

Appendix D

Addendum to the groundwater impact assessment

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Memorandum

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19 August 2021

To: Peak Gold Mines
From: Tom Neill and Joel Georgiou
Subject: Response to Submissions - New Cobar Complex addendum to the groundwater impact assessment

Dear Jonathon,

1 Background

EMM Consulting Pty Ltd (EMM) was engaged by Peak Gold Mines Pty Ltd (PGM) to build a numerical groundwater model (GC1.0) to support the Environmental Impact Statement (EIS) (EMM 2021a) for the New Cobar Complex Project. The groundwater model is documented in detail within the Groundwater Impact Assessment (GIA) (EMM 2021b) which supports the EIS.

In a separate, but parallel process to the EIS, PGM was granted a Water Supply Works Approval (85WA753861) on 2 December 2019, which allows PGM to pump groundwater from a shaft located within the historical Great Cobar underground mine workings and into the Great Cobar pipeline. The approval is required to meet future mine site water demands.

Part A of Section DS6593-00001 of the approval states that an updated groundwater model must be included as part of a Groundwater Management Plan (GMP). The GMP must include:

- a conceptual groundwater model including a water balance;
- model calibration against observed heads; and
- sensitivity and/or uncertainty analysis.

EMM upgraded and refined the EIS model (GC1.0) to specifically address the following requirements attached to approval 85WA753861:

- additional refinement to simulate the historic Great Cobar underground workings, including the vertical shaft, at a finer detail;
- modelling of additional predictive scenarios to simulate the estimated water requirements and effect on groundwater pressures; and
- additional predictive uncertainty analysis on these scenarios.

2 Response to submissions

The New Cobar Complex Project EIS was publicly exhibited from 25 February 2021 to 24 March 2021, and DPIE wrote to PGM on 31 March 2021 requesting responses to the matters raised by NSW Government agencies, local government authorities and the community that were received during the public exhibition of the EIS.

DPIE-Water and the Natural Resources Access Regulator (NRAR) made a submission on the project, which noted:

- That the numerical model had been prepared in accordance with the Australian Groundwater Modelling Guidelines to a standard suitable for the scale of activity and the relatively low-risk of groundwater impacts in the area. However, the model was not independently peer reviewed as required by the Aquifer Interference Policy (AIP).
- That a basic landholder rights (BLR) bore (85WA752553) had been overlooked in the original GIA.

DPIE Water and NRAR recommended that prior to approval:

- an independent peer review of the numerical groundwater model be undertaken; and
- that the GIA be updated to include BLR bore 85WA752553, and address whether mitigation under the AIP was required.

This memo has been prepared to address these two recommendations.

3 Independent peer review

Hugh Middlemis of HydroGeoLogic is an independent consultant specialist with over 40 years of industry experience. Hugh undertook an independent peer review consistent with the best practise guidelines on groundwater modelling and uncertainty analysis (included as Appendix A). In this context, the best practice principles and procedures of the Australian Groundwater Modelling Guideline (Barnett et al. 2012) were applied to conduct the review, with consideration given to recent guidance on uncertainty analysis (Middlemis et al. 2019).

Hugh concluded that the groundwater modelling assessment has generally been conducted consistent with best practice and is fit for the purpose for guiding impact assessment, mitigation and management planning and licensing.

The review concurred that there is an acknowledged lack of data on the historical mine progression and inflows, and related groundwater effects of mining, including on the existing Great Cobar open pit void lake, which affects the ability to develop a predictive modelling tool. The review highlighted that there is an opportunity to improve the monitoring network during the proposed mining development, to obtain data that can be used to validate and refine the hydrogeological understanding and numerical model, including: expanded groundwater bore network, including east of the Great Chesney Fault; pit void lake level and hypsographic data; underground inflow volume time series and spatial distributions.

4 GIA update

4.1 Groundwater numerical model

A groundwater numerical model has been developed for the GIA in accordance with the Australian Groundwater Modelling Guidelines (Barnett, et al. 2012). The model is further described in Section 8 of the GIA (EMM 2021b).

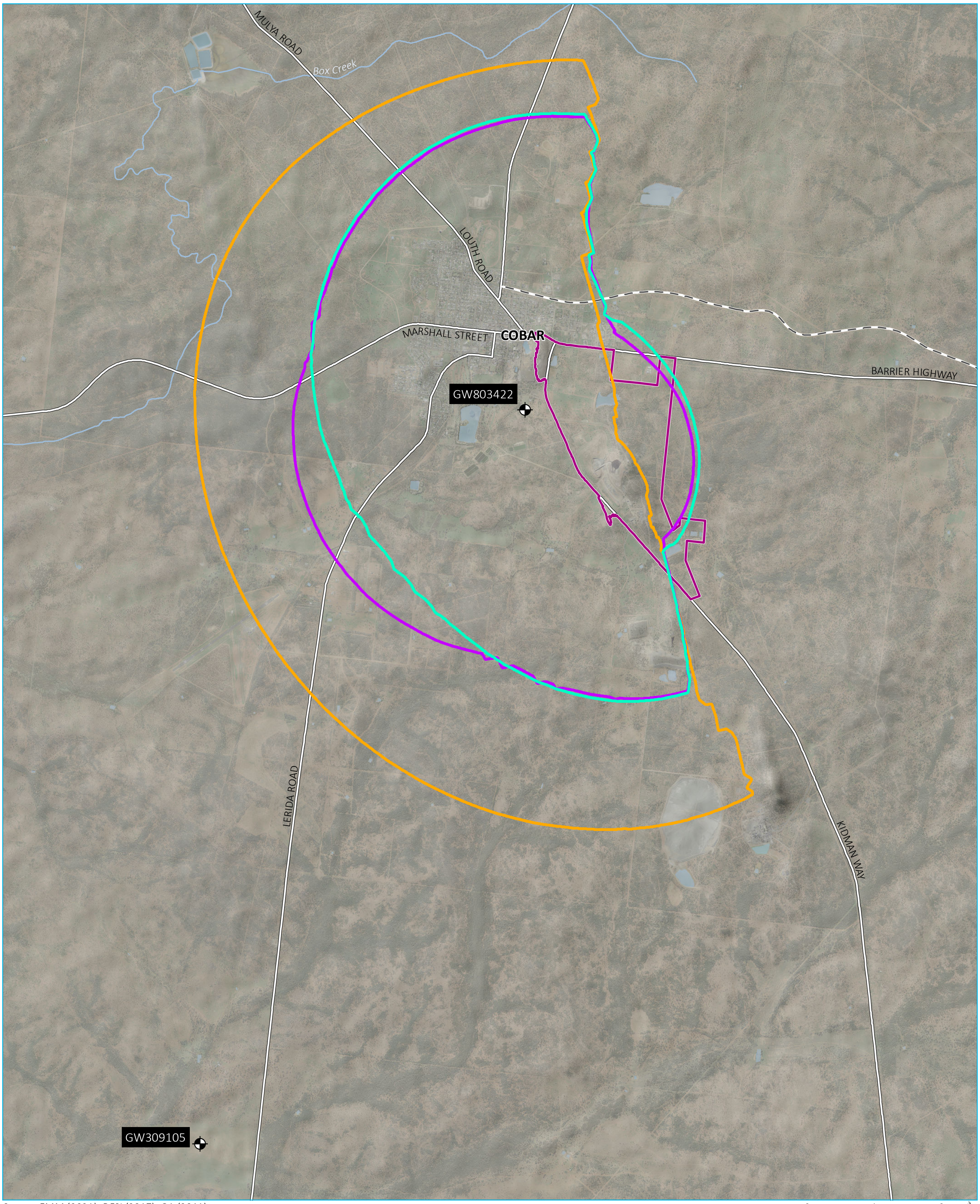
The predictive model scenarios presented in this memo are as follows:

- GC_tpred1: active mine dewatering for the base case using aquifer parameters obtained from history match assessment (GIA Section 8.4);
- GC_tpred2: active mine dewatering for the base case, plus additional water supply from the Great Cobar shaft;
- GC_tpred3: active mine dewatering for low mine inflow aquifer properties, plus additional water supply from the Great Cobar shaft; and

- GC_tpred4: active mine dewatering for high mine inflow aquifer properties, plus additional water supply from the Great Cobar shaft.

