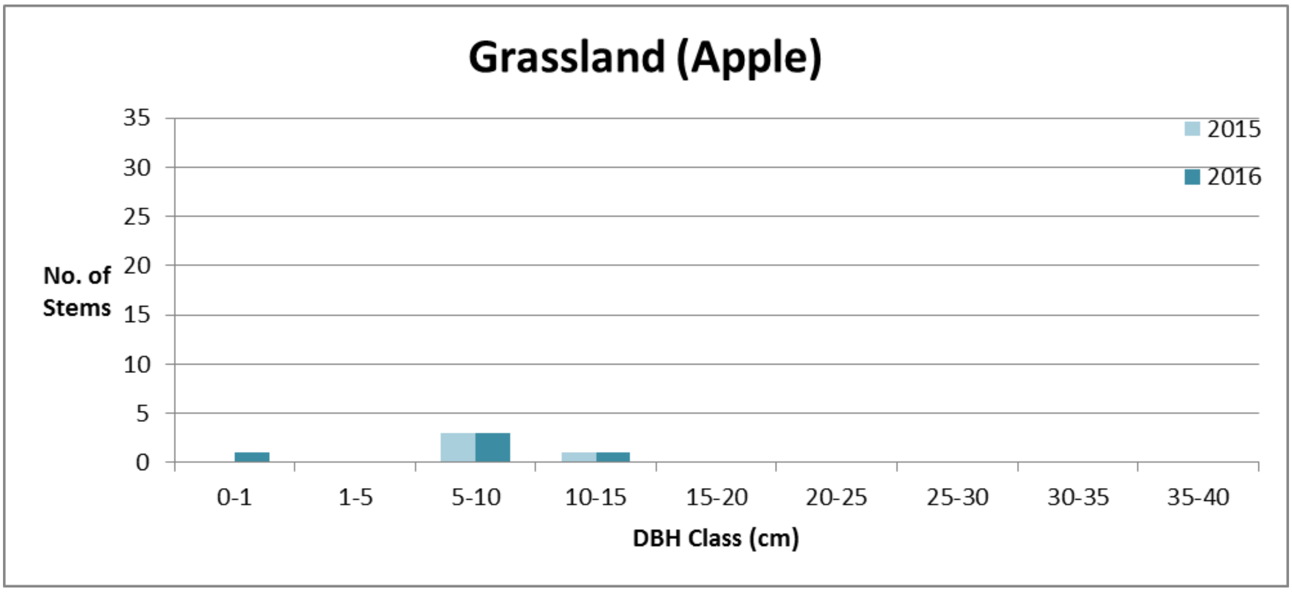


Figure 22 Change in age class distribution of canopy stems for Grassland (Apple) MU across 20 quadrats, 2015 (n=4) to 2016 (n=5). Note that DBH of canopy specimens was not measured in 2017.

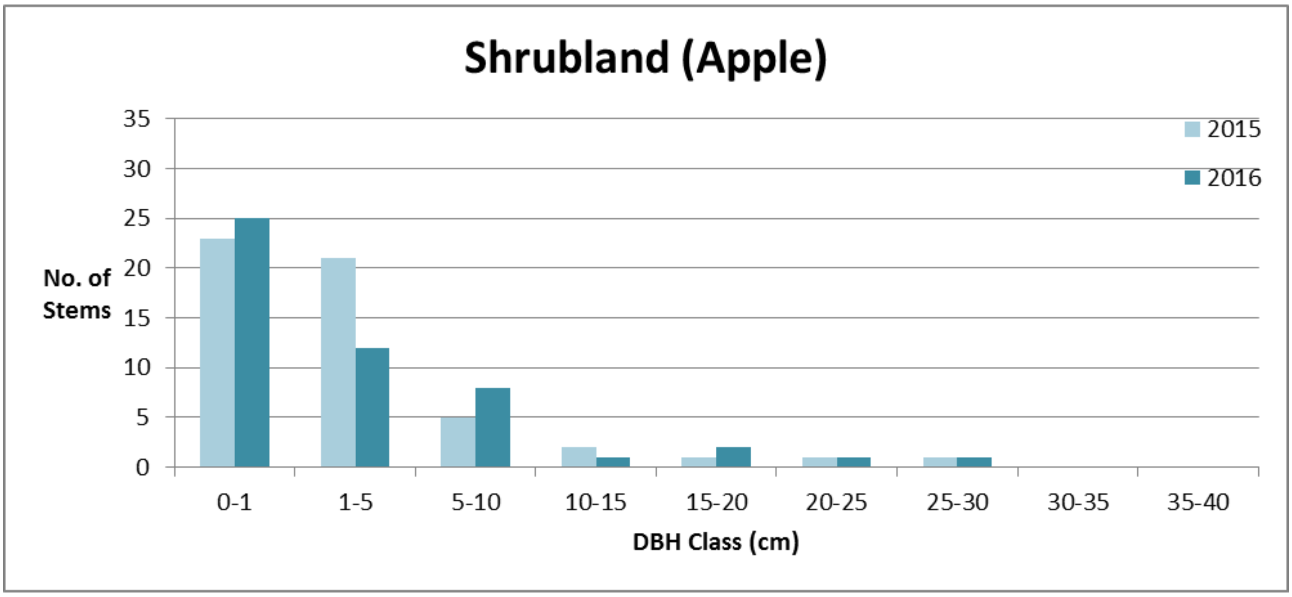


Figure 23 Change in age class distribution of canopy stems for Shrubland (Apple) MU across 20 quadrats, 2015 (n=54) to 2016 (n=50). Note that DBH of canopy specimens was not measured in 2017.

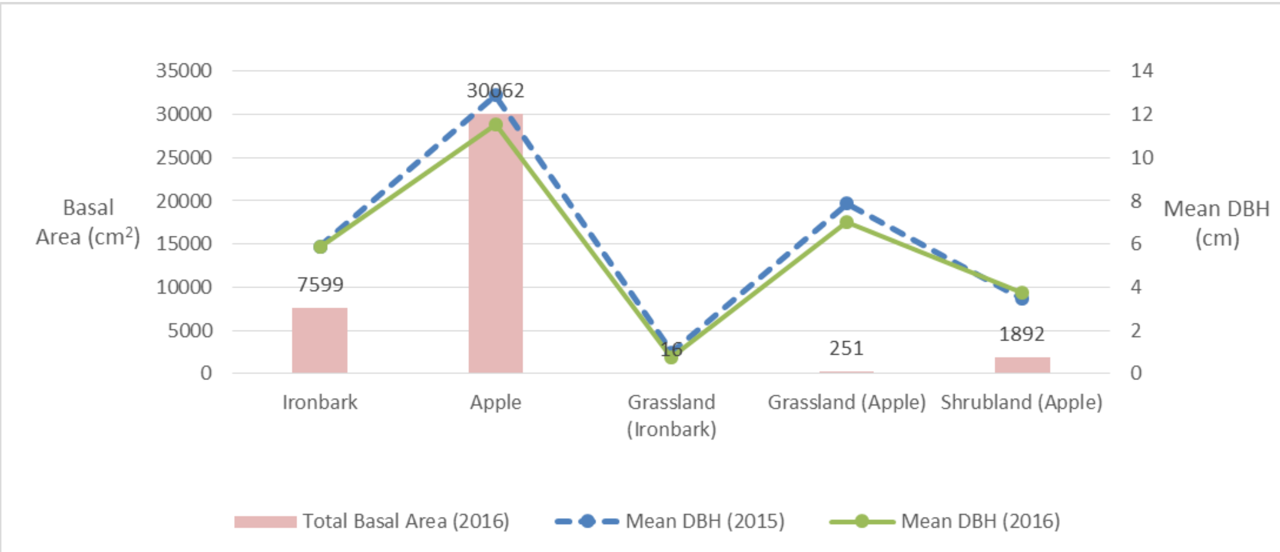


Figure 24 Total basal area (2016 data) and mean DBH (2015, 2016) of canopy stems for Ironbark MU (n=170, 175), Apple MU (n=135, 137), Grassland (Ironbark) MU (n=6, 10), Grassland (Apple) MU (n=4, 5), and Shrubland (Apple) MU (n=54, 50). Note that DBH of canopy specimens was not measured in 2017.

4.2.5 Shrub Composition & Structure

In total, four woody shrub species were present within study transects in Year 3 (Table 6), a reduction of one species from previous years. *Leucopogon muticus*, recorded as a single individual in 2015 has not been relocated since, while *Acacia falcata* was absent in 2017. Overall, *Brachyloma daphnoides* was the most abundant shrub species, but only in transect-pair WOL03 where it forms an important component of

Warkworth Sands Woodland: indeed, 90% of individuals were recorded within the regenerating shrubland of WOL03G. In keeping with previous years, no woody shrub species were present within the Ironbark transect-pair WOL02, but a single *Acacia filicifolia* was present in transect WOL01G for the first time.

Table 6 Number of stems of woody shrub species recorded across six transects in Year 3, shown in decreasing order of total abundance.

	Forest			Grassland		Shrubland	Total
Species	01F	02F	03F	01G	02G	03G	
Brachyloma daphnoides	0	0	24	0	0	218	242
Leptospermum polyanthum	0	0	0	0	0	82	82
Grevillea montana	0	0	0	0	0	10	10
Acacia filicifolia	3	0	8	1	0	0	12
Total	3	0	32	1	0	310	346

Figure 25 shows the change in average numbers of woody shrub stems per quadrat in each transect, 2015 to 2017. As in previous years, there is much variation between transects in relation to woody shrub species presence, with four transects out of the six supporting some species. The low standard errors returned for transect WOL03G (Apple Shrubland) shows consistency along the length of this transect within each monitoring year.

From a MU perspective, the 700 stems/ha for Apple and 12400 stems/ha for Shrubland (Apple) well exceed all other MUs (Table 7), but both show decreases from 2015 and 2016. Such reductions can be explained by senescence brought on by the dry conditions during Year 3, particularly for younger seedlings that more easily suffer from extreme water stress.

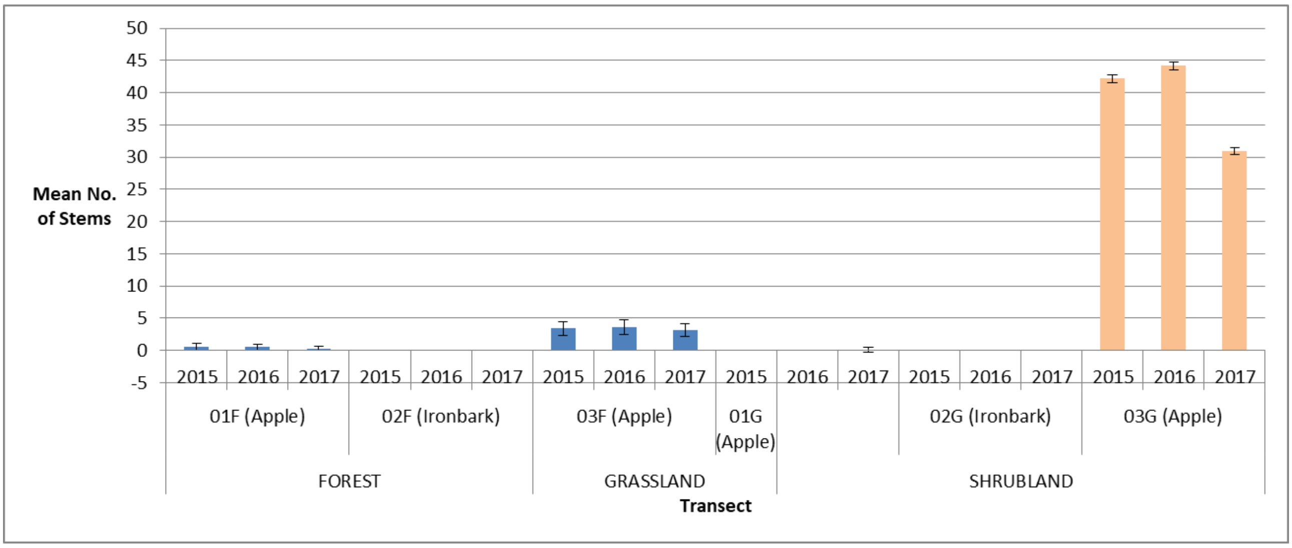


Figure 25 Change in mean number of woody shrub stems per quadrat for each transect from 2015 to 2017, with standard error values (n=10 for each transect).

Table 7 Change in number and density of woody shrub stems for all management units, 2015 to 2017.

Shrubs	Ironbark *		Grassland (Ironbark) *		Apple **		Grassland (Apple) *		Shrubland (Apple) *	
	Stems	Stems/ha	Stems	Stems/ha	Stems	Stems/ha	Stems	Stems/ha	Stems	Stems/ha
2015	0	0	0	0	40	800	0	0	422	16880
2016	0	0	0	0	41	820	0	0	442	17680
2017	0	0	0	0	35	700	1	40	310	12400
Change from 2015	0	0	0	0	-5	-100	+1	+40	-112	-4480
Change from 2016	0	0	0	0	-6	-120	+1	+40	-132	-5280

* n=10; ** n=20

For *Acacia* species, only the Apple and Apple (Grassland) MUs supported these important early colonizers of disturbed ground (Figure 26). The most significant change from earlier years was the appearance of a single *Acacia filicifolia* seedling within transect WOL01G, and the disappearance of *Acacia falcata* from transect WOL3F. Of the two *Acacia* species recorded within transects, *Acacia filicifolia* is the most abundant and is an important component of Warkworth Sands Woodland. Densities of 220 stems/ha were found for *Acacia filicifolia* in the Apple MU (remaining stable from previous years), while 40 stems/ha for this species were recorded in the Apple (Grassland) MU (Table 8).

