

Advice to decision maker on coal mining project

IESC 2019-110: Bulga Optimisation Project MOD 3 / Bulga Underground Operations MOD 7 (EPBC 2018/8300 and SSD 4960 / DA 376-8-2003) –Expansion

Requesting agency	The Australian Government Department of the Environment and Energy The New South Wales Department of Planning, Industry and Environment
Date of request	1 November 2019
Date request accepted	1 November 2019
Advice stage	Assessment

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) provides independent, expert, scientific advice to the Australian and state government regulators on the potential impacts of coal seam gas and large coal mining proposals on water resources. The advice is designed to ensure that decisions by regulators on coal seam gas or large coal mining developments are informed by the best available science.

The IESC was requested by the Australian Government Department of the Environment and Energy and the New South Wales Department of Planning, Industry and Environment to provide advice on Bulga Coal Management Pty Ltd's Bulga Optimisation Project MOD 3/Bulga Underground Operations MOD 7 in New South Wales. This document provides the IESC's advice in response to the requesting agencies' questions. These questions are directed at matters specific to the project to be considered during the requesting agencies' assessment process. This advice draws upon the available assessment documentation, data and methodologies, together with the expert deliberations of the IESC, and is assessed against the IESC Information Guidelines (IESC, 2018).

Summary

The proposed Bulga Optimisation Project MOD 3/Bulga Underground Operations MOD 7 (the project) is an extension of the existing Bulga Coal Complex (BCC) located approximately 12 km southwest of Singleton in the Hunter Valley, New South Wales. The project includes mining deeper seams within the South Pit Area and relocation of tailings from the Deep Pit and Bayswater Pit tailings storage facilities (TSF) to the Main Pit TSF which will require expansion to accommodate these tailings and those generated from the proposed additional mining. The project will disturb 20.2 ha of previously undisturbed land including approximately 16.2 ha of Central Hunter Valley Eucalypt Forest and Woodland, listed as a critically endangered ecological community (CEEC) under the *Environment Protection and Biodiversity*

Conservation Act 1999 (EPBC Act). The project will extract an additional 63 Mt of thermal and coking coal from the BCC extending the life of open cut operations by about four years until 2039.

Key potential impacts from this project are:

- further drawdown in the Permian aquifers and a greater spatial extent of drawdown within the alluvial aquifers, both of which are predicted to reduce baseflow to surface water systems within the Hunter River Catchment;
- impacts to the Warkworth Sands Woodland CEEC if this community is found to be dependent on groundwater affected by the project;
- changed flow regimes (particularly frequency, duration and timing of zero- and low-flow periods) and altered surface water quality from changed catchment areas and controlled and uncontrolled discharges; and
- long-term and event-based declines in surface water and groundwater quality from the final void lake.

The IESC has identified key areas in which additional work is required to address the key potential impacts, as detailed in this advice. These are summarised below.

- The proponent has acknowledged that the model is intended to predict impacts on the Permian aquifers only. While the alluvium is included, it is not represented in detail (KCB 2019, p. 68) which limits confidence in predicted impacts on surface water and groundwater-dependent ecosystems (GDEs). Further effort is required to ensure the model design and parameterisation adequately represent the alluvium in order to better simulate impacts on the alluvial aquifers from the project.
- More comprehensive sensitivity and uncertainty analyses should be undertaken which address the identified limitations with the groundwater modelling including the representation of the alluvium, mine deepening and in-pit tailings placement. These analyses need to examine a range of plausible parameterisations and rainfall scenarios to provide confidence in the predicted impacts. Analyses also need to explore how the model limitations may affect the calculation of worse-case scenarios or likelihood of outcomes.
- Additional groundwater data in the alluvium are required to supplement the current data to support the quantification of the impacts of the project and identify its contribution to cumulative impacts.
- Quantify the likely changes in flow regimes (e.g. changes in frequency, duration and timing of low- and zero-flow periods) and predict how these changes will affect instream biota. Baseline and ongoing monitoring data on instream biota should be collected to inform and verify these predictions, and to guide suitable mitigation strategies.
- Additional flood modelling which is consistent with national flood guidance provided for rural catchments and considers the current flood risks and rainfall intensities. The proponent should provide a sensitivity analysis which assesses the likely impacts of more severe rainfall events on risks of storage dams overtopping.
- Additional surface water quality data, particularly for Loders Creek and the Hunter River downstream of discharges, as well as aquatic ecology monitoring data, both upstream and downstream of the proposed discharge locations, are required to assess potential downstream impacts. This monitoring is needed to establish baseline conditions as well as during and post-mining to determine if impacts are occurring and to identify possible cumulative impacts.