4.2 Additional groundwater monitoring

Following submission of the EIS and further updates to the groundwater model, an additional bore within the model domain was identified. Groundwater bore 85WA752553 (also known as GW309105) is located approximately 12.5 km to the south west of Cobar, as shown in Figure 4.1. Given that the bore lies outside the simulated maximum extent of the 0.5 m drawdown contours over the entire predicted mining period, it is assumed that the bore is at low risk of impact from development of the New Cobar Complex. For completeness, this bore was imported to the groundwater model as a watertable monitoring point, and the simulated hydrographs at this location were exported for each of the predictive model simulations to assess the potential impacts of dewatering associated with the New Cobar Complex Project.



\\emmsvr1\emm\Jobs\2019\J190278 - New Cobar Complex\GIS\02_Maps_GWA\GWA015_WSModMaxDD_BaseInflow_20210629_03.mxd 30/06/2021

Source: EMM (2021); DFSI (2017); GA (2011)

0 1 2 km
GDA 1994 MGA Zone 55
N

KEY

- Groundwater bore
- Base case additional water supply modelled drawdown (0.5 m contour)
- Low inflow additional water supply modelled drawdown (0.5 m contour)
- High inflow additional water supply modelled drawdown (0.5 m contour)
- Project area
- Rail line
- Major road
- Named watercourse
- Waterbody

Groundwater bore locations

Peak Gold Mines
New Cobar Complex Project
Great Cobar shaft water supply modelling
Figure 4.1

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4.3 Modelled hydrograph results

Groundwater elevation hydrographs for the additional model scenarios and uncertainty runs are presented for the additional water supply work (GW309105) located to the south west of Cobar in Figure 4.2 and Figure 4.3.

Figure 4.2 shows modelled hydrographs at GW309105 for the four predictive model scenarios, showing modelled induced drawdown and recovery following mine dewatering. Changes in aquifer properties result in changed starting groundwater levels, so drawdown is not directly compared for the scenarios.

The base case model (GC_tpred1) with no additional dewatering results in a minimum groundwater elevation of approximately 185 mAHD. Shaft water supply extraction for GC_tpred2 results in no additional drawdown at this location, with GC_tpred2 modelled hydrographs overlying GC_tpred1. The bounds of reasonable aquifer properties with water supply extraction from the historic void result in hydrographs on either side of this range, with minimum groundwater elevation from 183.8 to 185.1 mAHD.

Each of the scenarios show drawdown of less than 0.5 m at GW309105, though continuing to increase at the end of simulation, 1,000 years following the cessation of mining. This is considered to be likely associated with ongoing groundwater discharge at the New Cobar open cut pit, but not deemed environmentally significant.

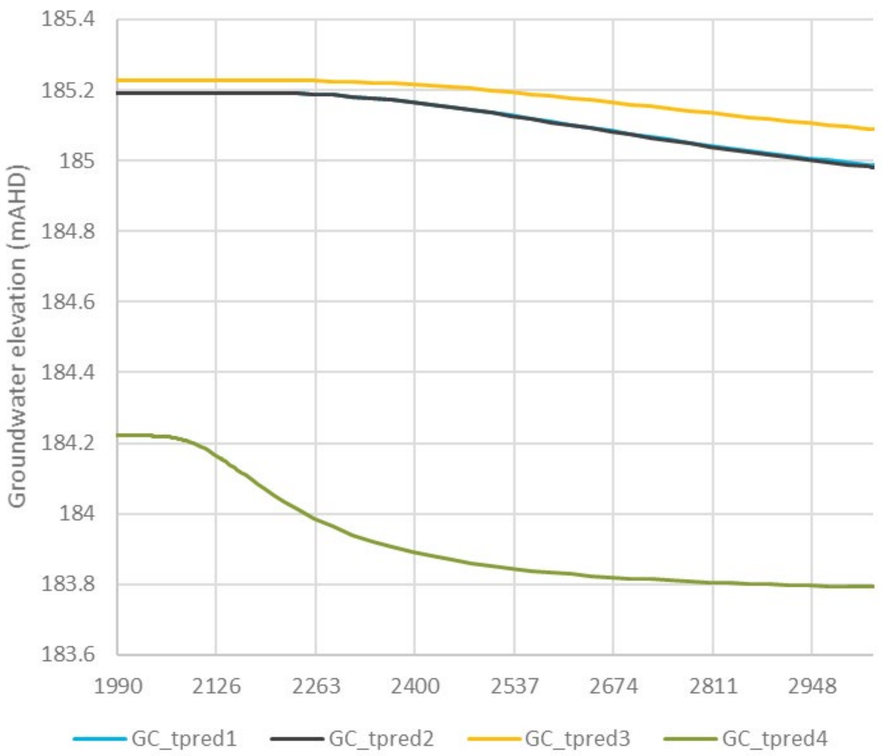

Figure 4.2 Modelled groundwater elevation hydrographs at water supply work GW309105

Modelled groundwater level hydrographs at GW309105 for GC_tpred2 and the void properties uncertainty runs are presented in Figure 4.3. As with the maximum spatial extent of drawdown, the void geometry and adopted parameters have very little influence on more regional drawdown effects, including at GW309105.

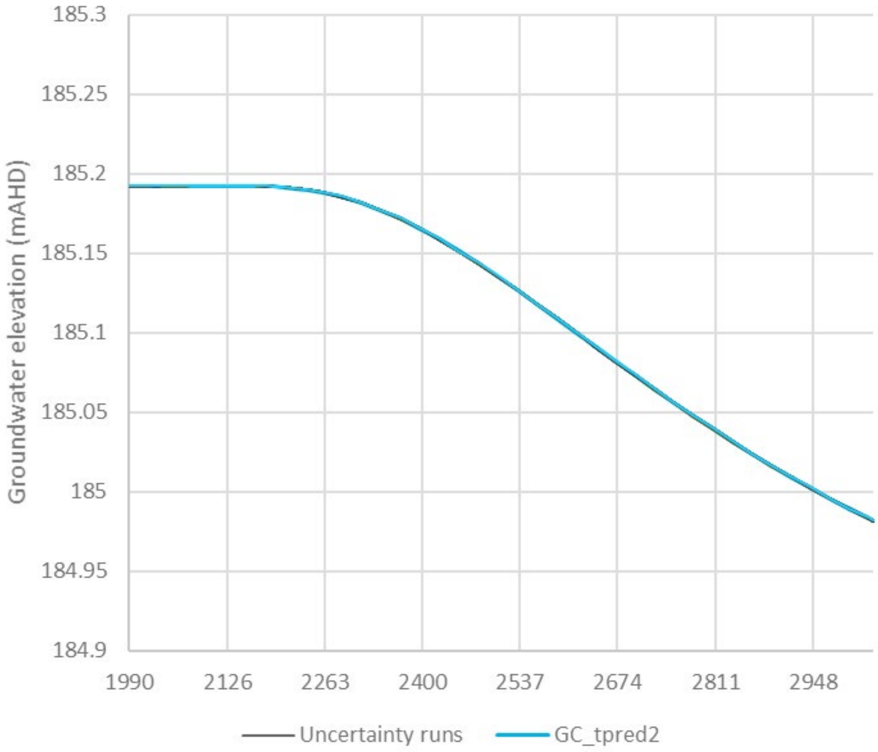

Figure 4.3 Modelled mine void uncertainty analysis of groundwater elevation hydrographs at water supply work GW309105