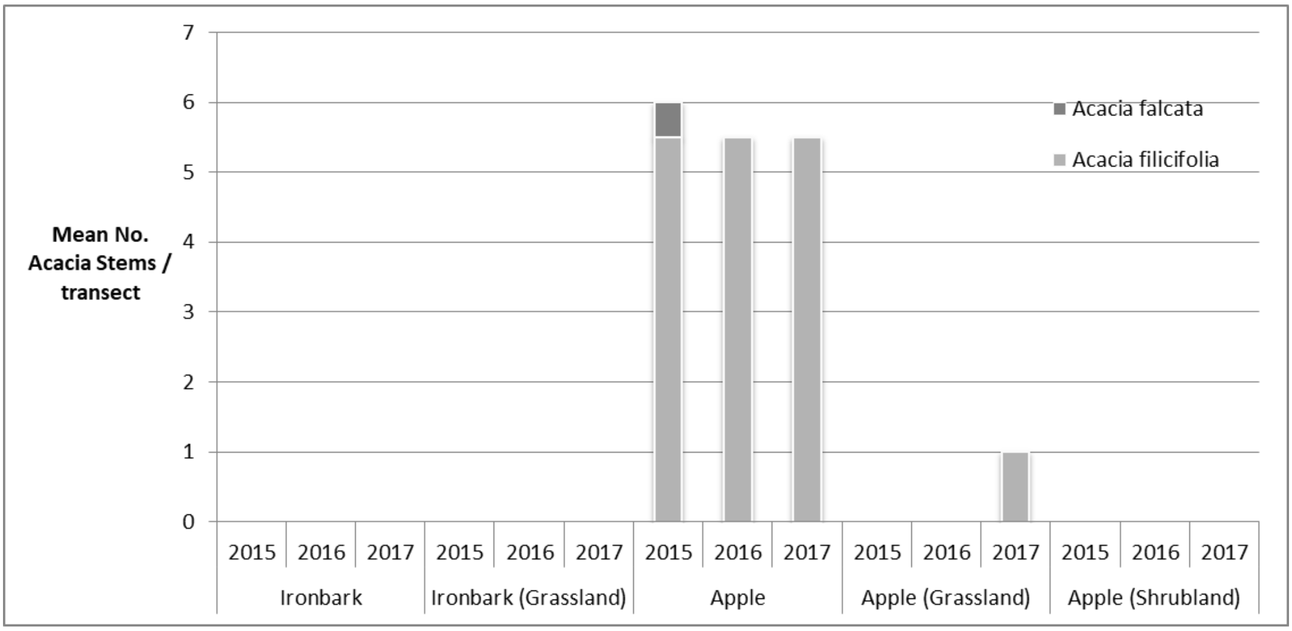


Figure 26 Change in number of *Acacia* stems per transect for each Management Unit, 2015 to 2017. Ironbark MU (n=0), Grassland (Ironbark) MU (n=0), Apple MU (n=12), Grassland (Apple) MU (n=0), and Shrubland (Apple) MU (n=0).

Table 8 Change in number and density of *Acacia* stems for all management units, 2015 to 2017.

Acacia spp	Ironbark		Grassland (Ironbark)		Apple		Grassland (Apple)		Shrubland (Apple)	
	Stems	/ha	Stems	/ha	Stems	/ha	Stems	/ha	Stems	/ha
A. filicifolia	0	0	0	0	11	220	1	40	0	0
A. falcata	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	11	220	1	40	0	0
Change from 2015	0	0	0	0	0	0	+1	+40	0	0
Change from 2016	0	0	0	0	-1	-20	+1	+40	0	0

4.2.6 Leaf Litter & Bare Ground

Percentage cover of leaf litter was significantly higher across all MUs during Year 3, explainable by the increased shedding of leaf material under prolonged drought conditions (Figure 27). Increased litter loads were most notable across Grassland and Shrubland MUs, which in previous years carried only minor amounts. Dead and dying *Banksia integrifolia* individuals within the Shrubland (Apple) MU contributed large amounts of litter in particular in this area. The poor growth of grasses and herbs under the dry conditions within Grassland MUs allowed the accumulation of leaf litter from surrounding forests to become more noticeable.

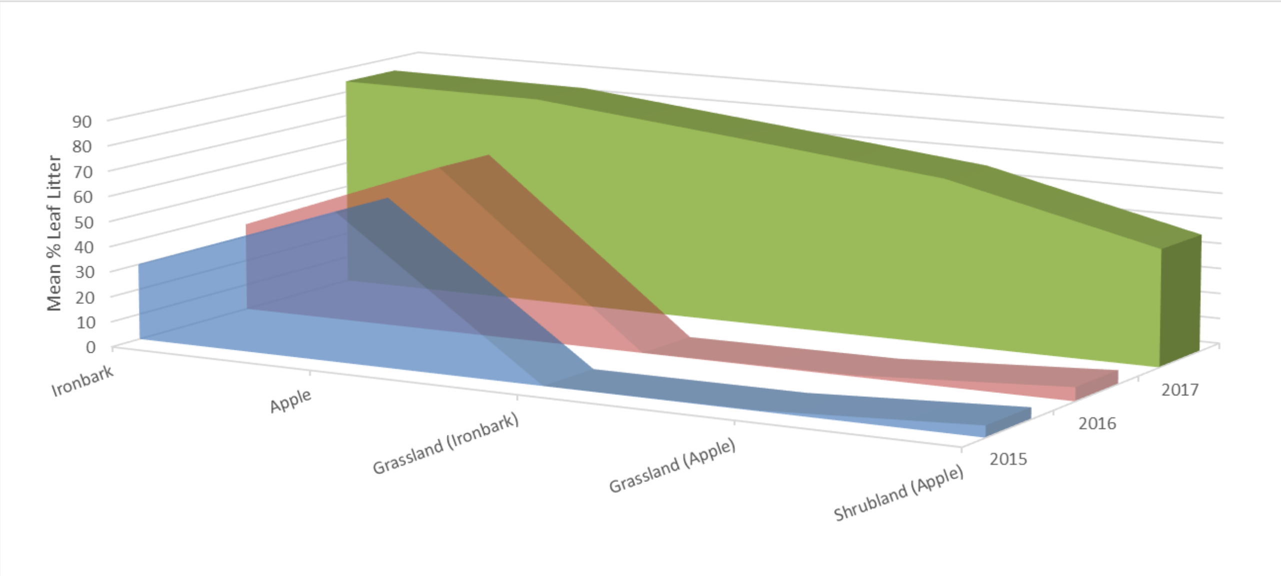


Figure 27 Change in mean leaf litter within management units from 2015 to 2017, expressed as estimated % cover, for the Ironbark MU (n=10), Apple MU (n=20), Grassland (Ironbark) MU (n=10), Grassland (Apple) MU (n=10), and Shrubland (Apple) (MU (n=10).

Percentage cover of bare ground increased over all MUs during Year 3, which again is related to the dry conditions and poor growth of ground layer species (Figure 28). There has been a reduction in the extent of bare areas within the Shrubland (Apple) MU, those areas likely now carrying excessive litter loads. Bare ground is a transient feature of the landscape, influenced by wind, dry conditions (leaf fall, lack of ground layer growth) and animal activity, but it does provide a broad indication of the extent of live plant material present on the ground from year to year.

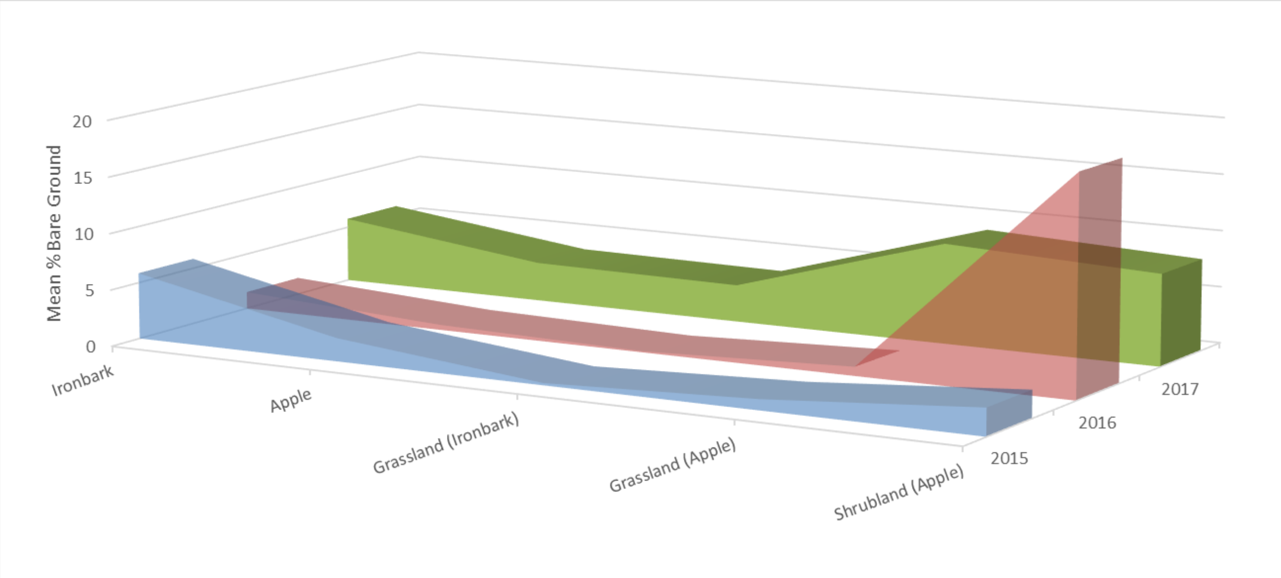


Figure 28 Change in mean extent of bare ground within management units from 2015 to 2017, expressed as estimated % cover, for the Ironbark MU (n=10), Apple MU (n=20), Grassland (Ironbark) MU (n=10), Grassland (Apple) MU (n=10), and Shrubland (Apple) (MU (n=10).

4.2.7 Biometric Data & Photopoints

Floristic data generated from the 20x20m quadrats placed at the ends of each transect for Year 3 are shown in Appendix 8.8.

Appendix A8.9 contains photos taken at the four cardinal points of the compass from the ends of each transect. For each transect-pair, these fall at the extremities of the combined 100m transect length.

4.3 Fauna

A total of 59 bird species were recorded at *Wollombi Brook* by census in 2017 (n = 54 in 2016 and 48 in 2015). Additional fauna recorded include 13 native and 2 introduced mammals. The full list of fauna species recorded on the *Wollombi Brook BOA* is listed further in Appendix A8.10.

4.3.1 Birds

The diurnal bird census recorded 59 bird species across the6 monitoring sites in 2017. Total bird species diversity, based on surveys for the 2015 - 2017 monitoring years, combined with previous records of the offset, is 115 bird species (n = 114 in 2016 and 108 in 2015). Notable observations for 2017 was the flowering of mistletoe at many of the monitoring sites, with several species of honeyeater present in June 2017. One new honeyeater species was detected in 2017, the Spiny-cheeked Honeyeater, which is more typically found in western parts of the Upper Hunter.

Simpson's Index was used to compare the *Wollombi Brook BOA* bird species diversity between fauna monitoring sites (Figure 29). Highest variability was recorded at Sites WB01, WB02 and WB04, with generally lower scores in winter compared to spring. Site WB05 scored the lowest diversity again in 2017. This is the least structurally diverse site with regard to vegetation, being dominated by regrowth Bulloak trees with open grassland. Site WB02 (Wollombi Brook) has consistently recorded the highest diversity of bird species, due to the range of habitats. This site is located along Wollombi Brook, thus containing both riparian River Oak trees and wetland / aquatic plant species, plus open forest / woodland immediately adjacent. This site provides a diverse range of strata for birds to forage and shelter, in comparison to other sites which support scattered paddock trees and grassy ground layer vegetation.

The performance target for *Wollombi Brook BOA*, based on diversity index scores for birds, will be for the regeneration sites (WB05) to achieve comparable mean scores to the remnant woodland sites (WB01 – WB04, and WB06).

Three threatened bird species were recorded in 2017, the Grey-crowned Babbler, Speckled Warbler and Varied Sittella. All three species have previously been recorded at *Wollombi Brook BOA* and are relatively widespread and common in the Upper Hunter Valley.

