

APPENDIX N

Groundwater Model Update – Independent Peer Review

(AGE, 2026)



Memorandum

Project number 20260002.FIN

To Helen Astill & Anthony Kirke

Company Core Lithium

From Keith Phillipson & James Barratt

Date 10 April 2026

RE: BP33 Groundwater Model Peer Review

1 Introduction

Lithium Developments (Grants NT) Pty Ltd (who are a wholly owned subsidiary of Core Lithium) is developing the Finniss Lithium Project located approximately 25 km south-west of Darwin in the Northern Territory. After the discovery of lithium during 2016, Core Lithium developed the project by commencing mining at the Grants pit in late-2022, and then transitioned the Project into care and maintenance since 2024 due to the market conditions. A project optimisation study (Restart Study) also commenced in late-2024 which was completed in 2025. Core Lithium are in the process of completing additional assessments for the revised underground mine plan at the nearby BP33 deposits which aims to extract ore to a depth of 850 metres below surface.

Numerous hydrogeological assessments have been undertaken at Grants and BP33, with a numerical groundwater model developed by CloudGMS Pty Ltd in 2018 and subsequently updated in 2021 and 2023 (CloudGMS, 2018¹; CloudGMS, 2021²; CloudGMS, 2023³). This FEFLOW model primarily focussed on predicting potential impacts to the groundwater system and associated environmental receptors resulting from the development of the proposed underground mine at BP33. In 2025, Artesium Consulting Services Pty Ltd (Artesium) were appointed to update the existing numerical model to complete predictions for potential groundwater inflows and environmental impacts during both the operational and closure phases to support the mine's Environmental Referral to the Northern Territory Government.

Subsequently, Core Lithium engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to undertake an independent peer review of the modelling work completed by Artesium. This memorandum forms that review and focusses on how the conceptual and numerical models function and inform the groundwater impact assessment.

¹ CloudGMS, 2018. Development of a Groundwater Model for the Grants Lithium Project. Final Version 1.0. September 2018.

² CloudGMS, 2021. Finniss Lithium Project BP33 Groundwater Modelling Report. Final Version 3.0. October 2021.

³ CloudGMS, 2023. BP33 Dewatering Assessment 2023 Memorandum. Draft Version 0.1. September 2023.

For this peer review, AGE was requested to undertake the following tasks:

- attend weekly project progress meetings attended by representatives of Artesium, Core Lithium and AGE; and
- review Artesium’s technical Modelling Report (Artesium, 2026⁴).

To assist with the peer review process, the following additional reports were also made available to AGE:

- CloudGMS, 2018. Development of a Groundwater Model for the Grants Lithium Project. Final Version 1.0. September 2018;
- CloudGMS, 2021. Finniss Lithium Project BP33 Groundwater Modelling Report. Final Version 3.0. October 2021; and
- CloudGMS, 2023. BP33 Dewatering Assessment 2023 Memorandum. Draft Version 0.1. September 2023.

2 Peer review methodology

The primary objective of the independent peer review is to assess whether the completed conceptual and numerical modelling adheres to relevant guidelines including the Australian Groundwater Modelling Guidelines (AGMG) (Barnett et al, 2012⁵) and best practise methodologies. This independent peer review was undertaken by Keith Phillipson and James Barratt by attending weekly project progress meetings with Artesium and Core Lithium as well as reviewing the Modelling Report (Artesium, 2026). CVs are attached in Attachment A.

The Modelling Report (Artesium, 2026) consists of the following major chapters:

1. Introduction.
2. Description of the Study Area.
3. Methodology.
4. Hydrogeological Conceptual Model.
5. Model Confidence Level Classification.
6. Groundwater Numerical Modelling.
7. Mine Rewatering Modelling.
8. Groundwater Monitoring.
9. Conclusions.
10. Recommendations.
11. References.

The report provided for review also included the following two appendices:

- Appendix A: Numerical Modelling Assumptions, Material Properties and Calibration.
- Appendix B: Simulated Hydraulic Heads for LOM.

3 Review discussion

The following sections provide a summary of key aspects of the various stages of the model development, following the process outlined in the AGMG.

⁴ Artesium Consulting Services Pty Ltd (Artesium), 2026. Groundwater Model Update – Core Lithium BP33 Mine Groundwater Dewatering Model Update. Project no: 2026-002. 9 April 2026.