4.4 Minimal impact consideration

The AIP outlines minimal impacts considerations for assessing potential groundwater impacts in NSW. The minimal impact considerations are a series of thresholds that define minimal impacts from aquifer interference activities. There are two levels of minimal impact considerations, being Level 1 and Level 2. If the predicted impacts are less than the threshold level specified by the Level 1, then these impacts are acceptable under the AIP. Where the predicted impacts at a water supply work are greater than the Level 1 minimal impact considerations, then 'make good' provisions should apply. Based on the NSW Government's mapped areas of groundwater productivity in NSW (DPI 2012b), the Project is within the 'less productive' fractured rock source of the Lachlan Fold Belt Murray-Darling Basin. Therefore, the relevant Level 1 impact consideration threshold is no more than 2 m decline in water table at any water supply works.

The maximum predicted drawdown at water supply work GW309105 is well below 2 m in all modelled scenarios. Therefore, the Level 1 impact consideration threshold will not be exceeded and predicted impacts are considered acceptable. Make good provisions are not required under the AIP.

5 Conclusion

DPIE Water and NRAR recommended that prior to approval, an independent peer review of the numerical groundwater model needs to be undertaken, and assessment is required to include BLR bore 85WA752553. The independent review was conducted by Hugh Middlemis, who concluded that the groundwater modelling assessment has generally been conducted consistent with best practice and is fit for the purpose for guiding impact assessment, mitigation and management planning and licensing.

From a minimal impact perspective on water supply work GW309105, the Level 1 impact consideration threshold will not be exceeded and predicted impacts are considered acceptable. Make good provisions are therefore not required under the AIP.

Yours sincerely

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6 References

Barnett B, Townley L, Post V, Evans R, Hunt R, Peeters L, Richardson S, Werner A, Knapton A, Boronkay A (2012). Australian Groundwater Modelling Guidelines. National Water Commission. http://webarchive.nla.gov.au/gov/20130420190332/http://archive.nwc.gov.au/library/waterlines/82.

EMM 2021a, New Cobar Complex Project, State Significant Development (SSD10419) Environmental Impact Assessment. Prepared by EMM Consulting on behalf of Peak Gold Mines.

EMM 2021b, New Cobar Complex Project, State Significant Development (SSD10419) Groundwater Impact Assessment. Prepared by EMM Consulting on behalf of Peak Gold Mines.

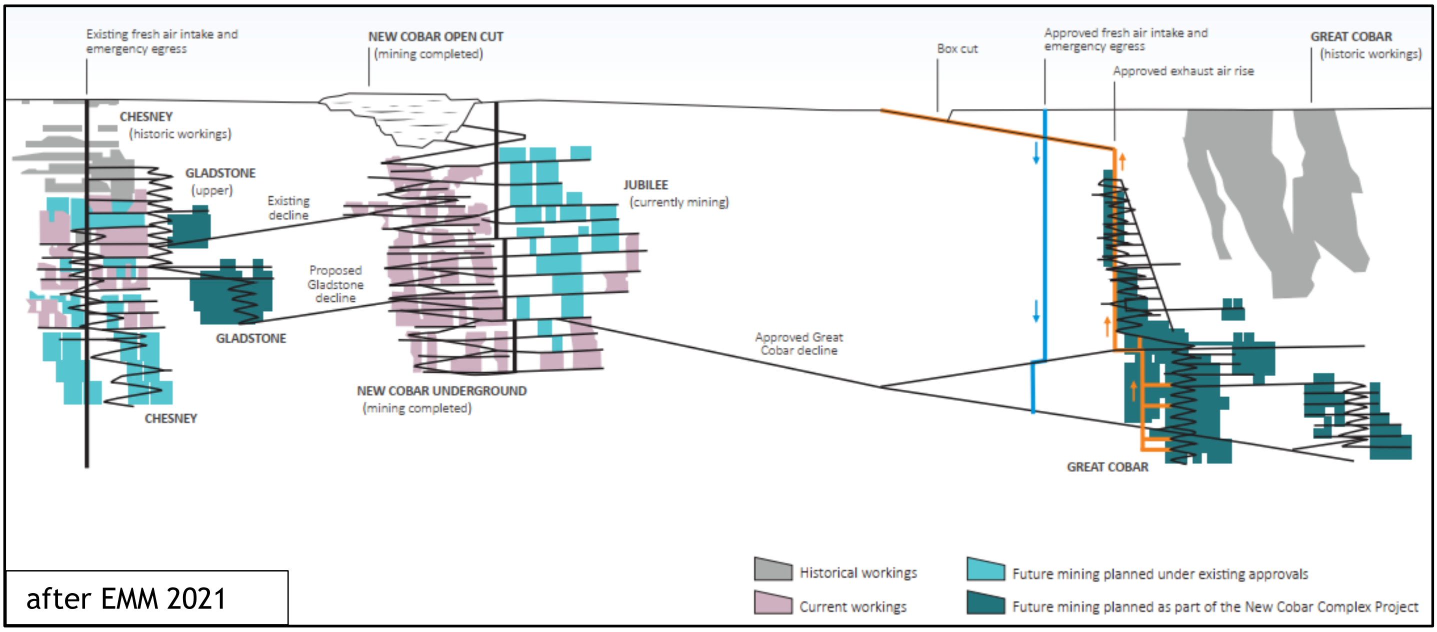
Middlemis H, Walker G, Peeters L, Richardson S, Hayes P, Moore C (2019) Groundwater modelling uncertainty – implications for decision making. Summary report of the national groundwater modelling uncertainty workshop, 10 July 2017, Sydney, Australia. Flinders University, National Centre for Groundwater Research and Training. https://dspace.flinders.edu.au/xmlui/handle/2328/39111

Appendix A

Groundwater Assessment Peer Review

New Cobar Complex SSD-10419
Groundwater Assessment Peer Review

Prepared for:	Peak Gold Mines	26 July 2021



after EMM 2021

HydroGeoLogic

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HydroGeoLogic

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Version 1	12 May 2021	Initial draft
Version 2	26 July 2021	Updated re some details in EMM memo 16 July 2021

THIS REPORT SHOULD BE CITED/ATTRIBUTED AS:

Middlemis H (2021). New Cobar Complex SSD-10419 Groundwater Assessment Peer Review. Prepared by HydroGeoLogic for Peak Gold Mines. 26 July 2021.

1. INTRODUCTION

1.1 New Cobar Complex

The New Cobar Complex is a proposed amalgamation of existing and new mining projects near the township of Cobar in western NSW (Figure 1), forming State Significant Development SSD-10419. The New Cobar Complex is owned and operated by Peak Gold Mines Pty Ltd (PGM), a wholly-owned subsidiary of Aurelia Metals Limited.