- Given that there may be future controlled discharges and uncontrolled spillages from the mine water storages, or leakage from the final void lake, ongoing monitoring should include sulfate and total and dissolved metals and metalloids, in addition to the three physico-chemical parameters identified by the proponent.
- The proponent should provide groundwater quality data for potential contaminants (other than salinity) particularly in the Wollombi Brook alluvium. This information is needed to understand the current condition of the water resource.
- Surveys for GDEs, including stygofauna and groundwater-dependent vegetation in the Wollombi Brook alluvium and in the riparian zone of Loders Creek, are needed to assess whether groundwater depressurisation or altered groundwater regimes are affecting this biota.
- Additional investigation and monitoring are needed in the Warkworth Sands Woodland to confirm the current hydrogeological conceptualisation that this community sources groundwater from a perched aquifer. Monitoring should continue during operations and post-mining to verify that this critically endangered ecological community (CEEC) is not impacted by the project.

Context

Mining first commenced at the Bulga Coal Complex (BCC) in 1982. Currently, only open cut mining is occurring as underground operations ceased in 2018. Future underground mining is planned and has been approved. This proposal does not alter the approved but yet-to-commence underground mining at the site. The proposed project requires changes to both the current approvals for open cut (MOD 3) and underground (MOD 7) operations. The open cut operations approval requires changes to allow mining of deeper coal seams, relocation of tailings and expansion of the Main Pit TSF, changes to mine areas and final landforms, the proposed additional coal extraction and the lengthening of the mine life. The underground operations approval requires changes because some infrastructure, including the gas-fired power generation plant, which is approved as part of the underground operations, will need to be relocated to facilitate deeper open cut mining.

The project is located next to Wollombi Brook and its associated alluvium, within the Hunter River Catchment. Water resources in this area are heavily used by the mining and agriculture industries. Some creeks such as Wollombi Brook are known to be highly connected to groundwater and their alluvial aquifers probably support GDEs. An area of the Warkworth Sands Woodland, listed as a CEEC under the EPBC Act, lies approximately 3.5 km northwest of the project.

Response to questions

The IESC's advice in response to the requesting agencies' specific questions is provided below.

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

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).
- 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.
- 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.

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).
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.
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).
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.
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).

Surface water

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).
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.
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.
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.
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.

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.

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.
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.
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.

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.

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.
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.

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.

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.

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.
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.
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.

Groundwater

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.
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).

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.

Groundwater

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.
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.
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.

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.
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.
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.
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.
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.
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).

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.
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.
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.
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.
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.
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.
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.
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.
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.
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.
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.

Date of advice	16 December 2019
Source documentation provided to the IESC for the formulation of this advice	Engeny 2019. <i>Bulga Optimisation Project Modification Surface Water Impact Assessment</i>. Prepared by Engeny Water Management on behalf of Umwelt Pty Ltd for Bulga Coal Management Pty Ltd. Report number N1600_007. HEC 2019. <i>Bulga Coal Complex Bulga Optimisation Project Modification 3 Site Water Balance</i>. Prepared by Hydro Engineering & Consulting Pty Ltd on behalf of Umwelt Pty Ltd for Bulga Coal Management Pty Ltd. KCB (Klohn Crippen Berger) 2019. <i>Bulga Coal Complex Bulga Optimisation Project Modification, Ground Water Impact Assessment</i>. Prepared by Klohn Crippen Berger on behalf of Umwelt Pty Ltd for Bulga Coal Management Pty Ltd. Umwelt 2019a. <i>Bulga Optimisation Project Modification Biodiversity Assessment Report</i>. Prepared by Umwelt Pty Ltd on behalf of Bulga Coal Management Pty Ltd. Report number 4100/R06/V4. Umwelt 2019b. <i>Statement of Environmental Effects. Bulga Optimisation Project Modification 3 and Bulga Underground Modification 7</i>. Prepared by Umwelt