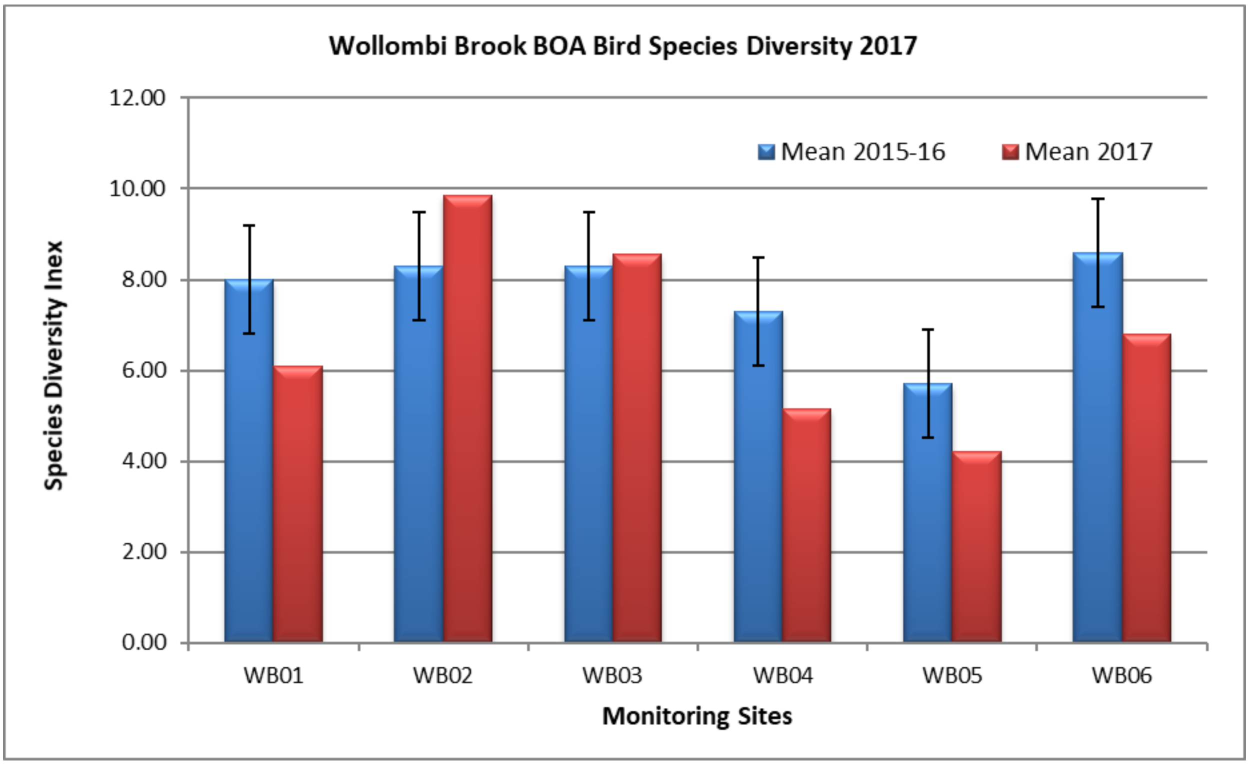


Figure 29 Bird Species Diversity in 2017, *Wollombi Brook BOA*. Vertical bars represent standard errors.

4.3.2 Mammals

Larger Mammals - Infra-red motion detection (or game) cameras were installed to monitor for presence of larger mammals at three monitoring sites, WB01, WB02 and WB03 in 2017. Images recorded include Eastern Grey Kangaroo, Red-necked Wallaby, Swamp Wallaby, Dingo / Dog, Fox and Brown Hare. Opportunistic observations of additional mammals include Swamp Wallaby and burrows of Common Wombat along Wollombi Brook. The Common Brushtail Possum was detected during spotlight searches at one site, WB04.

A summary of mammals recorded at *Wollombi Brook BOA* in 2017 is presented below in Table 9.

Table 9 Larger Mammals recorded in *Wollombi Brook BOA*, 2017.

Common Name	WB01	WB02	WB03	WB04	WB05	WB06
Common Brushtail Possum				3 spot		
Eastern Grey Kangaroo	observed	observed	1 photo	observed	observed	observed
Common Wombat		burrows				
Red-necked Wallaby			observed	1 photo		
Swamp Wallaby				1 photo		
Dog / Dingo			3 photo			
Fox			3 photo	1 photo		
Brown Hare	1 photo		3 photo			
Pig	diggings	diggings	diggings		diggings	

Note: Reference to 'photo' refers to detection of a species on 1 day. For instance, the Eastern Grey Kangaroo may have been detected by camera 20 times in one day, but results are summarised as species per day, not total images recorded.

Micro-chiropteran Bats - Echolocation calls recorded the presence of 8 bat species in 2017 (Table 10), with a total of 137 call sequences suitable for identification. This compares to 40 calls in 2016 and 106 calls recorded in 2015. Despite the number of sites sampled and time of year, the number of calls per species is considered very low for the survey effort. The most commonly recorded species was the threatened Eastern Freetail-bat. Factors which may influence the low species diversity and abundance of microbats at *Wollombi Brook BOA* is the very young age of the remnant forest and woodland. Very few habitat trees that contain hollows occur within the offset, which will limit the number of tree hollow dependent bat species. Bat activity was considered very low at Site WB02 (Wollombi Brook). Microbat activity is often very high around water bodies, as a source of drinking water but also higher insect activity. No evidence of the Large-footed Myotis has been detected at this site, despite being high quality habitat for the species.

Table 10 Microchiropteran bat echolocation calls, *Wollombi Brook BOA*, 2017.

Common Name	EPBC Act	BC Act	WB01	WB02	WB03	WB04	WB05	WB06	Total Calls
Eastcoast Freetail-bat		**V**	32 calls					58 calls	**90**
Southern Freetail-bat				20 calls		1 call		3 calls	24
White-striped Freetail-bat			1 call						1
Eastern Bent-wing Bat	**V**	**V**	1 call						**1**
Large-eared Pied Bat	**V**	**V**		1 call					**1**
Long-eared Bat			1 call		2 calls	1 call			4
Gould's Wattled Bat			8 call						8
Chocolate Wattled Bat			3 calls		6 calls				9
TOTAL CALLS			**46**	**21**	**8**	**2**	**0**	**61**	**138**

BOLD TEXT – listed as Threatened under national *Environment Protection & Biodiversity Conservation Act 1999 (EPBC Act)* or NSW *Biodiversity Conservation Act 2016 (BC Act).*

4.3.3 Opportunistic Observations

Frog activity was very low during surveys in 2017, attributed to the very low rainfall recorded over the period. A farm dam near site WB02 was completely dry, with only 3 species heard calling along Wollombi Brook, including the Eastern Dwarf Tree Frog *Litoria fallax,* Whistling Tree Frog *Litoria verreauxii* and Common Eastern Froglet *Crinia signifera.*

4.3.4 Threatened Fauna

Six threatened species were recorded during the 2017 monitoring surveys at *Wollombi Brook* (Figure 30, Table 11). An additional 7 threatened fauna have been recorded at *Wollombi Brook BOA* from previous monitoring surveys and the Bulga Coal EIS (Umwelt 2013). A list of all threatened fauna recorded at *Wollombi Brook BOA* are included in Table 11.

Table 11 Threatened fauna recorded at *Wollombi Brook BOA,* 2017.

Common Name	Scientific Name	EPBC Act	BC Act	Site Recorded	Method
Grey-crowned Babbler	*Pomatostomus temporalis*		V	WB01 - WB05	Census
Speckled Warbler	*Chthonicola sagittata*		V	WB02,04,06	Census
Varied Sittella	*Daphoenositta chrysoptera*		V	WB04	Census
Eastern Freetail Bat	*Micronomus norfolcensis*		V	WB01,06	Anabat
Large-eared Pied Bat	*Chalinolobus dwyeri*	V	V	WB02	Anabat
Eastern Bent-wing Bat	*Miniopterus schreibersii oceanensis*	V	V	WB01, WB04	Anabat
Previous Records		**EPBC Act**	**BC Act**	**Site**	**Year**
Little Eagle	*Hieraaetus morphnoides*		V	WB04	Umwelt 2013
Little Lorikeet	*Glossopsitta pusilla*		V	WB06	Umwelt 2013
Hooded Robin	*Melanodryas cucullata*		V	WB01	Census
Scarlet Robin	*Petroica boodang*		V	WB05,WB06	census
Diamond Firetail	*Stagonopleura guttata*		V	WB06	Umwelt 2013
Squirrel Glider	*Petaurus norfolcensis*		V	WB06	Spotlight
Eastern Cave Bat	*Vespadelus troughtoni*	V	V	WB03	Umwelt 2013

Note: Status refers to threatened status under the national *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or NSW *Biodiversity Conservation Act 2016* (BC Act). **E –** Endangered; **V –** Vulnerable.

4.3.5 EPBC Act Listed Fauna (Regent Honeyeater, Swift Parrot, Large-eared Pied Bat)

No evidence of the presence of the threatened Regent Honeyeater or Swift Parrot was recorded by diurnal bird census surveys conducted in June, August and November 2017. No evidence of either species has been detected since monitoring surveys commenced in 2015, despite very heavy flowering of eucalypt trees, particularly Slaty Red Gum and Spotted Gum in 2015 in particular (Table 12).

Table 12 Habitat Assessment (Swift Parrot , Regent Honeyeater), *Wollombi Brook BOA,* 2017.

Habitat Feature	12 June 2017	11 August 2017	7 November 2017
Presence of Pollen / Nectar	Low	Low	None
Eucalyptus crebra	Low	None	None
Eucalyptus molucanna	None	None	None
Corymbia maculata	Low	Low	None
Eucalyptus glaucina	Low	None	None
Presence of Mistletoe	Moderate	Low abundance	Low abundance
Presence of Swift Parrot	No	No	No
Presence of Regent Honeyeater	No	No	No

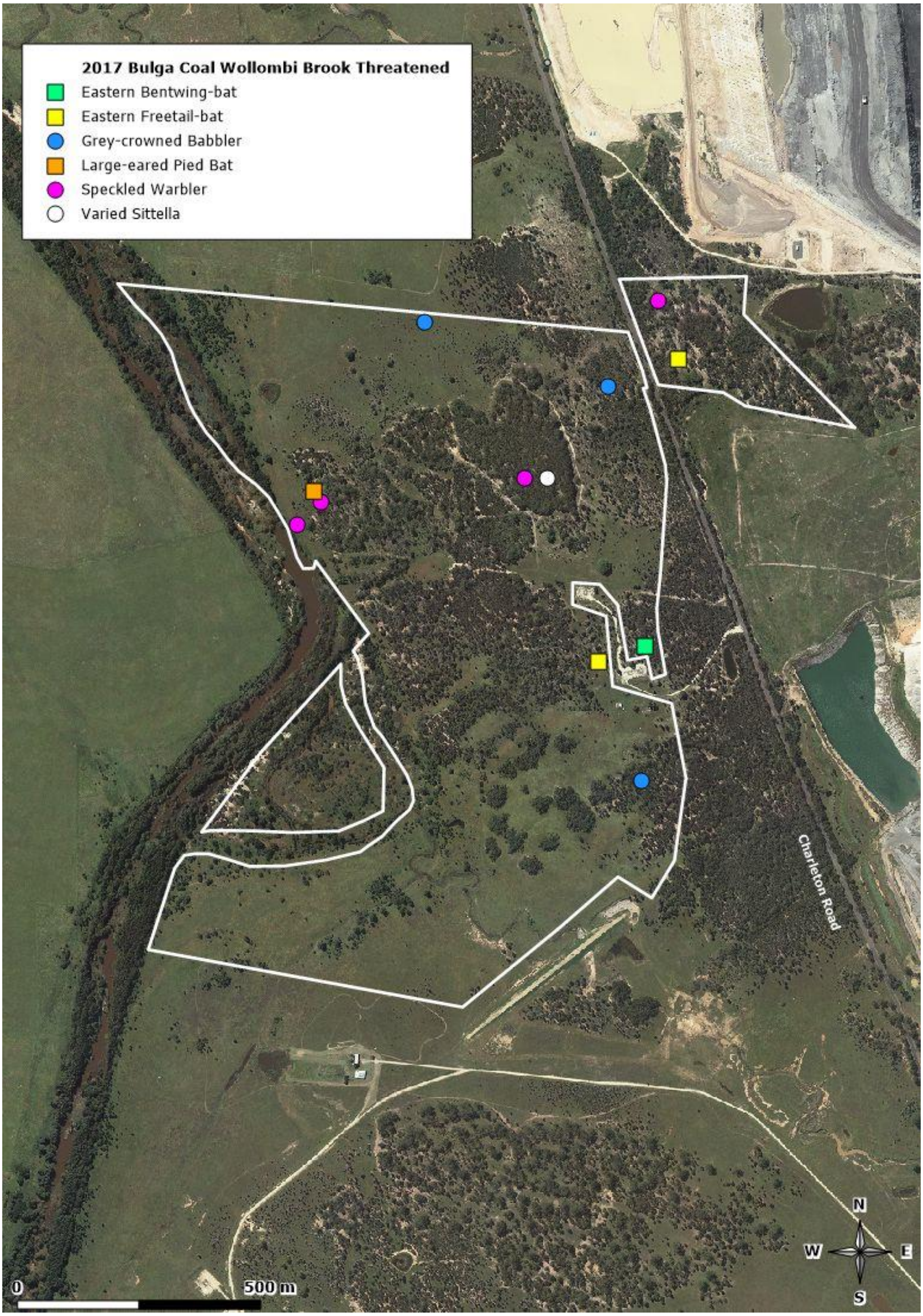


Figure 30 Threatened fauna recorded at *Wollombi Brook BOA*, 2017.