⁵ Barnett et al, 2012, Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra.

3.1 Objectives

The objectives of the groundwater assessment are presented in the Introduction section (Section 1.1) of the Modelling Report (Artesium, 2026), where the study is described as an update to the existing groundwater conceptualisation and numerical model for the Grants and BP33 mining areas. In summary, the objectives are to assess the groundwater response to historical and proposed mining activities, including estimates of mine dewatering requirements, changes in groundwater levels within and surrounding the mining areas, and the spatial extent of drawdown over the life of mine. Further definition of the purpose of the numerical modelling and calibration work is also provided in Appendix A of the Modelling Report (Artesium, 2026). The report states that the objective of the project was to provide dewatering rates and to delineate potential zones of influence for the planned expansion of underground workings at the BP33 mine, through updating the previously developed CloudGMS numerical model.

It is the reviewer's opinion that the overall model design and modelling approach have been developed with these objectives in mind, and that the selected outputs are generally appropriate for addressing the stated assessment objectives.

3.2 Conceptual model

The hydrogeological conceptual model is presented in Chapter 4 of the Modelling Report (Artesium, 2026), with supporting information provided in Chapters 2 and 3. The conceptualisation draws on geological mapping, groundwater level monitoring, hydrochemical data, and mine infrastructure information to describe groundwater conditions at the Grants and BP33 sites.

The conceptual model describes a vertically stratified groundwater system comprising shallow surficial and alluvial units, an intermediate weathered bedrock zone, and a deeper bedrock zone likely characterised by reducing fracture density and hydraulic conductivity with depth within the Burrell Creek Formation. Groundwater level monitoring data showed different hydraulic responses between shallow and deeper monitoring bores, with drawdown observed in deeper bores proximal to the Grants Open Pit and negligible changes recorded in shallow bores over the same monitoring period. These observations are interpreted by the Artesium modelling team as indicating limited vertical hydraulic connectivity between the shallow groundwater system and deeper aquifers. Interpolation of the observed groundwater level drawdown data suggests that little or no drawdown beyond around 360 m away from the Grants Open Pit in the shallow and intermediate 'aquifers' has been observed. Data are only available for a single monitoring point in the deeper relatively fresh bedrock 'aquifer' in close proximity to the pit and hence the cone of influence of dewatering operations in the deep system is not known.

Hydrochemical data further differentiate these groundwater systems, with shallow, intermediate, and deep groundwater exhibiting distinct chemical signatures. The pit lake chemistry is reported to more closely resemble deeper groundwater chemistry than shallow groundwater, consistent with the final depth of Grants Pit which as shown in Figure 4-1 in the Modelling Report (Artesium, 2026) extends through the shallow and intermediate systems into the deep bedrock zone. These datasets are used by the authors to support the conceptual separation of groundwater systems with depth.

Recharge processes are described as being strongly influenced by seasonal rainfall and climatic variability, with high evapotranspiration rates identified as a key component of the site water balance. Surface drainage features and ephemeral creeks are conceptualised as interacting primarily with shallow groundwater systems, based on groundwater level behaviour and water quality observations presented in the report. Cumulative rainfall departure (CRD) plots presented in the Modelling Report (Artesium, 2026) suggest above average rainfall over the recent period since 2022 resulting in relatively high observed groundwater levels in those monitoring points which are not affected by historical mining activities.

Mining features, including the Grants Open Pit, underground workings, pit lakes, and the BP33 box cut, are incorporated into the conceptual model as hydraulic features influencing groundwater flow. At Grants, the Open Pit is described as a hydraulic sink, with observed groundwater inflows and monitoring data indicating declining drawdown rates over time and quasi steady state conditions. At BP33, the conceptual model incorporates planned underground development and the scheduled backfilling of stopes, as represented in the numerical model simulations.

The report presents conceptual cross-sections and long-sections illustrating aquifer stratification, groundwater flow directions, and the relationship between mining features and groundwater systems. These figures provide the conceptual basis for the numerical groundwater model described in subsequent chapters. The report does not present alternative conceptual models, and the adopted conceptualisation is therefore used as the sole framework for numerical modelling and impact assessment.