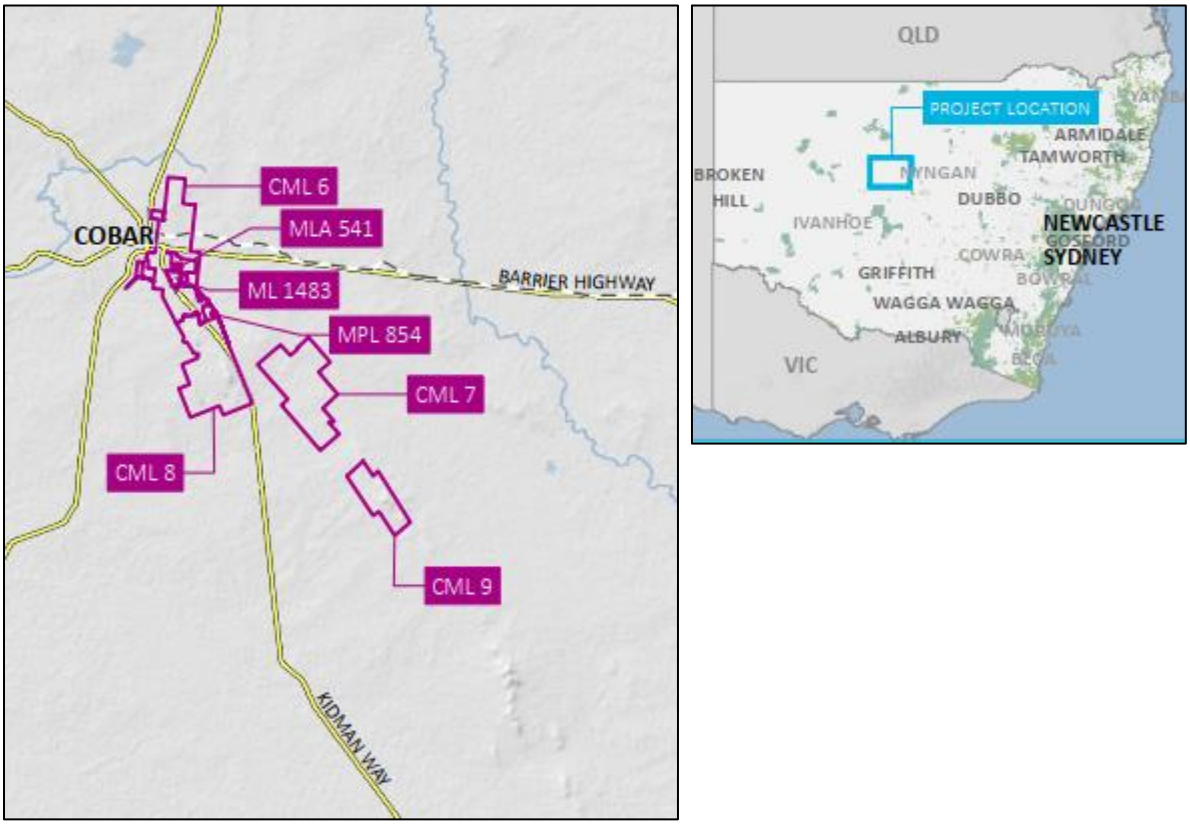

Figure 1 New Cobar Complex mining leases (after EMM 2021)

The Cobar area has a history of gold, silver, copper, lead and zinc production since mining began in 1870 (EMM 2021). Peak Gold Mines has been operational since 1991 when mining commenced at the Peak deposit about 10km south-east of Cobar. Mining at the New Cobar Complex about 3km south-east of Cobar commenced with the open pit mine in 2000, then transitioned to underground mining in 2004.

1.2 Peer Review Methodology

The scope of work comprises a desktop peer review of the Groundwater Assessment ('GA'; EMM 2020a) that supports the New Cobar Complex Environmental Impact Assessment (EMM 2021), to address this item of the DPIE Water advice of 12 April 2021:

> *Undertake an independent peer review of the numerical groundwater model. The numerical model has been prepared in accordance with the Australian Groundwater Modelling Guidelines to a standard suitable for the scale of activity and the relatively low-risk of groundwater impacts in the area. However, the*

model has not been independently peer reviewed as required by the Aquifer Interference Policy (AIP).

Accordingly, this independent peer review was conducted consistent with the best practice guidelines on groundwater modelling and uncertainty analysis, with a focus on:

- the hydrogeological understanding and conceptualisation, and implementation in numerical and/or analytical models, and the fitness for the purpose of groundwater impact assessment via simulations of mining and depressurisation/dewatering effects, and related water management and mitigation actions, and mine closure scenarios;
- conformance to best practice guidelines in relation to model calibration performance, with consideration of domain, grid, boundary conditions, layering and parameterisation; non-uniqueness and sensitivity-uncertainty prediction scenarios and results;
- whether the assessments made, or conclusions reached, are supported by the evidence presented, and whether additional information, monitoring, assessment and/or modelling may be required to inform the assessment of the project.

The best practice principles and procedures of the Australian Groundwater Modelling Guideline (Barnett et al. 2012) were applied to conduct this review, as there are no standard procedures for peer reviews of groundwater investigations and impact assessments as such. Consideration was also given to recent guidance on uncertainty analysis (Middlemis and Peeters, 2018, regarding coal mines and CSG; and Middlemis et al. 2019, which is more generally applicable and actually was the basis for the former). A key principle in these guidelines is that assumptions and simplifications should be justified and clearly reported in an open manner that is amenable to review.

The main evidentiary basis for this peer review is the Groundwater Assessment ('GA'):

- EMM Consulting (2020a). New Cobar Complex Project SSD-10419 Groundwater Assessment. Presented as Appendix I to EIA (EMM 2021). Prepared for Peak Gold Mines. November 2020.

Other reports were considered, notably the Cobar EIA itself for general project information, and the rehabilitation strategy for information on mine closure:

- EMM Consulting (2021). New Cobar Complex Project SSD-10419 Environmental Impact Assessment. Prepared for Peak Gold Mines. February 2021.
- EMM Consulting (2020b). New Cobar Complex Project SSD-10419 Rehabilitation and Landscape Management Strategy. Presented as Appendix N to EIA (EMM 2021). Prepared for Peak Gold Mines. December 2020.
- EMM (2021) Response to Submissions - New Cobar Complex groundwater modelling update. Prepared for Peak Gold Mine. 16 July 2021.

The review outcomes are summarised using the modelling guideline compliance summary checklist (after Table 9-1 of Barnett et al. 2012), presented as Table 1 below in section 2, which has cross-references to numbers of GA sections, tables and figures. Some details are discussed further in section 3. This desktop review was conducted in May and July 2021 by Hugh Middlemis of HydroGeoLogic; brief bio information is provided in section 5.

2. NEW COBAR PEER REVIEW OUTCOME SUMMARY

Table 1 - Groundwater Model Compliance: 10-point essential summary: New Cobar Complex