During the 2017 monitoring period, flowering was evident on a small number of narrow and broad-leaved ironbark and slaty gum eucalypts. The abundance of flowers was low in June and absent by August and November. Mistletoe was widespread across the BOA in flower in August and November 2017.

The Swift Parrot was originally found in high numbers within the Hunter Valley at the Singleton Training Range (Thomson and Murray, 2006). Since this discovery, the site has regularly recorded the species. In 2017, the Swift Parrot was recorded in low numbers across scattered locations in NSW (Ingwersen *et. al.,* 2017). The largest concentration of Swift Parrots in the NSW was recorded in the Ellalong – Pelton area south of Cessnock, when 200+ birds were found in mid-May.

Despite the *Wollombi Brook BOA* being in close proximity to the Singleton Training Range, no evidence of the Swift Parrot has been recorded since commencement of monitoring. This may be a reflection of limited foraging resources compared to more extensive remnants in the locality, or timing of surveys not coinciding with their presence.

The Regent Honeyeater was recorded in very low numbers in the Hunter Valley in 2017 (Ingwersen *et. al.,* 2017). The highest concentration of sightings was near Pokolbin in the Lower Hunter Valley, where flocks of up to 20 birds were observed. Preferred habitat for the Regent Honeyeater at *Wollombi Brook BOA* is the River Oaks lining the banks of Wollombi Brook, where the species is known to breed on flowering mistletoe.

For the Large-eared Pied Bat, it's occurrence at *Wollombi Brook BOA* is restricted to foraging in the aerial space above and within the offset. The species roosts in caves or similar structures, none of which is present at *Wollombi Brook BOA*. The species was detected at one site in 2017 (WB02). Surveys of the nearby Singleton Training Range in 2005 captured a number of individuals of this species, and was commonly recorded by Anabat detection (Thomson and Murray, 2006). The nearby sandstone caves and rock outcrops within Wollemi National Park are likely to provide roost and breeding sites for the species.

4.4 Ecological Thinning Trial

As detailed in Bell (2016), two thinning zones were stablished for the ecological thinning trials, one in an area of 0.4 ha dominated by Bulloak and the other of 0.6 ha where Tea-tree forms dense stands. Four quadrats (5x5m) were established within these thinning zones (Bulloak: BU_THIN01, BU_THIN02; Tea-tree: TI_THIN01, TI_THIN02), four within nearby areas of similar densities of the target thinning species (Bulloak: BU_UNTH01, BU_UNTH02; Tea-tree: TI_UNTH01, TI_UNTH02), and four within nearby reference sites where target species were absent or in very low abundance (Bulloak: BU_TARG01, BU_TARG02; Tea-tree: TI_TARG01, TI_TARG02). Floristic (cover abundance) and basic structural data were collected from each quadrat.

Baseline floristic survey (in July 2016) of these twelve quadrats showed a total diversity of 47 native and 10 weed species. Re-survey of these quadrats was undertaken in November 2016 (~4 months after thinning; 53 natives & 9 weeds), and then again in November 2017 (16 months after thinning; 63 natives & 11 weeds). Over the sixteen months of this experiment, there has been a collective increase of 16 native species (a 34% increase on baseline data) and 1 weed species, although it is not possible to determine what proportion of this is due to the thinning process and what may be explainable by climate variability. However, given the dry conditions experienced during 2017 it seems likely that the thinning process is the primary cause rather than climate. Only very limited resprouting of cut Bulloak and none of Ti-tree was noted in treated areas, and no new germinates of those two species have yet been detected.

Comparative analysis of baseline data with that collected 4 and 16 months post-thinning showed little observable change in dominant species and floristic associations between treated and untreated quadrats, which is not surprising as there is little overall biomass present (Figures 31 – 32). More informative is the tracking of mean native and weed species within the respective treatments groups (Figures 33 – 34). From Figure 33, it can be seen that an increase in mean native species diversity is evident for the Ti-tree thinning. Over the same period the unthinned and target controls for this group, after an initial increase in diversity (perhaps correlating to the arrival of Spring), remained static or experienced a decrease in diversity. Relatively small changes were evident in weed species diversity, with an initial increase following thinning leading to a decrease. In the Bulloak trial, native species diversity increased immediately following thinning and then remained static (Figure 34). Over the same period, unthinned quadrats showed a decrease then sizeable increase in diversity, while a continual increase was evident in the target quadrats. Weeds in general showed a gradual decrease in diversity during this period. With continual annual monitoring, it is hoped that the influence of climate can be differentiated more conclusively from the effects of thinning.

Fresh germinates of some key shrub species (*Acacia filicifolia, Grevillea montana, Pimelea linifolia*) were evident in the Ti-tree thinning area, which is encouraging for the return of Warkworth Sands Woodland.

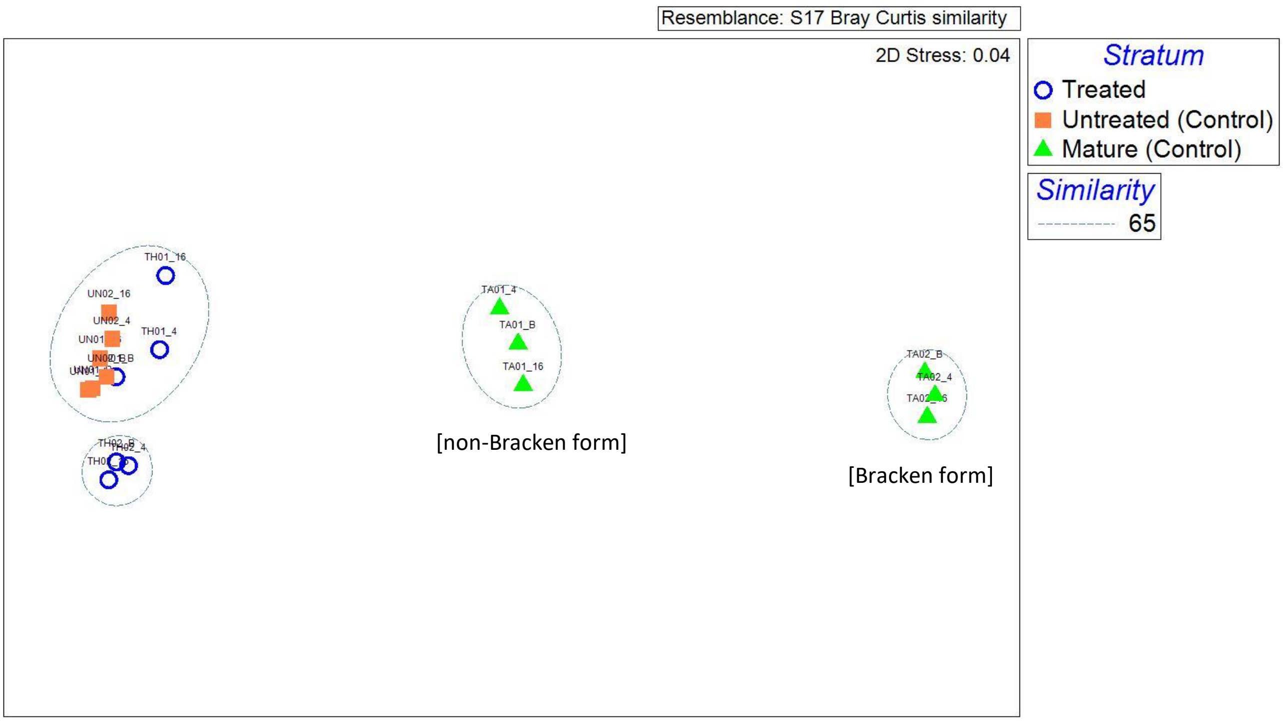


Figure 31 Ti-tree thinning trial, nMDS ordination of floristic data from baseline (_B) and post-thinning (_4: 4 months after thinning; _16: 16 months after thinning). TH = thinned; UN = unthinned control; TA = target mature control. Stress = 0.04, p<0.01 at 65% similarity.

Figure 32 Bulloak thinning trial (Ironbark form), nMDS ordination of floristic data from baseline (_B) and post-thinning (_4: 4 months after thinning; _16: 16 months after thinning). TH = thinned; UN = unthinned control; TA = target mature control. Stress = 0.01, p<0.01 at 64% similarity.

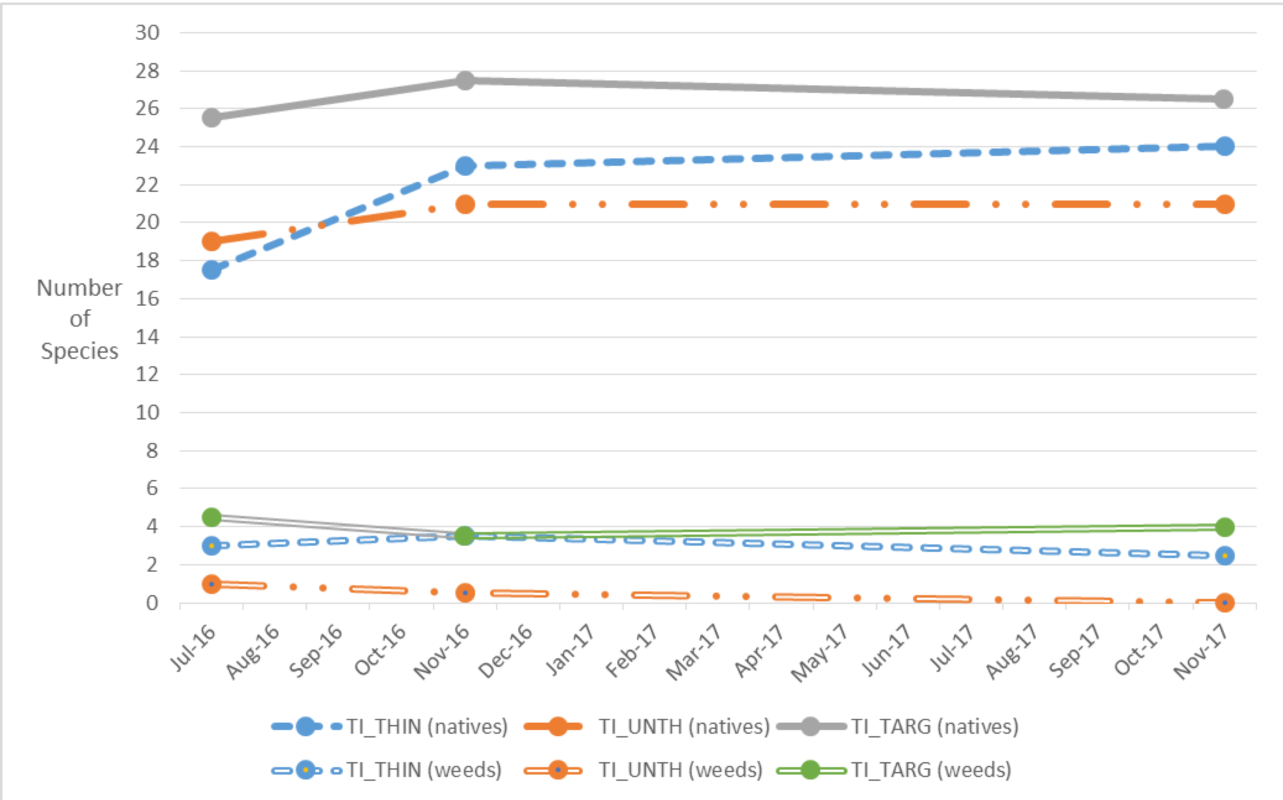


Figure 33 Change in mean floristic composition of native (upper) and weed (lower) species 16 months post-thinning of *Leptospermum polyanthum*. TI_THIN = thinned; TI_UNTH = unthinned; TI_TARG = target. Baseline data (pre-thinning) collected July 2016; post-thinning data collected November 2016 & November 2017 (n=2 for each treatment).