3.3 Numerical model

The numerical groundwater model for the Grants and BP33 sites was updated by Artesium based on an existing CloudGMS FEFLOW groundwater model (CloudGMS, 2018; 2021; and 2023), incorporating revised mine plans, additional monitoring data, and updated modelling assumptions. The update retains the same numerical modelling platform and finite-element framework used in earlier studies, while refining model inputs and representation of mining activities.

Groundwater flow is simulated using FEFLOW (Finite Element subsurface FLOW system), a three-dimensional finite-element groundwater modelling code. The model is constructed to implement the conceptual hydrogeological framework described in Sections 3 and 4 of the Modelling Report (Artesium, 2026), including vertically stratified groundwater systems, mine excavations, proposed underground workings, and surface water features.

The model domain is discretised using an unstructured finite-element mesh composed of triangular prism elements with a total of 1,482,984 mesh elements. As a finite-element model, discretisation is not defined by uniform horizontal cell sizes or total cell counts, but by the spatial distribution and density of mesh elements and nodes. Mesh refinement is applied in the vicinity of the Grants Open Pit, the BP33 box cut, proposed BP33 underground workings, and other areas of interest, with coarser discretisation used toward the outer limits of the model domain.

Vertically, the model is subdivided into 43 layers and 44 slices to represent surficial materials, weathered and fractured zones, and deeper relatively fresh bedrock units characterised by decreasing hydraulic conductivity with depth, consistent with the stratigraphic framework described in the conceptual model. Hydraulic properties are assigned by geological unit and depth in accordance with this framework. As shown in Figure 3-19 in the Modelling Report (Artesium, 2026) it is noted that the groundwater model extends to around -800 mamsl (metres above mean sea level) to allow it to simulate the full depth of the proposed underground mining operations at BP33. However, no hydraulic testing data are currently understood to be available below around -130 mamsl. As such the modelled rate of decline of around one order of magnitude between around -120 and -800 mamsl represents an initial assumption which although plausible hydrogeologically does not appear to be based on any field hydraulic testing since no tests have been completed below around -130 mamsl.

Boundary conditions are applied to represent surface water features, pit lakes, and model domain limits. Recharge is applied as a spatially distributed flux based on climatic inputs and recharge assumptions described in Section 2 and Appendix A of the Modelling Report (Artesium, 2026). Mining activities, including dewatering, underground development, and backfilling, are incorporated as time-varying stresses and boundary conditions consistent with the mine schedules provided.

The numerical solution is obtained using the PARDISO direct solver appropriate for large three-dimensional finite-element meshes, as documented in Appendix A of the Modelling Report (Artesium, 2026). The numerical model provides the basis for simulating groundwater flow responses to historical and proposed mining activities.

3.4 Calibration

3.4.1 Calibration approach

Calibration of the model is predominantly presented in Appendix A of the Modelling Report (Artesium, 2026). Rather than use automated techniques, the modelling team have chosen to employ a manual iterative approach which is illustrated in Figure 12-1 of the Modelling Report (Artesium, 2026). This approach involved assessing each calibration iteration against the available observations to determine using a range of qualitative and quantitative measures whether or not the calibration was acceptable. Where an iteration was deemed not acceptable, then both conceptual and numerical models were revised to generate a new set of calibration output for assessment. Whilst this manual iterative approach is unlikely to generate calibrated hydraulic parameters which represent an optimal statistical match to the available hydrogeological data, it does have some advantages over a fully automated approach including:

- testing of different conceptual models against the available data;
- full consistency between the conceptual and numerical models; and
- simpler leveraging of expert knowledge and likely prevention of physically unrealistic hydraulic parameters which can result from automated calibration where parameters are sufficiently constrained.

Both steady state and transient calibrations are reported to have been undertaken. The steady state calibration was undertaken with reference to average groundwater levels observed over the period from June 2017 to January 2022 and prior to mining of the Grants Open Pit. Thereafter a transient calibration was undertaken including calibration to observed groundwater levels and estimated actual inflows to Grants Open Pit over the nine year period from January 2017 to January 2026. Monthly stress periods have been adopted such that the transient calibration period comprises 109 stress periods in total.