Question	Y/N	Comments re New Cobar Complex groundwater modelling
1. Are the model objectives and model confidence level classification clearly stated?	Yes	Objectives clearly stated for groundwater assessment (s.1.2) and model (s.8.1), claiming Class 1 plus some Class 2/3. This review assessed Class 1 overall plus some Class 2/3 (see Table 2).
2. Are the objectives satisfied?	Yes	Method and results suitable for groundwater impact assessment purposes within arguably low risk context of low permeability and saline fractured rock aquifer with little use and no high priority GDEs, and sensitivity/uncertainty analysis to address limitations.
3. Is the conceptual model consistent with objectives and confidence level?	Yes	Hydrogeological Conceptual Model appears sound (GA Table 6.1, Figures 6.2, 6.3), consistent with data, objectives and Class 1/2 confidence level, suitable for mining impact assessment.
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	Basic knowledge base outlined in GA s.4 and s.5, based mainly on specific studies for proposed New Cobar Complex since 2019. Only 6 bores in New Cobar Complex, data since mid-2020. More data from 8 bores at Peak Complex since 1990, characterising regional trends. Acknowledged limited data to fully conceptualise fault influences. Little reported data on mine extents, levels, inflows.
5. Does the model design conform to best practice?	Yes	The model setup is consistent with best practice design and execution (noting the arguably low risk context), in terms of: • methodology (GA s.8) and software (Modflow-USG and Vistas); • design; equivalent porous medium approach applied to fractured rock aquifers; leakage from tailings storages and mine water management dams excluded from scope; • extent (20x20 km) and quad-tree rectangular grid (max. 200m cells, min. 25m, except 6.25m min. at Great Cobar open pit); • layers (24); 3 main layers each for weathered and fractured rock, with extra 18 fractured rock sub-layers in mine areas; • layer elevations; generally horizontal and uniform ~50-100m; • boundaries; constant head at 15-30m below ground level for regional thru-flow north-east to south-west ~0.5-0.6 ML/d; • rainfall recharge; from chloride mass balance method, steady rate ~0.13mm/y, gives small input to model ~0.14 ML/d; • evapotranspiration; 2400 mm/y max. rate, extinction depth 2m, but deep water table, so ET active only in low-lying areas and effectively zero flux out ~0.0 ML/d; • parameters; uniform per layer ok as parsimonious approach; Great Chesney fault low Kh (GA Table 8.4), uncertainty tested; • u/g mine levels; annual steps in drain features (GA Table 8.3); gives inflows of ~1 ML/d since 2008 (GA Figure 8.8), roughly consistent with recorded 2018-19 average of 0.7 ML/d; • u/g mine voids; high-K method (1000 m/d), Sy = 5-50% OK, assumed that backfill does not change void properties; • open pit voids for current and future conditions use high-K lake method (K=1000m/d, Sy=100%); Great Cobar pit void lake has negative recharge ~0.02 ML/d for evaporation groundwater sink; no existing lake present, so benchmarking not possible; • New Cobar pit void assumed currently dry due to very low if any inflow (partly due to u/g under-drainage?) exceeded by evaporation; during mining drain cells set down to 158 mAHD (GA Table 8.3), likely under-drained by u/g workings; post-mining, drain features are retained, and aquifer recovery causes inflows to increase 0.02-0.05 ML/d (GA Table 8.9).

Question	Y/N	Comments re New Cobar Complex groundwater modelling
6. Is the model calibration satisfactory?	Yes (for Class 1 model)	Model calibration statistical performance is poor; 18% scaled RMS; scatter plot shows bias at all levels. Hence overall Class 1 despite some Class 2/3 attributes on other criteria. Some time series groundwater level trends ok (GA Fig. 8.6), but not all and no match to measured rises at Peak Complex bores GW3-GW5 (tailings seepage effect?). No parameter identifiability assessment. Basic parameter sensitivity analysis via 15 simulations that applied factors from 10 to 0.01 to recharge and to key aquifer properties for the weathered and fractured rock units: Kh, Kv, Sy, SS (GA Table 8.7). High sensitivity to high Kh and Kv of fractured rock, and to low Sy. Deterministic uncertainty analysis based on sensitivity was later applied to address limitations.
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Model parameter values are adequately consistent with drilling and testing information. History match (GA Figure 8.8) gives modelled dewatering ~1 ML/d (11 L/s) since 2008, compared to measured inflows of about 0.7 ML/d (8 L/s), indicating plausible fluxes but not a close match. Performance arguably adequate for low risk setting (brownfields, low K, saline water, no GDEs).
8. Do the model predictions conform to best practice?	Yes	Drain cells applied to base of mine as annual steps in mining progression. Steady stresses of rainfall recharge and constant head regional groundwater inflow and outflow, reasonably justified by lack of observed seasonal groundwater dynamics. Scenario differencing (mining case minus null case) is a best practice method to reduce uncertainty. Predicted drawdown is calculated as difference from 2020 levels (GA Fig. 8.13), ignoring existing drawdown to 2020, but report does not emphasise this. Hence assessment of cumulative impacts is not clearly presented, but GA Fig. 8.5 shows modelled 2020 and pre-mining levels. Most drawdown impacts minimal (AIP Level 1) but exceeds level 1 at GW803422 (GA Figure 9.1), so level 2 make good may apply. EMM memo 16 July 2021 notes that predicted drawdown at bore 85WA752553 (GW309105) is less than 0.5m, within Level 1. No high priority GDEs, and potential GDE assessment concludes low impact risk mainly due to depth to saline water (GA s.9.3). Great Cobar shaft water supply pumping (GA Figs 9.4, 9.5, App. D) uses refined grid model, conducts sensitivity/uncertainty analysis. Post-mining: see item 5 above for void parameters applied to mined-out areas (u/g and o/c). Assumption applied that any u/g void backfill does not change properties. This will invoke a bias, not highlighted in the report, that will over-estimate void storage volumes in New Cobar and thus under-estimate post-mining groundwater level recovery. Not a material issue, as low sensitivity to storage was demonstrated.
9. Is the uncertainty associated with the simulations/predictions reported?	Yes	Despite poor calibration, prediction uncertainty likely not major, given: modelled inflows are broadly consistent with historical mining data (similar stresses); 12-year prediction is less than 18-year Peak Complex history match (range not stretched); boundary fluxes unchanged as drawdown effects do not reach boundaries. Base case mining impacts presented as 2m drawdown contour for 2032 compared to 2020 levels. Selected key parameters tested for sensitivity (see item 6. above). Deterministic uncertainty analysis (UA) based on sensitivity results, arguably adequate given low risk context. Limited UA results indicate base case impacts are conservative (GA Fig. 8.17) with low likelihood of exceedance. Qualitative UA commentary basic but adequate for moderately low risk context GA, consistent with AIP minimal impact issues.

Question	Y/N	Comments re New Cobar Complex groundwater modelling
10. Is the model fit for purpose?	Yes	New Cobar Complex groundwater modelling assessment has generally been conducted consistent with best practice, noting low risk context (brownfields, low K, saline water, no GDEs). It is fit for the purpose of mining project groundwater assessment, AIP minimal impact considerations and to inform licensing.

3. DISCUSSION

3.1 Model Confidence Level Classification

The Australian Groundwater Modelling Guidelines ('AGMG'; Barnett et al. 2012) present a schema for model confidence level classification. The schema is based on considerations underpinning the hydrogeological conceptual model and the data available, especially aquifer responses to hydrological stresses, as well as the model design, construction and performance. It is expected that any model will have attributes that fall into more than one 'class', with the overall 'confidence level' indicated from the weight of criteria that are met.

The AGMG actually recommends the confidence level method for application to situations when a formal uncertainty analysis has not been conducted (ie. unlike this case), although it is a common misconception that the model confidence level assessment is mandatory for every model. Nonetheless, the Groundwater Assessment report (EMM 2020a, section 8.2.1) claims a Class 1 model confidence level classification, with some aspects of Class 2 and Class 3. While the GA report does not provide comprehensive justification of the Class 1 adequacy, it makes the valid statement that the uncertainty analysis approach is designed to address the Class 1 limitations.

This peer review concurs with the Class 1 assessment (see Table 2 below), confirming the model as fit for purpose in principle, and suitable for impact assessment scenario modelling purposes, noting the deterministic uncertainty analysis conducted.

From past experience, this reviewer knows that agencies often have low confidence in results from so-called Class 1 models. This reviewer considers that a Class 1 model should be deemed adequate for assessment purposes in this case, given the historical brownfields mining setting, existing approvals, and the likely low risk context, noting:

- the fractured rock aquifer conditions exhibit low permeability and saline water;
- two existing groundwater users (GW804322; 22 m deep, 0.5 L/s at 3000 EC) and GW309105, about 12.5 km south of Cobar (little data on this bore, but predictions indicate less than 0.5 m drawdown, well within Level 1 AIP criteria);
- monitoring shows no evidence of widespread groundwater level decline due to historical mining operations, which have reported relatively low inflow volumes (New Cobar Complex averages 1-15 L/s, and for Peak Complex <0.5L/s);
- there are no high priority GDEs identified in the vicinity;
- a deterministic uncertainty analysis was conducted to quantify potential impacts under a range of conditions.