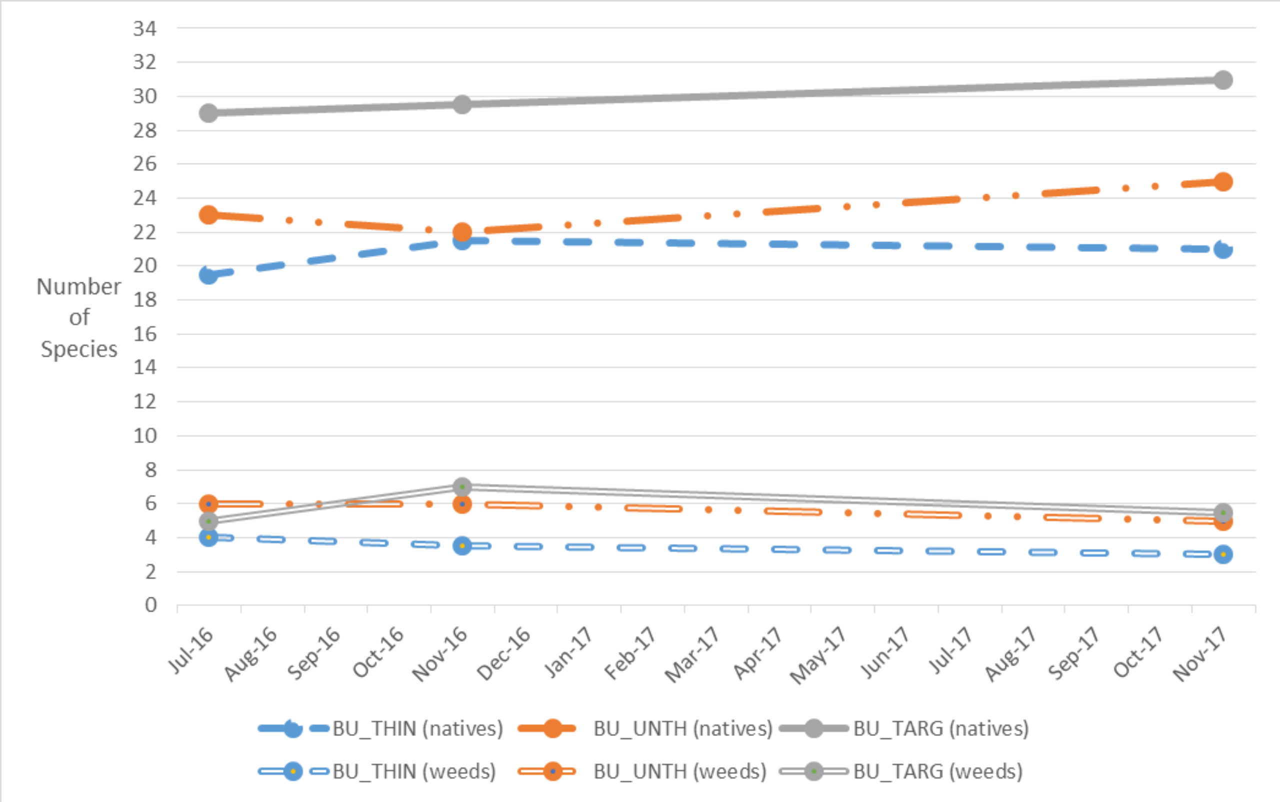


Figure 34 Change in mean floristic composition of native (upper) and weed (lower) species 16 months post-thinning of *Allocasuarina luehmannii*. BU_THIN = thinned; BU_UNTH = unthinned; BU_TARG = target. Baseline data (pre-thinning) collected July 2016; post-thinning data collected November 2016 & November 2017 (n=2 for each treatment).

5. Discussion

The *Wollombi Brook* BOMP (in Sections 4 & 5) outlines the scope of the flora and fauna monitoring program, which includes an assessment of ongoing management and improvement strategies. The preliminary long term management targets for *Wollombi Brook* is the "*regeneration and revegetation of derived native grasslands into woodland vegetation*", with at least 10 ha of Warkworth Sands Woodland EEC and 16 ha of Central Hunter Grey Box – Ironbark Woodland EEC being specified. Performance indicators are outlined in Section 4.1 of the BOMP to monitor the success of the ongoing management of the BOA. One indicator is that "*the native forest areas are maintaining similar or increasing flora and fauna species diversity*". Monitoring of flora and fauna populations conducted to date allows for this performance indicator to be assessed.

5.1 Flora Summary

Monitoring of vegetation at *Wollombi Brook*, accomplished primarily through the collection of replicated quantitative data, has now been undertaken for three consecutive years. Data on species diversity, threatened taxa, weed prevalence and distribution, canopy and shrub composition and structure, and ground cover attributes have been documented and graphed, and have been compared and illustrated against 2015 and 2016 results.

By way of summary, Table 13 collates the results of all attributes measured across six 50m transects during 2015, 2016 and 2017. Ironbark and Apple MUs have been categorized into 'benchmark' data, while Grassland (Ironbark & Apple) and Shrubland (Apple) MUs are considered 'regenerating'. The following key points can be extracted from this table in relation to baseline data collected during the Year 3 monitoring period:

- mean overall species diversity is 36.6 species per management unit, ranging from 29 in Shrubland (Apple) MU to 43 in Ironbark MU. Weed species range from 14% of all species in Shrubland (Apple) to 46.9% in Grassland (Apple), with only slight changes on 2016 data;
- basal area of canopy species was not measured in 2017, however based on 2016 data this attribute ranges from 16 cm^2 in Grassland (Ironbark) to 30,062 cm^2 in the Apple MU, with all but the Apple and Shrubland (Apple) MUs;
- mean DBH of canopy species was not measured in 2017, however based on 2016 data this attribute ranges from 0.75 cm in Grassland (Ironbark) to 11.56 cm in the Apple MU;
- canopy stem density reduced across all MUs in 2017, ranging from a low in Grassland MUs (0 and 60 stems/ha) to considerably higher numbers in Shrubland (500 stems/ha), Apple (1340 stems/ha) and Ironbark (1680 stems/ha). Dramatic decreases are likely related to water stress on young plants following drought conditions, coupled with grazing by resident macropods and rabbits;
- woody shrubs are generally absent, with the exception of the Apple (700 stems/ha) and Shrubland (12,400 stems/ha) MUs, but both showing a decrease on 2016 data;
- similarly the total number of *Acacia* stems is very low across all MUs, with only 220 stems/ha evident in the Apple MU, and 40 stems/ha for the Grassland (Apple) MU;

Table 13 Summary attributes for 'benchmark' and 'regenerating' management units from 2015 to 2017, based on transect and quadrat data.

	Category:	*'Benchmark'*		*'Regenerating'*		
	Management Unit:	**Ironbark**	**Apple**	**Grassland (Ironbark)**	**Grassland (Apple)**	**Shrubland (Apple)**
Mean species diversity	total (2015)	41	38	41	39	33
	(2016)	40	43	45	38	35
	(2017)	43	38	41	32	29
	native (%) (2015)	29 (70.7)	28 (73.7)	22 (53.7)	19 (48.7)	28 (84.9)
	(2016)	32 (80.0)	29 (67.4)	25 (55.6)	17 (44.7)	27 (77.1)
	(2017)	32 (74.4)	28 (73.7)	24 (58.5)	17 (53.1)	25 (86.2)
	weeds (%) (2015)	12 (29.3)	10 (26.3)	19 (46.3)	20 (51.3)	5 (15.1)
	(2016)	8 (20.0)	14 (32.6)	20 (44.4)	21 (55.3)	8 (22.9)
	(2017)	11 (25.6)	10 (26.3)	17 (41.5)	15 (46.9)	4 (13.8)
Canopy	basal area (cm^2) (2015)	7052	33359	11	201	1830
	(2016)	7599	30062	16	251	1892
	(2017)	-	-	-	-	-
	mean DBH (cm) (2015)	5.89	12.88	0.98	7.88	3.47
	(2016)	5.88	11.56	0.75	7.03	3.77
	(2017)	-	-	-	-	-
Density	Canopy (stems/ha) (2015)	3420	2700	120	80	1080
	(2016)	3500	2760	200	100	1020
	(2017)	1680	1340	60	0	500
	Woody shrubs (stems/ha) (2015)	0	800	0	0	16880
	(2016)	0	820	0	0	17680
	(2017)	0	700	0	40	12400
	Acacia stems (stems/ha) (2015)	0	240	0	0	0
	(2016)	0	240	0	0	0
	(2017)	0	220	0	40	0
Weed cover	(mean %) (2015)	0.5	1.7	43.4	88.2	0.3
	(2016)	0.5	3.2	77.7	93.1	0.7
	(2017)	0.3	0.7	1.8	19.3	0.2
Leaf litter cover	(mean %) (2015)	30.1	59.2	0.1	0.3	4.5
	(2016)	35.0	66.0	0.1	0.6	5.4
	(2017)	84.5	83.8	75.1	66.1	46.3
Bare ground cover	(mean %) (2015)	5.6	2.1	0.2	1.0	2.4
	(2016)	1.5	0.5	0.1	0.8	19.3
	(2017)	5.8	3.5	3.3	8.9	8.1

- percentage cover of weed species ranges from minimal in Ironbark, Apple, Grassland (Ironbark) and Shrubland MUs (all <2% cover) to moderate in the Grassland (Apple) MU (19.3% cover). All MUs showed a decrease from 2016 data, likely attributable to the dry conditions;
- the invasive exotic species *Melinis repens, Panicum coloratum* var*. coloratum, Richardia brasiliensis* and *Richardia stellaris* are common in several transects, and may require management in future years to restrict spread;
- monitoring of the ecological thinning trial of native invasive woody shrubs *Leptospermum polyanthum* and *Allocasuarina luehmannii* has shown only minor change in floristic composition after 16 months, but species such as *Hibbertia* are visibly more prevalent;
- estimated leaf litter cover increased in 2017, ranging from 46.3% in Shrubland (Apple) to 84.5% in Ironbark. Dramatic increases from earlier years are likely a reflection of the dry climatic conditions and canopy leaf shedding as a result of this;
- estimated bare ground also increased in 2017, but remains at <10% cover, again a likely reflection of dry climatic conditions and limited growth of ground layer species.

5.2 Fauna Summary

A total of 59 bird species were recorded at *Wollombi Brook* by census in 2017, which is an increase in diversity over previous monitoring years. Comparison of bird species diversity between sites revealed 2 sites exceeded the average annual score, whilst the remaining 4 sites were significantly lower than the annual average. Total bird species diversity, based on surveys for the 2015 - 2017 monitoring years, combined with previous records of the Bulga Coal operation, has recorded a total of 115 bird species. In 2017, three threatened bird species were recorded, the Grey-crowned Babbler, Speckled Warbler and Varied Sittella. All three species have previously been recorded at *Wollombi Brook BOA* and are relatively widespread and common in the upper Hunter Valley.

Echolocation calls recorded the presence of 8 bat species in 2017, with a total of 138 calls suitable for identification. Microbat activity was low in 2017, possibly influenced by the dry conditions experienced over the period June to November. The low abundance of natural tree hollows within the BOA may influence species diversity and abundance, and activity along Wollombi Brook was low, despite appearing high quality habitat for microbats.

Frog activity was very low in 2017, with only three species detected. A small dam near Wollombi Brook was dry due to absence of rainfall over the period June to November. This small dam typically supported a number of frog species, several of which were not detected in 2017.

Six threatened species were recorded in *Wollombi Brook BOA* in 2017 at *Wollombi Brook*. The use of remote cameras did not detect high introduced predator / species at Wollombi Brook in 2017. The Fox and wild dog / dingo were only detected on a small number of days, despite monitoring extending over a period of 153 consecutive days.

5.3 Progress Against Performance Indicators

The Biodiversity Offset Management Plan (BOMP) for *Wollombi Brook* includes a list of preliminary performance indicators that are to be used to assess the performance of the offset lands within the first three years of implementation. Table 14 addresses these indicators following the third year of monitoring at *Wollombi Brook*.

6. Future Management

6.1 Invasive Shrubs, Grasses & Herbs

Three key invasive grass species (*Eragrostis curvula, Melinis repens* & *Panicum coloratum* var. *coloratum*) and several exotic herbs will require ongoing monitoring and management at *Wollombi Brook*, as their persistence and spread within the BOA may adversely affect the biodiversity value of existing and regenerating endangered ecological communities. Red Natal Grass (*Melinis repens*) in particular remains well established in and around Warkworth Sands Woodland, and has the ability to continue spreading across previously disturbed lands. Stokes (2010) found that control of *Melinis repens* using herbicides was problematic due to differing responses during pre- and post-emergence from the soil. A range of herbicides were tested in her Florida study, but none were found to comprehensively control the species without negatively impacting on native taxa. In Western Australia, control of this species has been suggested as follows: Spray 13 ml/L (6.5 L/ha) Fusilade® Forte + wetting agent or for generic fluazifop-p (212g/L active ingredient) 8ml/L or 4L/ha + wetting agent. In less sensitive areas spot spraying of glyphosate at 1-2% solution + surfactant prior to flowering and seed set. Application of herbicides following fire events is an optimum time to undertake control of populations (https://florabase.dpaw.wa.gov.au/browse/profile/14985).

Lindsay & Cunningham (2012) have shown how exotic grass species impact on grassy woodlands such as those in the Hunter Valley. However, other exotic grasses and herbs present within the BOA will be difficult to manage. There are currently no registered herbicides to control Mexican Clovers (*Richardia* spp), and these species may persist until shaded out by shrub and canopy regeneration. Coolah Grass (*Panicum coloratum* var. *coloratum*) may best be controlled by spot application of herbicide, but it is likely that this species will persist in former grazing lands with improved pastures. Invasion of native grassy ecosystems by invasive exotic grasses is a key threatening process on the NSW *Biodiversity Conservation Act 2016,* requiring the NSW Government to prepare a Threat Abatement Plan.

During the 2017 monitoring period, deposits of European Olive (*Olea eurpaea* subsp. *cuspidata*) seeds were observed within one of the thinning trial monitoring plots (Figure 35). These appear to have arrived in a faunal faecal pellet, and their fate should be monitored in subsequent monitoring events.

6.2 Invasive Native Shrub Thinning

The native woody shrub *Leptospermum polyanthum* is currently present in dense stands within regenerating Warkworth Sands Woodland near transect-pair WOL03, and during 2016 a trial thinning experiment was initiated (Section 4.4). This species is not a natural component of this EEC, and it is suggested that ongoing removal will be required to avoid detrimental impact on this community. However, it would be sensible to postpone any further thinning in this area until at least 3 years post-thinning (~July 2019), so that more conclusive results can be determined and continuing positive restoration trends are evident.