3.4.2 Calibration results

Standardised Root Mean Square (SRMS) groundwater level errors of 9.14 to 11.53% are reported for the steady state calibration and 2.46 to 6.60% for the transient calibration. As such statistically the transient calibration in particular is within the range of + or – 10% SRMS generally considered to be acceptable. Seasonal fluctuations of around 5 m which are observed at most monitoring points are generally matched well, which suggests that the modelled recharge time series and specific yield are well calibrated. It is noted, however, that these two parameters tend to be highly correlated since observed seasonal fluctuations can be matched by varying recharge rates or specific yield. This is discussed further below in relation to the calibrated specific yield values which are considered to be lower than ranges typically reported in the hydrogeological literature.

Average modelled inflows to Grants Open Pit and the BP33 box cut also compare relatively well to average estimated actual inflows for these two existing features. For Grants Open Pit the modelled average inflow of around 635 m³/d is slightly lower than the 710 m³/d estimated from the actual data. Conversely the calibrated model appears to slightly over-estimate estimated actual inflows to the BP33 box cut by up to around 100 m³/d (300-400 m³/d modelled, versus estimate actual inflows of around 295 m³/d).

It is noted that this level of fit between observed and modelled groundwater levels and pit inflows has been achieved using single values of hydraulic properties and recharge in each modelled layer. The relatively good matches achieved to the data therefore suggests that this simplification of the actual heterogeneous system as laterally homogeneous is reasonable.

Whilst model results suggest substantial drawdown at GWB01 and GWB03 due to historic development of the Grants Open Pit from month 61 onwards, no actual data are available for either of these monitoring points and hence the accuracy of modelled drawdown in close proximity to Grants Open Pit is not known. Observed data for the remaining monitoring points, including GWB07 and GWB08 which are located around 300 m east of Grants Open Pit, generally show little or no significant drawdown. The model results suggest up to around 10 m of drawdown over the recent period. As such, the calibrated model appears to be over-predicting observed drawdown associated with historical mining of Grants Open Pit. This is recognised in Section 12.2.2 of the Modelling Report (Artesium, 2026) and the report authors suggest that the model be used as a tool to assess maximum possible future impacts, as comparison with the available observations suggests a tendency to over-predict drawdown at distance away from the Grants Open Pit.

Calibrated model parameters are presented in Table 12-8 in the Modelling Report (Artesium, 2026) and are for the most part plausible and within hydrogeologically realistic ranges. The only notable exception being modelled specific yield values of 0.01 (or 1%) for Sand, Silt and Clay and Alluvium in model layer 1, values which are lower than considered typical for unconsolidated units. For instance, as shown in Figure 3.1, Johnson (1967) reports average values for various unconsolidated strata in the range 0.02 to 0.27 (2 to 27%). As such the reported values for these near surface units are considered to be lower than those generally quoted in the literature. Calibrated specific yield values for the underlying bedrock units are in the range 3 to 7.3 x10⁻³ (0.3 to 0.7%) and are also considered to be low. It is noted, however, that the reported calibrated recharge values to these strata are also relatively low (40 – 50 mm per annum equivalent to 2.6 to 3.25% of long term average rainfall) and hence it is considered likely that a similarly good calibration to observed groundwater levels could have been achieved by increasing both the modelled specific yield and recharge. This is an example of equifinality in groundwater modelling whereby two different parameter combinations can result in the same outcome.

The sensitivity of model predictions to these relatively low specific yield values has been assessed by Artesium (2026) by completion of a scenario-based sensitivity analysis which includes a scenario whereby the calibrated specific yield values for all model layers have been multiplied by a factor of 10, bringing them more into line with typical literature values (Scenario 1.4). The results of this analysis are discussed in Section 3.5.

As mentioned previously and noted in the Modelling Report (Artesium, 2026) in the absence of any test results below around -130 mamsl both the modelled rate of decline and absolute values of hydraulic conductivity in the deeper strata not supported by any actual data below this elevation. Similarly, the absence of deep groundwater monitoring also limits the degree to which modelled parameters in this zone can be calibrated. As such, predicted drawdowns and inflow in the deep strata would be expected to be subject to a relatively high degree of uncertainty which may be significant since the BP33 underground mine will also extend more than 700 m below the terminal depth of the existing Grants Open Pit or the BP33 Box Cut. As discussed in Section 3.5, the significance of this particular data limitation has been assessed to a degree by the completion of additional scenarios focussing on the hydraulic conductivity and specific yield of the deeper horizons which will be intersected at BP33 but have not been historically.