Table 2 - model confidence level assessment (after Middlemis and Peeters, 2018)

Model Confidence Class characteristics: New Cobar Complex (2021)

Class		Data		Calibration		Prediction		Quantitative Indicators
1	~	Not much / Sparse coverage		Not possible		Timeframe >> Calibration		Predictive Timeframe >10x Calib'n.
	√	No metered usage (in local area)	√	Large error statistic.		Large stresses/periods.		Predictive Stresses >5x Calib'n.
(simple)		Low resolution topo DEM.	√	Inadequate data spread.	√	Poor/no verification.		Mass balance > 1% (or one-off <5%)
		Poor aquifer geometry.		Targets incompatible with model purpose.		Transient prediction but steady-state calibration.		Properties <> field values.
		Basic/Initial conceptualisation.					√	Poor performance stats / no review
2	√	Some data / OK coverage.	~	Weak seasonal match.		Predictive Timeframe > Calib'n.		Predictive Timeframe = 3-10x Calib'n.
	~	Some usage data (dewatering est.).	~	Some long term trends wrong.		Different stresses &/or periods.		Predictive Stresses = 2-5x Calib'n.
	~	Some Baseflow estimates and some K & S measurements.	~	Partial performance (e.g. some stats / part record / model-measure offsets).	~	No verification but key simulations constrained by data		Mass balance < 1% (all periods) (OK at times reported; probably all time)
(impact assessment)	~	Some high res. topo DEM and adequate aquifer geometry.	~	Head & Flux targets constrain calibration.	√	Calib. & prediction consistent (transient or steady-state).	~	Some properties maybe <> field values. (possible in frac. rock setting)
	~	Sound conceptualisation, reviewed & stress-tested.	~	Non-uniqueness, sensitivity and qualitative uncertainty addressed. (some aspects OK)	~	Magnitude & type of stresses outside range of calib'n stresses.	√	Some poor performance (but no coarse discretisation in key areas/times).
3	x	Plenty data, good coverage.	x	Good performance statistics	√	Timeframe ~ Calibration	√	Predictive Timeframe <3x Calib'n. (OK except of course for post-mining)
	x	Good metered volumes (all users).	x	Most long term trends matched (some OK	~	Similar stresses &/or periods.	~	Predictive Stresses <2x Calib'n.
	x	Local climate data & baseflows.	x	Most seasonal matches OK (some OK).	x	Good verification or all simulations constrained by data	√	Mass balance < 0.5% (all periods)
(complex simulator)	x	Kh, Kv & Sy measurements from range of tests.	~	Calibration to present day head & flux targets.	NA	Steady state prediction only when calibration in steady state.	~	Properties ~ field measurements. (OK; complex frac. rock setting / EPM)
	x	High res. topo DEM all areas & good aquifer geometry.	x	Non-uniqueness minimised &/or parameter identifiability &/or minimum variance or RCS assessed.	√	Suitable computational methods applied & parameters are consistent with conceptualisation		No poor performance or coarse discretisation in key areas (grid/time).
	x	Mature conceptualisation.	~	Sensitivity &/or Qualitative Uncertainty	x	Quantitative uncertainty analysis	√	Review by experienced Hydro/Modeller.

(after Table 2-1 of AGMG (Barnett et al. 2012) and Figure 5 of IESC uncertainty guidance (Middlemis & Peeters 2018))

	Criterion met at higher Class
~	Criterion partially met at relevant Class
√	Criterion met at the relevant Class
x	Criterion not met by current model study

3.2 Overview on Fitness for Purpose

A model's fitness for purpose should be judged in relation to the stated modelling objectives, which in this case are set out in section 8.1 of the GA (EMM 2020a):

- assess the historical and predicted changes to groundwater pressure caused by the historical open cut and current and historic underground stope mining operations;
- assess the likely impacts on any water courses, riparian environments, and other water users, namely the GW803422 water supply work [irrigation bore at the Rugby ground], the historical Great Cobar open cut and the surrounding potential GDEs; this was later augmented (EMM memo 16 July 2021) to include bore 85WA752553 (GW309105), about 12.5 km south of Cobar.
- estimate the likely mine inflows to inform licensing requirements and support the water balance assessment studies;
- estimate the extent of drawdown to inform supporting geochemical studies; and
- simulate any mitigation systems to offset undesirable groundwater impacts, if applicable.

Before continuing, it is noted that the second point above mentions the 'historical open cut', although it is not clear whether this refers to the historical (1919) Great Cobar open pit void (currently a pit void lake feature), and/or the existing New Cobar open pit void (currently understood to be dry). Indeed, the narrative in the GA report does not take pains to clarify whether the open pit voids or the underground voids are being discussed, which can cause some confusion when interpreting model design, execution and results. During this review, several phone calls and emails were exchanged with the EMM modeller (Mr Neill), who provided adequate clarifications. For example, the groundwater model actually does include features to adequately represent groundwater interactions with both open cuts, and the prediction results presented demonstrate little change to the estimated groundwater discharge from the post-mining pit void lakes.

The modelling objectives (above) invoke a design intent to address the SEARs (Secretary's Environmental Assessment Requirements) and other agency requirements that are set out in the GA in section 1.2.

In summary, the modelling objectives are reasonable and adequate in that they essentially require quantification of mine inflows and related drawdown impacts. This is designed to address the identified direct and indirect effects of mining in a manner consistent with the risk-based mining project assessment approach of Moran et al. (2010) that is set out in GA section 7, and the related methods of Robinson et al (2010). These are accepted methodologies for best practice mining impact assessments, including source-pathway-receptor impact analysis that is consistent with the risk-based causal pathway impact analysis that is recommended in the best practice modelling guidelines (Barnett et al. 2012) and uncertainty analysis guidance (Middlemis et al. 2018 and 2019).

The GA generally provides adequate details, explanations and justifications regarding the conceptual hydrogeological model and the numerical model design and execution to enable assessment sufficient to meet the objectives and the SEARs. Any exceptions identified by this review are discussed herein, but are not sufficient to undermine confidence in the overall modelling fitness for the purpose of mining impact assessment, given the generally low risk context (eg. brownfields, low permeability, saline groundwater, no priority GDEs nearby).

3.3 Conceptualisation, Design and Calibration Performance

The hydrogeological conceptualisation basis is sound, based on a range of investigations over many years, and has generally been implemented aptly in the model. The 3D model domain/extent, layer setup, grid design, boundary conditions and parameters applied are generally consistent with the available information and conceptualisation, with some minor exceptions noted below.

The model grid design is acceptable, despite the apparent lack of an explanation as to why the grid was refined to 6.25 m cells at the Great Cobar open pit but only 25 m cells at the New Cobar open pit (GA Figure 8.1). It later becomes apparent (GA section 9.3 and related Appendix D), although is not specifically stated, that the grid refinement was required in order to apply the model to the Great Cobar shaft water supply scenarios. The model as reported is fit for the purpose of such analysis, and for the related sensitivity analysis that was conducted. That water supply assessment concluded that water stored in the Great Cobar shaft is sufficient to supply the water requirements for the project in the absence of the Burrendong Dam water source, with a low risk in water supply security terms.