Table 14 Progress against preliminary performance indicators after three monitoring years, *Wollombi Brook* BOA.

	Performance Indicator	Progress	Comments
1	*An appropriate long-term land conservation mechanism for the BOA is agreed upon in consultation with the relevant authorities*	√	-
2	*All boundary fences are in place and reports of unauthorised access to the BOA are addressed as soon as practical*	*X*	Fencing and gates have been installed. Access remains along a Crown road reserve to Wollombi Brook, but in 2017 damage to this fence has allowed unauthorised access into the BOA.
3	*There are no livestock grazing activities within the boundaries of the BOA (except where required for ecological restoration purposes. i.e. weed control)*	√	All livestock have been removed.
4	*Monitoring indicates that natural regeneration of the DNG is occurring and that the natural regeneration zones:*		
	(a) contain a flora species assemblage trending towards the target native woodland communities;	√	2017 monitoring data suggests a continuing positive trend.
	(b) include a range of flora species from each vegetation strata represented in the target community (such as trees, shrubs, and ground cover forbs and grasses), even if only as seedlings initially; and	√	Regenerating WSW in particular shows good recruitment of canopy and shrub species, although this has been tempered by recent dry conditions.
	(c) support no more than 20 per cent foliage cover of perennial weed species (as a total of all strata, based on monitoring plot data)	*X*	Weed cover is minimal in Forest and Shrubland (<1%), but more extensive in Grassland MUs (up to 20%, higher in good years). Perennial exotic grasses should decline over time.
5	*Monitoring indicates that remnant woodland areas are maintaining similar or increasing flora and fauna species diversity;*	√	After three years of monitoring, species diversity is being maintained, or changing in response to varying climatic conditions.
6	*There is no evidence of significant pest animal or weed infestation within the BOA that is adversely affecting the quality of existing or regenerating vegetation;*	*X*	2017 monitoring revealed low feral animal activity, but several weed and invasive native plant species require ongoing management.
7	*It can be demonstrated that accurate records are being maintained substantiating all activities and monitoring associated with the BOMP.*	√	This report documents results from the third year of monitoring.

Figure 35 Seeds of European Olive (*Olea europaea* subsp. *cuspidata*) deposited in monitoring plot BU_TARG01 by unknown fauna.

Bulloak (*Allocasuarina luehmannii*) will also require ongoing thinning in some parts of the BOA, but again it would be prudent to await assessment of monitoring results approximately 3 years post-thinning. The BOMP recommends and outlines a method for the thinning of Bulloak within *Wollombi Brook*, which has been followed to date during the thinning trial. This process of progressive thinning and poisoning of cut stumps should be continued when positive restoration trends are evident from monitoring of the trial experiment.

6.3 Canopy Thinning

Based on data collected to date, the Ironbark management unit supports 1680 stems per hectare, while the Apple management unit supports in excess of 1300 stems per hectare (both decreasing from 2015 and 2016 data). For Ironbark, this equates to 1 stem per $6m^2$ of ground, while for Apple it is 1 stem per $8m^2$. Both of these values well exceed the ideal goal for grassy woodlands, which is more in the vicinity of 1 stem per $100m^2$ (100 stems per hectare) or greater. Consequently, there will come a time when some canopy thinning from the developing forests at *Wollombi Brook* would be desirable, so that the restored woodland more accurately reflects original vegetation patterns. This could perhaps initially be trialed over a smaller area in coming years, with the subsequent changes documented in monitoring programs.

6.4 Fence Repair

Regular illegal access into the *Wollombi Brook BOA* appears to have been occurring for some time off the existing Crown road reserve, where cut fencing approximately 50m east of the existing gate was observed. This should be repaired as soon as possible, and more regular patrols of the BOA undertaken to detect such breaches earlier. The use of security cameras may deter future damage to fencing and gates along the boundary.

6.5 Pest Species

Feral animal presence, as determined by remote camera monitoring and observations, detected four species in 2017, wild dog / dingo, Fox, Brown Hare and Pig. Evidence of feral pig diggings are widespread across the *Wollombi Brook BOA*.

Current and previous fauna monitoring surveys, including longer term monitoring by remote cameras, have indicated pest fauna species (with the exception of pigs) are not abundant on the *Wollombi Brook BOA*. The low abundance of pest species, particularly feral predators, may either be attributed to effective baiting programs, or low natural abundance across the landscape.

One of the preliminary short term management targets for *Wollombi Brook* is management of weed and pest species. The results of the 2017 monitoring suggest that the presence of introduced pest animals is low. Those that may occur at *Wollombi Brook* will be wide-ranging and contiguous with the wider landscape. However, targeted intensive management could be undertaken periodically (i.e. every couple of years) to reduce pest species to lower levels, or more regular program if damage to replanting / reafforestation activities are impacted.

6.6 Habitat Augmentation for Threatened Fauna

Section 3.7 of the BOMP (Active Revegetation and Habitat Augmentation) refers to measures in revegetation management zones to provide important features, particularly for the Regent Honeyeater, Swift Parrot and Large-eared Pied Bat. For the Regent Honeyeater and Swift Parrot, habitat augmentation measures would be restricted to revegetation and natural regeneration of Central Hunter Grey Box – Ironbark DNG woodland vegetation. The inclusion of specific winter flowering eucalypts, particularly Slaty Gum and Narrow-leaved Ironbark, would provide an important nectar and pollen resource for both species. Another habitat augmentation measure to increase the extent of Central Hunter Grey Box – Ironbark DNG should include restriction on the regeneration of Bulloak (*Allocasuarina luehmannii*) within the offset.

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8. Appendices

A8.1 Quadrat Photographs – Transect WOL01F (2017)

A8.2 Quadrat Photographs – Transect WOL01G (2017)

A8.3 Quadrat Photographs – Transect WOL02F (2017)

A8.4 Quadrat Photographs – Transect WOL02G (2017)

A8.5 Quadrat Photographs – Transect WOL03F (2017)

A8.6 Quadrat Photographs – Transect WOL03G (2017)

A8.7 Flora Species List (2017)

A8.8 Photopoint Monitoring

A8.9 Fauna Species List (2017)

A8.1 Quadrat Photographs - Transect WOL01F (2017)


WOL01F - Quadrat 1


WOL01F - Quadrat 2


WOL01F - Quadrat 3


WOL01F - Quadrat 4


WOL01F - Quadrat 5


WOL01F - Quadrat 6


WOL01F - Quadrat 7


WOL01F - Quadrat 8


WOL01F - Quadrat 9


WOL01F - Quadrat 10

A8.2 Quadrat Photographs - Transect WOL01G (2017)


WOL01G - Quadrat 1


WOL01G - Quadrat 2

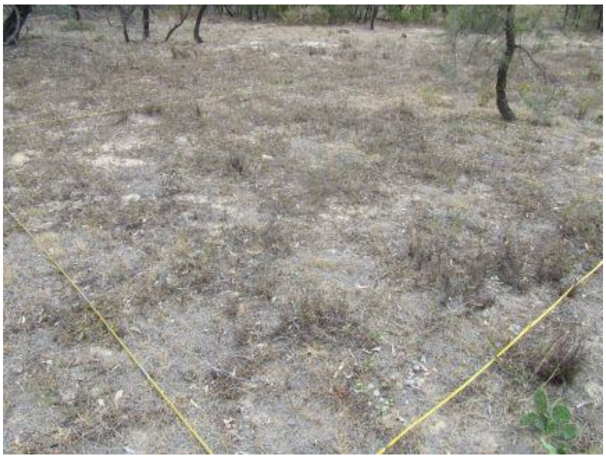

WOL01G - Quadrat 3


WOL01G - Quadrat 4


WOL01G - Quadrat 5


WOL01G - Quadrat 6

WOL01G - Quadrat 7



WOL01G - Quadrat 8

WOL01G - Quadrat 9

WOL01G - Quadrat 10

A8.3 Quadrat Photographs - Transect WOL02F (2017)

WOL02F - Quadrat 1

WOL02F - Quadrat 2

WOL02F - Quadrat 3

WOL02F - Quadrat 4

WOL02F - Quadrat 5

WOL02F - Quadrat 6

WOL02F - Quadrat 7

WOL02F - Quadrat 8

WOL02F - Quadrat 9

WOL02F - Quadrat 10

A8.4 Quadrat Photographs - Transect WOL02G (2017)


WOL02G - Quadrat 1


WOL02G - Quadrat 2


WOL02G - Quadrat 3


WOL02G - Quadrat 4


WOL02G - Quadrat 5


WOL02G - Quadrat 6

WOL02G - Quadrat 7

WOL02G - Quadrat 8

WOL02G - Quadrat 9

WOL02G - Quadrat 10

A8.5 Quadrat Photographs - Transect WOL03F (2017)


WOL03F - Quadrat 1


WOL03F - Quadrat 2


WOL03F - Quadrat 3


WOL03F - Quadrat 4


WOL03F - Quadrat 5


WOL03F - Quadrat 6

WOL03F - Quadrat 7

WOL03F - Quadrat 8

WOL03F - Quadrat 9

WOL03F - Quadrat 10

A8.6 Quadrat Photographs - Transect WOL03G (2017)

WOL03G - Quadrat 1

WOL03G - Quadrat 2

WOL03G - Quadrat 3

WOL03G - Quadrat 4

WOL03G - Quadrat 5

WOL03G - Quadrat 6

WOL03G - Quadrat 7

WOL03G - Quadrat 8

WOL03G - Quadrat 9

WOL03G - Quadrat 10

A8.7 Flora Species List (2017)

Species	WOL01F	WOL01G	WOL02F	WOL02G	WOL03F	WOL03G
Acacia filicifolia	3	1			4	
*Acetosella vulgaris***	5	1				
Allocasuarina luehmannii	4		2	5	3	9
*Anagallis arvensis***		1				
Angophora floribunda	4				9	1
Aristida contorta					1	4
Aristida ramosa	8	8	10	10	6	8
Aristida vagans	1		7	5	7	1
Aristida warburgii						6
Astroloma humifusum	10	8		1		5
*Axonopus fissifolius***				9		
Banksia integrifolia subsp. integrifolia					4	3
*Bidens subalternans***	2		4	1		
Brachyloma daphnoides					3	10
Brunoniella australis			3			
Calotis cuneifolia			9	4		
Calotis lappulacea			2	1		
Carex inversa			1			
*Centaurium tenuiflorum***				2		
Cheilanthes distans			2			
Cheilanthes sieberi subsp. sieberi	10	10	10	10	2	6
*Chondrilla juncea***		2				
Chrysocephalum semipapposum	6	4	2	7		8
Commelina cyanea	6	8	9		9	
Convolvulus erubescens				1	1	
Conyza bonariensis&&				4		
Crassula sieberiana			1			
Cymbopogon refractus	4	3	10	10	5	4
*Cynodon dactylon***	2	6	1	10	4	
*Cyperus aggregatus***	1	1	3	1		
Dendrophthoe vitellina	2					
Dianella longifolia var. longifolia			5		5	
Dianella revoluta var. revoluta			3		3	1
Dichelachne micrantha				7	2	
Digitaria diffusa	1		7	1	2	
Echinopogon ovatus			1			
*Ehrharta erecta***					2	
Einadia hastata			1			
Einadia nutans subsp. nutans	1		1		1	
Eragrostis brownii	1		8	9	1	2
*Eragrostis curvula***			2	6		1
Eragrostis elongata				7		
Eragrostis leptostachya			6			
Eucalyptus crebra			10	2		
Eulalia aurea				2		
Fimbristylis dichotoma	4	5	8	10		4
*Galenia pubescens***	1					
*Gamochaeta americana***				5		

Species	WOL01F	WOL01G	WOL02F	WOL02G	WOL03F	WOL03G
Glossocardia bidens			1			
Glycine clandestina	2	1			3	3
*Gomphrena celosioides***			1			
Grevillea montana						2
*Heliotropium amplexicaule***	10	10				
Hibbertia linearis	1				5	3
Hypericum gramineum				8		
*Hypochaeris radicata***	2			3		
Laxmannia gracilis			4			1
*Lepidium spp.***		1				
Leptospermum polyanthum						8
Lomandra filiformis subsp. filiformis			10	9		
Lomandra glauca					7	9
Lomandra leucocephala subsp. leucocephala	2					2
Lomandra multiflora subsp. multiflora	1		3	4		
Loranthaceae indeterminate					5	
*Melinis repens***	6	2			5	7
Microlaena stipoides var. stipoides	4	5	2		9	2
Murdannia graminea			6			
*Oenothera stricta subsp. stricta***	2	4				
*Opuntia aurantiaca***	3	4	4		3	
*Opuntia stricta var. stricta***	10	8	3		4	3
Oxalis perennans	3	1			2	
Panicum effusum	1			1		
Perotis rara	1	3				
*Petrorhagia dubia***		1		3		
Phyllanthus virgatus				2		
Pimelea linifolia subsp. linifolia	8	2			3	6
*Plantago lanceolata***				1		
Podolepis canescens	7	10				3
Portulaca pilosa	1					
Pteridium esculentum					8	
*Richardia brasiliensis***	3	3	4	9		3
*Schkuhria pinnata var. abrotanoides***			2	1		
*Senecio madagascariensis***	1	2	6	8		
*Setaria parviflora***				1		
*Sida rhombifolia***		1	5			
*Silene gallica var. gallica***	1					
*Solanum nigrum***	1					
Sporobolus creber	1	5				
Stackhousia muricata			3	5		
Tricoryne elatior	4	7			5	
*Verbascum virgatum***		2				
*Verbena rigida var. rigida***				3		
Wahlenbergia gracilis			1	6		
Zornia dyctiocarpa var. dyctiocarpa	1		5			