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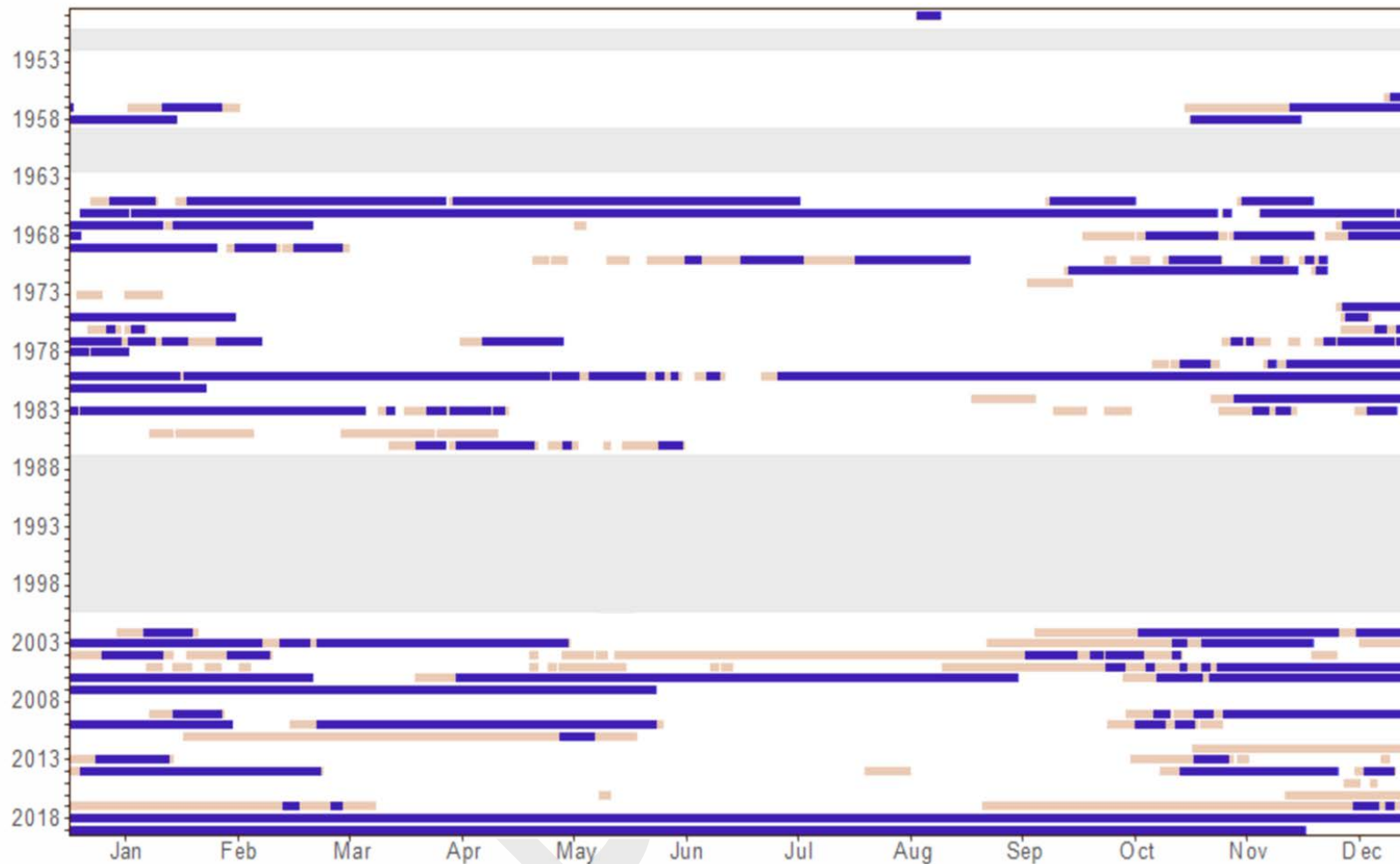


Figure 1. The plot highlights the frequency, timing and duration of zero-flow periods under current conditions in blue. The orange bars indicate the additional periods where flows are less than 1.38 ML/day which under current predictions could also be zero-flow periods. The grey shading indicates missing data. Data are from gauging station 210028 (Wollombi Brook at Bulga), which are the data that Engeny used to examine the nature of the predicted “negligible” 1.38 ML impacts on low flow periods.