Back to the mining scenarios, the model time-stepping involves a 10,000-year initial pseudo-steady state warm up, subsequent history match calibration 1990-2020 and then prediction to 2032 with annual stress periods, then 100-years post-mining transient followed by 1,000-years pseudo-steady state for long term impacts. There appears to be not a great deal of historical data on the mine progression and related inflows and pit void lake levels, so although the annual steps are somewhat coarse, the assumptions involved are not unreasonable, but this can result in some matches to time series groundwater levels and mine inflows that are less than ideal.

The MODFLOW-USG software applied is a recent version of that industry-leading platform, and it has suitable capability for the assessment purpose. The model calibration performance is poor statistically (18% scaled RMS), partly due to uncertainties arising from the fractured rock aquifer setting and also partly due to poor data capture of historical mine dewatering volumes (eg. GA Figure 8.8). The time series matches to monitoring data are mostly adequate, although rising trends apparent in some bores at the Peak Complex are excluded from the performance assessment as they are not matched by the model. It is possible that the rising trends could be in part due to seepage from the tailings storage facilities (TSF) at the Peak Complex, although the TSF is excluded from the assessment scope and there is no TSF seepage included in the model.

The simulated groundwater flow pattern generally reflects the hydrogeological understanding, although the reason why the modelled drawdown in 2020 extends further east of the Great Chesney Fault in the Peak Complex area than it does in the New Cobar

Complex area (GA Figure 8.5) is not well understood or explained. This is unfortunate because the groundwater level data record is short in the New Cobar Complex area, but it extends back to the early 1990s in the Peak Complex area, and the model performance is reasonable in this area (except for the noted rising trend). In any case, the fault properties were investigated further via the deterministic uncertainty analysis and the results are shown to be not sensitive.

3.4 Conceptualisation in Great Cobar area

There are some poor explanations and/or inconsistencies in some aspects of the report documentation regarding the Great Cobar area, which could be addressed with improved documentation (eg. in an Addendum to the Groundwater Assessment):

- the GA report states at Table 7.2 that the Great Cobar open pit void contains 'water to a level higher than surrounding groundwater' (suggested to be due to surface water inflows), and yet the conceptual hydrogeological model does not show this effect (GA Figure 6.2); rather, it shows the Great Cobar open pit extending below the water table (shown at around 230 mAHD), which may also be correct, but a cogent explanation for these differences is not provided, nor is there any data or predictions provided on the pit lake water levels;
- one of the many existing shafts at Great Cobar is licensed to PGM for water extraction purposes; it is connected to the nearby underground workings that are estimated to contain a volume of 1.6 GL (GA Table 7.2); the GA does not specify the shaft location or detail other physical properties, and it does not state whether measurement data exist for the water level in the shaft; however, the time series at Figure 8.6 and Figure 9.4 indicate a modelled shaft level of about 215 mAHD;
- the Rugby Club bore GW803422 is located roughly 1 km south of the Great Cobar open pit, with time series data indicating a current level of about 224 mAHD (GA Figure 5.2 & 9.1), which is apparently lower than the Great Cobar pit void lake and yet higher than the modelled level in the Great Cobar shaft that is connected with the underground workings;
- the GA suggests that there is no direct hydraulic connection from the existing Great Cobar underground workings to the Great Cobar open pit void lake (presumed from Figure 6.2 to have a water level of about 230 mAHD); the levels estimated above would support that view, otherwise there should be some equilibration apparent; clear explanations are not provided in the GA report for these differences between levels in the pit, shaft and bore near Great Cobar, although such narrative would help the reader to understand the conceptual hydrogeological model;
- the model is designed with an evaporative groundwater sink feature for the Great Cobar pit void lake (final paragraph of GA section 8.2.5), and the model water balance indicates that this discharge is about 0.02 ML/d (0.2 L/s), which reportedly does not change throughout the various simulations; however, that does not satisfy the expectation of a more comprehensive discussion of the impacts on the Great Cobar pit void lake, given the stated modelling objectives.

There is little discussion on the potential for hydraulic connections between the various undergrounds and the final void pits, and nor does it provide adequate detail on the pit characteristics (levels and areas of pit floors and pit lakes). However, based on the above discussion, it would appear unlikely that there is a significant flux exchange currently between the high level in the Great Cobar pit void lake and the nearby undergrounds. Conditions at the New Cobar open pit void and undergrounds may be similar, as discussed next.

3.5 Post-Mining Final Voids

The rehabilitation report (EIA Appendix N; EMM 2020b) notes in section 3.2.1(iii) that the project will not result in the formation of new landforms, and that existing landforms are the result of previous approvals, with the landform attributes outlined in the approved mining operation plan (MOP). This is assumed to include the historical Great Cobar open pit void (an existing tourist attraction) and the existing 100 metre deep New Cobar open pit void. Access to all underground workings is through the existing portal and decline at the base of the existing New Cobar open pit, and via proposed declines.

The management of the existing approved New Cobar open pit is reportedly unchanged from the existing approvals by Cobar Shire Council, while the proposed Box Cut at the New Cobar Complex will be backfilled post-mining. At the completion of mining the New Cobar portal will be sealed in accordance with the Resources Regulator requirements.

Paraphrasing the GA and rehabilitation reports (EMM 2020a,b) on the proposed waste rock and void backfill management principles and related potential water quality issues:

- waste rock from underground workings will be used preferentially to backfill underground stopes, with priority given to using potentially acid-forming (PAF) material, while some waste rock material may be brought to the surface for:
  - storage within the existing emplacements at the New Cobar Complex until it is used in tailings lift construction or rehabilitation works across the Peak and New Cobar complexes; or, at the end of mine life;
  - returned progressively underground for disposal, or otherwise encapsulated by non-acid forming (NAF) materials in waste rock emplacements;
- the post-mining open pit and underground voids are predicted to remain groundwater sinks, and the slow recovery of groundwater levels will result in inward draining of groundwater to the underground voids that will prevent outward seepage of any acidic and metalliferous water, and thus no preventative or mitigating controls are proposed to manage acid mine drainage in underground workings (EIA Appendix N, section 3.2.1; EMM 2020b).

The rehabilitation report (EMM 2020b) at section 3.2.1(iii) cites a report (NSR 2000) on groundwater modelling conducted for the New Cobar final pit void that showed that the void would function as a groundwater sink, with a water level predicted to reach an equilibrium level of 20 to 30 m above the pit floor. The rehabilitation report states that the latest Groundwater Assessment (ie. EMM 2020a) identified that latest modelling predictions show that groundwater levels will be ‘below the floor of the open cut and it will not pond water’. However, it is understood that is referring to operational conditions only, when underground workings will effectively under-drain the open pit.

The GA (EMM 2020a) provides adequate information, but in a very confusing manner, regarding how the 2020 groundwater modelling program represents the final voids:

- existing open pit voids are represented with void properties (eg. high permeability and 100% porosity values; GA Table 8.4), which are applied to during mining and post-mining;
- underground workings are also represented with void properties from the end of underground mining at each site (GA section 8.6.2), but with a hybrid porosity (Sy) value of 5% to 50% (GA Table 8.4), presumably to represent a degree of backfilling;
- open pit discharge boundary conditions represent inflows during mining, and are understood to continue post-mining (report does not clarify, and Tables 8.3 and 8.8 provide no details for New Cobar open pit post-2004):
    - New Cobar open pit void drain elevation at 158 mAHD (GA Table 8.3);
    - Great Cobar open pit void lake specified discharge at 0.02 ML/d (Table 8.5);
- underground mine inflows are represented via drain boundary conditions during mining only:
    - GA Table 8.3 for mining 1992-2020;
    - GA Table 8.8 for mining 2020-2032;
    - underground drains are assumed to be de-activated at the end of mining at each site, evidenced by decreased mine inflows post-2025 in GA Figure 8.10.