Values are abundance scores of 1-10, based on presence in 10 component quadrats per transect.
** = weed species

A8.8 Biometric Floristic Data (2017)

Species	2017_WOL01F_QU		2017_WOL01G_QU		2017_WOL02F_QU		2017_WOL02G_QU		2017_WOL03F_QU		2017_WOL03G_QU	
	% cover	No.	% cover	No.	% cover	No.	% cover	No.	% cover	No.	% cover	No.
Acacia filicifolia	1	4	0.1	2					0.1	1		
Acetosella vulgaris	0.1	50	0.1	3								
Allocasuarina littoralis									0.1	1	5	1
Allocasuarina luehmannii	5	20	2	4	0.1	1	2	10	0.1	1	5	20
Angophora floribunda	15	4							20	40	5	4
Aristida contorta											5	500
Aristida ramosa	1	50	1	50	6	1000	6	500	0.1	100	3	200
Aristida vagans	0.1	5			0.1	20	0.1	5	0.1	100	0.1	5
Aristida warburgii											3	500
Astroloma humifusum	3	100	1	20			0.1	2			0.1	6
Axonopus fissifolius							1	200				
Banksia integrifolia subsp. integrifolia									3	3	1	5
Bidens subalternans	0.1	10			0.1	5						
Brachyloma daphnoides											3	100
Brunoniella australis					0.1	10						
Calotis cuneifolia					0.1	50	0.1	2	0.1	5		
Calotis lappulacea					0.1	1	0.1	2				
Centaurium tenuiflorum							0.1	1				
Cheilanthes distans					0.1	200						
Cheilanthes sieberi subsp. sieberi	2	1000	2	500	0.1	500	0.1	200			0.1	10
Chondrilla juncea			0.1	1								
Chrysocephalum semipapposum	0.1	50	0.1	20			0.1	20			0.1	50
Commelina cyanea	0.1	2	0.1	20	0.1	100			0.1	50		
Conyza bonariensis							0.1	4				
Cymbopogon obtectus											0.1	1
Cymbopogon refractus	0.1	6	0.1	5	6	1000	4	200			0.1	10
Cynodon dactylon	0.1	5	3	500	0.1	1	2	200	0.1	2		
Cyperus aggregatus	0.1	2	0.1	3	0.1	5						
Dendrophthoe vitellina	0.1	3										
Dianella longifolia var. longifolia					0.1	1			0.1	1		
Dianella revoluta	0.1	2										

Species	2017_WOL01F_QU		2017_WOL01G_QU		2017_WOL02F_QU		2017_WOL02G_QU		2017_WOL03F_QU		2017_WOL03G_QU	
	% cover	No.	% cover	No.	% cover	No.	% cover	No.	% cover	No.	% cover	No.
Dianella revoluta var. revoluta					0.1	2			0.1	3		
Dichelachne micrantha							1	100				
Digitaria diffusa					0.1	10						
Echinopogon ovatus					0.1	1						
Ehrharta erecta									0.1	2		
Einadia nutans subsp. nutans	0.1	1			0.1	5			0.1	1		
Enchylaena tomentosa					0.1	2						
Eragrostis brownii	0.1	6			0.1	20	0.1	10			0.1	5
Eragrostis curvula					0.1	3	3	50				
Eragrostis elongata							0.1	10				
Eragrostis leptostachya					0.1	20						
Eremophila debilis					0.1	1						
Eucalyptus crebra					45	100	2	2	5	1		
Fimbristylis dichotoma	0.1	1	0.1	20	0.1	50	0.1	50				
Glycine clandestina	0.1	1							0.1	2		
Glycine tabacina					0.1	1						
Gomphrena celosioides					0.1	1						
Grevillea montana											4	20
Heliotropium amplexicaule	3	500	15	1000								
Hibbertia linearis	0.1	6							0.1	2		
Hypochaeris radicata	0.1	10	0.1	2								
Juncus subsecundus									0.1	1		
Laxmannia gracilis					0.1	2					0.1	3
Lepidium africanum					0.1	1						
Leptospermum polyanthum											5	50
Lomandra filiformis subsp. filiformis					1	200	1	500				
Lomandra glauca									0.1	1	0.1	200
Lomandra leucocephala subsp. leucocephala	1	100									0.1	20
Lomandra multiflora subsp. multiflora	0.1	5	0.1	1	0.1	2	0.1	3				
Loranthaceae indeterminate									0.1	3	0.1	1
Maireana microphylla					0.1	1						
Melinis repens	0.1	3			0.1	20			0.1	50	0.1	50
Microlaena stipoides var. stipoides	0.1	2	2	200					0.1	20	0.1	10

Species	2017_WOL01F_QU		2017_WOL01G_QU		2017_WOL02F_QU		2017_WOL02G_QU		2017_WOL03F_QU		2017_WOL03G_QU	
	% cover	No.	% cover	No.	% cover	No.	% cover	No.	% cover	No.	% cover	No.
Murdannia graminea					0.1	10						
Oenothera stricta subsp. stricta	0.1	2	0.1	7								
Opuntia aurantiaca	0.1	2	0.1	2	0.1	5			0.1	1		
Opuntia stricta var. stricta	0.1	10	1	20	0.1	7			0.1	3	0.1	3
Oxalis perennans	0.1	5					0.1	2	0.1	2		
Perotis rara	0.1	6	0.1	10								
Petrorhagia dubia			0.1	1								
Phyllanthus virgatus							0.1	2				
Pimelea linifolia subsp. linifolia	3	100	0.1	9					0.1	3	0.1	10
Plantago lanceolata							0.1	1				
Podolepis canescens	0.1	200	0.1	20							0.1	5
Portulaca pilosa	0.1	5										
Pteridium esculentum									20	1000		
Richardia brasiliensis	0.1	7	2	200	0.1	10	0.1	50			0.1	2
Schkuhria pinnata var. abrotanoides					0.1	10						
Senecio madagascariensis	0.1	1			0.1	3	0.1	10				
Sida rhombifolia					0.1	5						
Sporobolus creber			0.1	20								
Stackhousia muricata							0.1	2				
Tricoryne elatior	0.1	1	0.1	2					0.1	3		
Verbascum virgatum			0.1	1								
Verbena rigida var. rigida							0.1	3				
Vulpia muralis	0.1	3										
Wahlenbergia gracilis					0.1	1						
Zornia dyctiocarpa var. dyctiocarpa					0.1	3						

Note: “% cover” refers to estimated total cover of that taxon; “No.” refers to the count (or estimate) of individuals of that taxon.

A8.9 Photopoint Monitoring (2017)

WOL01F

WOL01F – looking North

WOL01F – looking East

WOL01F – looking South

WOL01F – looking West

WOL01G


WOL01G – looking North


WOL01G – looking East


WOL01G – looking South


WOL01G – looking West

WOL02F


WOL02F – looking North


WOL02F – looking East


WOL02F – looking South


WOL02F – looking West

WOL02G


WOL02G – looking North


WOL02G – looking East


WOL02G – looking South


WOL02G – looking West

WOL03F

WOL03F – looking North

WOL03F – looking East

WOL03F – looking South

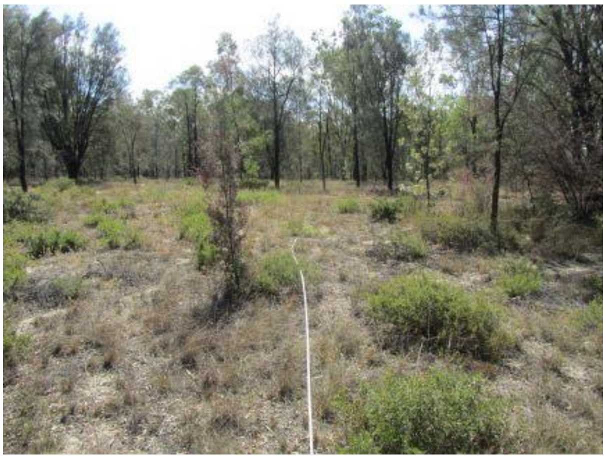
WOL03F – looking West

WOL03G


WOL03G – looking North


WOL03G – looking East


WOL03G – looking South


WOL03G – looking West

A8.10 Fauna Species List (2017)

FAMILY / Scientific Name	Common Name	Status		Wollombi Brook BOA Monitoring Site Record 2017						Record 2015 - 16	Bulga 2003-2011
		EPBC	BC Act	WB01	WB02	WB03	WB04	WB05	WB06		
BIRDS											
PHASIANIDAE											
Coturnix ypsilophora	Brown Quail			heard	heard	heard				+	+
ANATIDAE											
Cygnus atratus	Black Swan										+
Chenonetta jubata	Australian Wood Duck	M								+	+
Anas gracilis	Grey Teal										+
Anas superciliosa	Pacific Black Duck	M								+	+
Aythya australis	Hardhead										+
PODICIPEDIDAE											
Tachybaptus novaehollandiae	Australian Grebe										+
PHALACROCORACIDAE											
Phalacrocorax malanoleucos	Little Pied Cormorant										+
Phalacrocorax carbo	Great Cormorant									+	
ARDEIDAE											
Egretta novaehollandiae	White-faced Heron									+	+
Ardea pacifica	White-necked Heron									+	+
PLATALEIDAE											
Platalea regia	Royal Spoonbill										+
Platelea flavipes	Yellow-billed Spoonbil										+
ACCIPITRIDAE											
Elanus axillaris	Black-shouldered Kite	M								+	+
Hieraaetus morphnoides	**Little Eagle**	**M**	**V**								+
Accipiter fasciatus	Brown Goshawk	M									+
Haliaeetus leucogaster	White-bellied Sea Eagle	M									+
Aquila audax	Wedge-tailed Eagle	M						0,0,2		+	
FALCONIDAE											
Falco berigora	Brown Falcon	M			2,0,0					+	+
Falco peregrinus	Peregrine Falcon	M			1,0,0					+	+

Key to Appendix A8.10
Numbers 0,0,0 refer to species counts per sampling period (Winter 1, Winter 2, Spring)
Observe – refers to sighting outside of census period, Photo – taken for remote IR field camera spot – detected by spotlight search

FAMILY / Scientific Name	Common Name	Status		Wollombi Brook BOA Monitoring Site Record 2017						Record	Bulga
		EPBC	BC Act	WB01	WB02	WB03	WB04	WB05	WB06	2015 - 16	2003-2011
Falco cenchroides	Nankeen Kestrel	M			2,0,0	2,0,0			2,0,0	+	+
RALLIDAE											
Porphyrio porphyrio	Purple Swamphen									+	+
CHARADRIIDAE											
Elseyornis melanops	Black-fronted Dotterel	M									+
Vanellus miles	Masked Lapwing	M						0,0,2		+	+
COLUMBIDAE											
Macropygia amboinensis	Brown Cuckoo-dove										
Phaps chalcoptera	Common Bronzewing									+	+
Ocyphaps lophotes	Crested Pigeon								0,4,0	+	+
Geopelia humeralis	Bar-shouldered Dove			0,0,2	0,2,4				0,1,0	+	
Lopholaimus antarcticus	Topknot Pigeon										
CACATUIDAE											
Cacatua roseicapilla	Galah				2,2,0	0,1,0				+	+
Cacatua sanguinea	Little Corella									+	
Cacatua galerita	Sulphur-crested Cockatoo									+	+
Calyptorhynchus funereus	Yellow-tailed Black Cockatoo				0,3,0						+
PSITTACIDAE											
Glossopsitta concinna	Musk Lorikeet									+	+
Glossopsitta pusilla	**Little Lorikeet**		**V**								+
Alisterus scapularis	Australian King Parrot				2,0,0			0,0,2		+	+
Platycerus elegans	Crimson Rosella									+	+
Platycerus eximius	Eastern Rosella			2,0,0,		2,2,2			0,2,0	+	
Lathamus discolor	**Swift Parrot**	E	E								+
Psephotus haematonotus	Red-rumped Parrot							0,2,0			+
CUCULIDAE											
Cacomantis flabelliformis	Fan-tailed Cuckoo	M						0,1,0		+	+
Chrysococcyx lucidus	Shining Bronze-Cuckoo	M									+
Cacomantis pallidus	Pallid Cuckoo	M			0,0,1		0,0,1				+
Scythrops novaehollandiae	Channel-billed Cuckoo	M								+	+
Centropus phasianinus	Pheasant Coucal										+
Eudynamys orientalis	Eastern Koel										+

Key to Appendix A8.10
Numbers 0,0,0 refer to species counts per sampling period (Winter 1, Winter 2, Spring)
Observe – refers to sighting outside of census period, Photo – taken for remote IR field camera spot – detected by spotlight search