3.6 Final Open Pit Void Water Balances

Post-mining aquifer recovery should result in increased groundwater levels and hence increased inflows to pit voids, albeit at lower rates than the maximum operational dewatering rates when gradients would be a maximum. As the operational inflow rates are low, it is reasonable to expect that evaporation would be adequate to roughly balance the inflows to a large degree, although it is possible that a pit void lake could develop under some conditions. While the GA report narrative makes similar comments about evaporation balancing inflows, it provides no data on pit areas or depths, nor estimates of evaporation that may justify such a reasonable expectation.

The water balance information presented in GA Tables 8.6 and 8.9 appear to lump together all the open pit and underground drain discharges, presumably including drain discharge at New Cobar. This means that New Cobar open pit inflows are unknown at 2020. However, the total drain discharge at 2132 of 0.03 ML/d, and 0.05 ML/d at 3032 (GA Tables 9.6 and 9.7), is understood to represent New Cobar pit void inflow only because as all other (underground) drains (should) have been de-activated (GA section 8.6.2). Such low inflows are similar to estimated discharge from the Great Cobar pit lake and should be easily balanced by evaporation.

In summary, and assuming the New Cobar pit void drain is the only one operating post-mining:

- the New Cobar pit void is predicted to pond water from post-mining groundwater inflows, but only once surrounding groundwater levels have recovered above the pit floor, and even then, the level is constrained in the model to not exceed 158 mAHD, with modelled discharge appearing to amount to 0.05 ML/d at 3032;

- the existing Great Cobar pit void lake is simulated as discharging water at a rate of 0.02 ML/d throughout mining and post-mining, but the level is not constrained, and nor is it reported, and it is presumed that there is no measured data available.

Apart from the minor inconsistencies outlined above, and with consideration of the generally low risk context (historical brownfields, low permeability, saline groundwater, no priority GDEs nearby), the post-mining modelling has been conducted generally consistent with best practice in terms of the water balance aspects, although the GA report documentation is somewhat incoherent on this topic.

3.7 Final Void Water Quality

The GA has provided few details on what hydrochemical processes may affect the pit void lakes or the underground voids, nor indicated what will be their long term hydrochemical character. The rehabilitation report (EMM 2020b) provides a very simple assessment based on the slow recovery of groundwater levels that will eventually result in inward draining of groundwater to the underground and final pit voids that is postulated to prevent outward seepage of any acidic and metalliferous water. On this basis, no preventative or mitigating controls is proposed to manage acid mine drainage in underground workings.

The final void water quality aspect is assessed as inadequate, in that the GA report provides no details on even the basic water quality parameter of salinity for either the Great Cobar or the New Cobar pit void lake. The GA does not indicate whether there is a long term stable salinity value, nor how long it may take to reach it, nor details on other water quality characteristics and potential acid and metalliferous drainage processes.

3.8 Final Void Closure and Sustainability Issues

Without seeking to challenge existing approvals or the current policy review on mine rehabilitation (DPE 2017), and also noting that the processing plant and the tailings storage facility (TSF) are outside the scope of this project (GA, section 1.1.1), this reviewer outlines below some post-mining groundwater issues.

Best practice mine water management suggests that reduced long term risks to water resources could be achieved by backfilling pits to the pre-mining groundwater level to minimise final void lake evaporation and salinisation impacts (Johnson and Wright, 2003; Younger and Wolkersdorfer, 2004). However, this requires careful evaluation of potential leachate risks, along with consideration of community views. Some international standards (eg. current South African legislation) require that final void lakes should be backfilled for the mine to achieve closure. However, this can involve environmental risks and related financial liabilities, in comparison to environmentally stable pit lakes that act as groundwater sinks in the landscape and can offer a sustainable closure option that may avoid the expense of continual water treatment (Johnstone 2019; McCullough et al. 2013). Ignoring leachate issues for a moment, rather than a backfilling closure strategy, which can be a very expensive challenge to any project, repurposing of final voids for beneficial uses can provide social, environmental and/or economic benefits (DPE, 2017).

In this case, the New Cobar open pit void provides access via existing and proposed declines to the other underground mining areas, which seems to this reviewer to be a reasonable prima facie justification for not backfilling it.

Although there may be existing approvals for the pit lake voids based on a previous assessment, it is presumed that the proposed mining configuration differs from the previous assessment in many details. Without challenging those approvals, this review suggests that improved documentation may be warranted (eg. an Addendum to the GA) to present detailed information on the long term prediction of the final void lake water balances, lake levels, hydro-geochemistry, and a comprehensive justification on the sustainability of the rehabilitation plan in a manner that addresses issues raised in the mine rehabilitation discussion paper (DPE 2017).

4. CONCLUSION

The groundwater modelling and assessment (EMM 2020a) has generally been conducted consistent with best practice and is fit for the purpose for guiding impact assessment, mitigation and management planning and licensing.

There is an acknowledged lack of data on the historical mine progression and inflows, and related groundwater effects of mining, including on the existing Great Cobar open pit void lake, which affects the ability to develop a predictive modelling tool. There is an opportunity to improve the monitoring network during the proposed mining development, to obtain data that can be used to validate and refine the hydrogeological understanding and numerical model, including: expanded groundwater bore network, including east of the Great Chesney Fault; pit void lake level and hypsographic data; underground inflow volume time series and spatial distributions.

Details on the monitoring system are not presented in the groundwater assessment, although the Water Management Plan reportedly provides that information.

5. DECLARATIONS

For the record, the peer reviewer, Hugh Middlemis, is an independent consultant specialising in groundwater modelling. He has a degree in civil engineering and a master's degree in hydrology and hydrogeology, 40 years' experience, and established the HydroGeoLogic independent consultancy in 2013. Hugh was principal author of the first Australian groundwater modelling guidelines (Middlemis et al. 2001) that formed the basis for the latest guidelines (Barnett et al. 2012) and was awarded a Churchill Fellowship in 2004 to benchmark groundwater modelling best practice. He is principal author on two recent guidance reports on modelling uncertainty (Middlemis and Peeters 2018; and Middlemis et al. 2019).

We assert no conflict of interest issues in relation to this work. Hugh Middlemis has not worked on the New Cobar Complex project, nor for Peak Gold Mines, nor for Aurelia Metals.

We note the following in relation to previous interactions between the peer reviewer and the consultants preparing the overall EIA and the groundwater assessment (EMM Consulting):

- The peer reviewer has been engaged several times by EMM to conduct independent peer reviews of EMM groundwater assessments:
  - McPhillamys Gold Project (NSW) groundwater model review (2019-21).
  - Eastern Mallee EM1.3 model (Vic/NSW) for salinity management in Sunraysia (2019-21).
  - Snowy 2.0 (NSW) pumped hydro tunnel groundwater model review (2018-19).
  - Burrawang-Avon Tunnel (NSW) groundwater model review (2020).
  - Chandler Salt Project (NT) groundwater assessment (2016-17).
- The peer reviewer has also been engaged by third parties to conduct peer reviews of groundwater modelling investigations conducted by EMM:
  - Hume Coal project (NSW) groundwater assessment (2017-19; for NSW DPE).
  - Fingerboards mineral sands (Vic.) groundwater assessment (2018-19; for Kalbar).

We note that the peer reviewer's son (Roger Middlemis) has worked for EMM Consulting since March 2019 as an environmental engineer in their Adelaide office, and we understand that he did conduct some data processing tasks to support the Cobar modelling, but the modelling itself was executed predominantly by Mr Tom Neill.

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