FAMILY / Scientific Name	Common Name	Status		Wollombi Brook BOA Monitoring Site Record 2017						Record	Bulga
		EPBC	BC Act	WB01	WB02	WB03	WB04	WB05	WB06	2015 - 16	2003-2011
STRIGIDAE											
Ninox novaeseelandiae	Southern Boobook	M								+	
TYTONIDAE											
Tyto novaehollandiae	**Masked Owl**		V								+
PODARGIDAE											
Podargus strigoides	Tawny Frogmouth										+
AEGOTHELIDAE											
Aegotheles cristatus	Australian Owlet-Nightjar									+	+
HALCYONIDAE											
Dacelo novaeguineae	Laughing Kookaburra				0,0,2					+	+
Todiramphus sancta	Sacred Kingfisher	M							0,0,1	+	+
MEROPIDAE											
Merops ornatus	Rainbow Bee-eater	M		0,0,5	0,0,10					+	+
CORACIIDAE											
Eurystomus orientalis	Dollarbird									+	+
CLIMACTERIDAE											
Climacteris leucophaea	White-throated Treecreeper									+	+
Climacteris picumnus	**Brown Treecreeper**		V								+
MALURIDAE											
Malurus cyaneus	Superb Fairy-wren			5,0,0	10,4,10	0,6,0	0,4,0	0,0,2	2,0,10	+	+
PARDALOTIDAE											
Pardalotus punctatus	Spotted Pardalote									+	+
Pardalotus striatus	Striated Pardalote				0,2,0	0,2,0				+	+
Sericornis frontalis	White-browed Scrubwren				1,0,0					+	+
Chthonicola sagittata	**Speckled Warbler**		V		2,0,2		1,0,0		0,1,0	+	+
Smicrornis brevirostris	Weebill			0,0,1	2,0,0		5,10,0			+	+
Gerygone olivacea	White-throated Gerygone									+	+
Acanthiza pusilla	Brown Thornbill				2,0,0						+
Acanthiza reguloides	Buff-rumped Thornbill			20,0,0						+	+
Acanthiza chrysorrhoa	Yellow-rumped Thornbill			0,0,0	5,0,0		10,0,0	0,10,0		+	+
Acanthiza nana	Yellow Thornbill			20,10,0	0,2,0		10,10,0			+	+
Acanthiza lineata	Striated Thornbill										+

Key to Appendix A8.10

Numbers 0,0,0 refer to species counts per sampling period (Winter 1, Winter 2, Spring)

Observe – refers to sighting outside of census period, Photo – taken for remote IR field camera spot – detected by spotlight search

FAMILY / Scientific Name	Common Name	Status		Wollombi Brook BOA Monitoring Site Record 2017						Record 2015 - 16	Bulga 2003-2011
		EPBC	BC Act	WB01	WB02	WB03	WB04	WB05	WB06		
MELIPHAGIDAE											
Anthochaera carunculata	Red Wattlebird										+
Acanthagenys rufogularis	Spiny-cheeked Honeyeater				1,0,0						
Plectorhyncha lanceolata	Striped Honeyeater			2,0,0	2,0,0	2,2,0	2,2,0	2,0,0	1,0,0	+	+
Philemon corniculatus	Noisy Friarbird			0,0,2		0,0,2	0,1,0			+	+
Anthochaera phrygia	**Regent Honeyeater**	CE	CE								+
Entomyzon cyanotis	Blue-faced Honeyeater									+	
Manorina melanocephala	Noisy Miner			10,0,0	2,0,0	10,2,6	0,2,0	2,0,0	0,4,0	+	+
Meliphaga lewinii	Lewin's Honeyeater										+
Lichenostomus leucotis	White-eared Honeyeater										+
Lichenostomus chrysops	Yellow-faced Honeyeater			10,0,5	10,4,10		2,2,0	2,0,0	0,4,0	+	+
Lichenostomus penicillatus	White-plumed Honeyeater			1,0,0		5,0,2	0,10,0		0,5,4	+	+
Melithreptus brevirostris	Brown-headed Honeyeater				20,2,0	10,0,0	20,2,0	10,0,0	10,10,0	+	+
Melithreptus lunatus	White-naped Honeyeater										+
Myzomela sanguinolenta	Scarlet Honeyeater									+	+
Acanthorhynchus tenuirostris	Eastern Spinebill			1,0,0	1,0,0					+	
PETROICIDAE											
Microeca fascinans	Jacky Winter								0,1,0	+	+
Petroica rosea	Rose Robin									+	+
Melanodryas cucullata	**Hooded Robin**		**V**							+	+
Eopsaltria australis	Eastern Yellow Robin			2,0,2	2,0,4				2,2,0	+	+
Petroica boodang	**Scarlet Robin**		**V**							+	
Petroica goodenovii	Red-capped Robin				0,0,2				0,1,0	+	+
POMATOSTOMIDAE											
Pomatostomus temporalis	**Grey-crowned Babbler**		V	4,0,0		0,4,0				+	+
NEOSITTIDAE											
Daphoenositta chrysoptera	**Varied Sittella**		**V**				20,0,0			+	+
PACHYCEPHALIDAE											
Pachycephala pectoralis	Golden Whistler									+	+
Pachycephala rufiventris	Rufous Whistler			0,0,10	0,0,4	0,1,6	2,2,0		0,0,6	+	+
Colluricincla harmonica	Grey Shrike-thrush					0,1,0	1,0,0	0,1,0	0,0,2	+	+
DICRURIDAE											

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FAMILY /		Status		Wollombi Brook BOA Monitoring Site Record 2017						Record	Bulga
Scientific Name	**Common Name**	**EPBC**	**BC Act**	**WB01**	**WB02**	**WB03**	**WB04**	**WB05**	**WB06**	**2015 - 16**	**2003-2011**
Myiagra rubecula	Leaden Flycatcher										
Grallina cyanoleuca	Magpie-Lark	M			0,0,2	0,1,0		2,0,0	2,0,0	+	+
Rhipidura fuliginosa	Grey Fantail			20,2	2,4,0	2,2,2	2,2,0	0,1,0	2,0,2	+	+
Rhipidura rufifrons	Rufous Fantail										
Rhipidura leucophrys	Willie Wagtail			0,1,1				0,0,1	1,0,0	+	+
CAMPEPHAGIDAE											
Coracina novaehollandiae	Black-faced Cuckoo-shrike			1,0,0	1,0,0		1,0,0	1,0,0	1,0,0	+	+
ORIOLIDAE											
Oriolus sagittatus	Olive-backed Oriole				0,0,2	0,0,2				+	+
ARTAMIDAE											
Artamus personatus	Masked Woodswallow									+	+
Artamus superciliosus	White-browed Woodswallow									+	+
Artamus cyanopterus	**Dusky Woodswallow**		**V**								+
Cracticus torquatus	Grey Butcherbird				0,0,2	1,0,2				+	+
Cracticus nigrogularis	Pied Butcherbird			0,0,4		0,2,0	2,0,0			+	+
Gymnorhina tibicen	Australian Magpie			4,0,2	0,2,2	2,2,2		1,0,0	0,0,2	+	+
Strepera graculina	Pied Currawong				1,0,0	2,2,0	0,4,0			+	+
CORVIDAE											
Corvus coronoides	Australian Raven			10,1,10	2,1,10	0,10,10	0,4,0			+	+
CORCORACIDAE											
Corcorax melanorhamphos	White-winged Chough			1 photo	0,5,0	0,0,10			0,0,10	+	+
PTILONORHYNCHIDAE											
Ptilinorhynchus violaceus	Satin Bowerbird									+	+
MOTACILLIDAE											
Anthus novaeseelandiae	Australian Pipit									+	+
PASSERIDAE											
Taeniophygia bichenovii	Double-barred Finch			10,0,0					0,10,0	+	+
Neochmia temporalis	Red-browed Finch				0,20,0					+	+
Stagonopleura guttata	**Diamond Firetail**		V								+
DICAEIDAE											
Dicaeum hirundinaceum	Mistletoebird				0,2,4	0,0,2			0,0,2	+	+
HIRUNDINIDAE											

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		EPBC	BC Act	WB01	WB02	WB03	WB04	WB05	WB06	2015 - 16	2003-2011
Hirundo neoxena	Welcome Swallow			1,0,0						+	+
Hirundo ariel	Fairy Martin				20,0,0					+	+
SYLVIIDAE											
Acrocephalus australis	Australian Reed Warbler	M			0,0,2					+	+
Cisticola exilis	Golden-headed Cisticola										
ZOSTEROPIDAE											
Zosterops lateralis	Silvereye			0,0,20	0,10,10					+	+
STURNIDAE											
** Sturnus vulgaris*	* Common Starling									+	+
** Acridotheres tristis*	* Common Myna									+	+
TACHYGLOSSIDAE											
Tachyglossus aculeatus	Short-beaked Echidna										+
DASYURIDAE											
Dasyurus maculatus	**Spotted-tail Quoll**	**V**	**V**								
VOMBATIDAE											
Vombatus ursinus	Common Wombat									+	+
PETAURIDAE											
Petaurus breviceps	Sugar Glider										
Petaurus norfolcensis	**Squirrel Glider**		V							+	
PHALANGERIDAE											
Trichosurus vulpecula	Common Brushtail Possum						3 spot			+	+
MACROPODIDAE											
Macropus giganteus	Eastern Grey Kangaroo			8 photos		1 photo				+	+
Macropus rufogriseus	Red-necked Wallaby			3 photos		1 photo				+	+
Wallabia bicolor	Swamp Wallaby					1 photo				+	+
PTEROPODIDAE											
Pteropus poliocephalus	Grey-headed Flying-fox	V	V								+
RHINOLOPHIDAE											
Rhinolophus megaphyllus	Eastern Horseshoe-bat										+
MOLOSSIDAE											
Micronomus norfolkensis	**Eastern Freetail-bat**		V	32 calls					58 calls	+	+
Mormopterus sp.4	Southern Freetail-bat				20 calls		1 call		3 calls		+

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FAMILY / Scientific Name	Common Name	Status		Wollombi Brook BOA Monitoring Site Record 2017						Record	Bulga
		EPBC	BC Act	WB01	WB02	WB03	WB04	WB05	WB06	2015 - 16	2003-2011
Austronomus australis	White-striped Freetail-bat			1 call							+
VESPERTILIONIDAE											
Miniopterus schreibersii oceanensis	**Eastern Bent-wing Bat**		V	1 call						+	+
Chalinolobus dwyeri	**Large-eared Pied Bat**		V		1 call					+	
Chalinolobus gouldii	Gould's Wattled Bat			8 calls						+	+
Chalinolobus morio	Chocolate Wattled Bat			3 calls		6 calls				+	+
Nyctophilus sp.	Long-eared Bat			1 call		2 calls	1 call			+	+
Scotorepens balstoni	Inland Broad-nosed Bat									+	+
Scotorepens orion	Eastern Broad-nosed Bat										+
Vespadelus pumilus	Eastern Forest Bat									+	+
Vespadelus troughtoni	**Eastern Cave Bat**		V								+
Vespadelus vulturnus	Little Forest Bat									+	+
MURIDAE											
*Mus musculus **	House Mouse *										
*Rattus rattus **	Black Rat *									+	
CANIDAE											
Canis lupus dingo	Dingo / Dog					3 photos				+	+
** Vulpes vulpes*	* Fox					3 photos				roadkill	+
LEPORIDAE											
** Lepus capensis*	* Brown Hare			1 photo		3 photos				+	+
** Oryctolagus cuniculus*	* European Rabbit									+	+
SUIDAE											
** Sus scrofa*	* Pig									+	
Chelodina longicollis	Eastern Long-necked Turtle									+	+
GEKKONIDAE											
Diplodactylus vittatus	Wood Gecko										+
AGAMIDAE											
Amphibolurus muricatus	Jacky Lizard										+
Intellagama lesueurii	Eastern Water Dragon									+	+
Pogona barbata	Bearded Dragon										+
VARANIDAE											

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		EPBC	BC Act	WB01	WB02	WB03	WB04	WB05	WB06		
Varanus varius	Lace Monitor									+	+
SCINCIDAE											
Ctenotus robustus	Robust Ctenotus									+	+
Cryptoblepharus virgatus	Cream-sided Shinning Skink										+
Ctenotus taeniolatus	Copper-tailed Skink										+
Liopholis modesta	Eastern Ranges Rock-skink										+
Egernia striolata	Tree Skink										+
Eulamprus quoyii	Eastern Water-skink										+
Lampropholis delicata	Dark-flecked Garden Sunskink										+
ELAPIDAE											
Demansia psammophis	Yellow-faced Whip Snake										+
Furina diadema	Red-naped Snake										+
Pseudechis porphyriacus	Red-bellied Black-snake										+
Pseudonaja textilis	Eastern Brown Snake										+
MYOBATRACHIDAE											
Crinia signifera	Common Eastern Froglet				10+					+	+
Limnodynastes ornatus	Ornate Burrowing Frog									+	
Limnodynastes peronii	Brown-striped Frog									+	
Limnodynastes tasmaniensis	Spotted Grass Frog									+	+
Uperoleia laevigata	Smooth Toadlet										+
HYLIDAE											
Litoria caerulea	Green Tree Frog									+	+
Litoria fallax	Eastern Dwarf Tree Frog				10+					+	+
Litoria latopalmata	Broad Palmed Frog									+	+
Litoria peronii	Peron's Tree Frog									+	+
Litoria verreauxii	Whistling Tree Frog				10+					+	+

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