Specific yields, in percent, of various materials

[Rounded to nearest whole percent]

Material	Number of determinations	Specific yield		
		Maximum	Minimum	Average
Clay.....	15	5	0	2
Silt.....	16	19	3	8
Sandy clay.....	12	12	3	7
Fine sand.....	17	28	10	21
Medium sand.....	17	32	15	26
Coarse sand.....	17	35	20	27
Gravelly sand.....	15	35	20	25
Fine gravel.....	17	35	21	25
Medium gravel.....	14	26	13	23
Coarse gravel.....	14	26	12	22

Figure 3.1 Specific yield values for various unconsolidated strata reported by Johnson (1967)

3.5 Predictions

Predicted impacts of proposed BP33 operations have been assessed via reference to predictions for eight different scenarios as follows:

- Expected Case (Scenario 1.1a) - based on transient calibrated hydraulic parameters etc.
- No Mining (Scenario 1.1b) – No mining scenario, for the purpose of estimating cumulative impacts relating to both the historic Grants Open Pit and proposed BP33 developments.
- Medium K (Scenario 1.2) – hydraulic conductivity of the deeper aquifer increased by 5 times relative to the Expected Case.

- High K (Scenario 1.3) - hydraulic conductivity of the deeper aquifer increased by 10 times relative to the Expected Case.
- High Sy (Scenario 1.4) – Specific yield in all model layers scaled up by ten times relative to the Expected Case.
- 50% Recharge (Scenario 1.5) – Transient recharge scaled down by a factor of two times relative to the Expected Case.
- Double Recharge (Scenario 1.6) – Transient recharge scaled up by a factor of two times relative to the Expected Case.
- Dry Cycle (Scenario 1.7) – A re-run of the Expected Case but assuming dry, rather than long term average, recharge during the predictive period.

Compared to a Monte Carlo based predictive uncertainty analysis, this scenario based sensitivity analysis represents a relatively simple approach to assessing predictive uncertainty. Nevertheless, it is sufficient to identify possible ranges of key predictions and inform discussions on whether or not these predictions are likely to be reliable.

Given the previous observation that the calibrated specific yield values were at or below typical literature ranges (Section 3.4.2), the results for the High Sy Scenario 1.4 are considered particularly relevant and tend to confirm that model predictions are sensitive to this modelled parameter. As would be expected results for this scenario, suggest a smaller shallow BP33 ZOI (985 m) and higher BP33 maximum inflows (around 2,200 m³/d), than predicted in the Expected Case (1,310 m and around 1,400 m³/d respectively). However, given that Scenario 1.4 increased the specific yield in all model layers by an order of magnitude, the 25% reduction in ZOI and the 57% increase in predicted inflows are relatively minor.

Overall, the sensitivity analysis results suggest maximum shallow BP33 ZOI radii in the range 670 m (Scenario 1.6 – High recharge) to 1,435 m (Scenario 1.3 – High bedrock K), compared to the Expected Case prediction of 1,310 m, based on the calibrated parameters. As such, the Expected Case result is towards the upper end of the range of predicted ZOI values generated. Conversely, predicted maximum inflows to the BP33 in the Expected Case (1,400 m³/d) are towards the lower end of the range of predicted inflows (1,300 m³/d to 2,200 m³/d) resulting from the sensitivity analysis. However, given the order of magnitude changes in parameters implemented in the majority of the sensitivity scenarios the resulting ranges of predictions are considered to be relatively minor and suggest that the model predictions are relatively robust.

Nevertheless, results for all sensitivity analysis scenarios tend to over-estimate the estimated actual ZOI of around 360 m associated with historic extraction from Grants Open Pit (Figure 3-13 in the Modelling Report).

4 Does the model conform to Australian modelling guidelines?

The AGMG outlines a process of evaluating the appropriateness of various aspects of model development to determine if the model is adequate and 'fit for purpose'. It provides guidance on how particular aspects of model development should proceed and provides considerations for the modeller. The aim of the guidelines is to provide a more appropriate and consistent approach to model development across the industry.

The guidelines provide a review checklist (see Table 9-2 of the AGMG) that lists key areas of model development. The review checklist has been completed (where relevant) for the BP33 groundwater model and is provided in Table 1. The comments provide justification for the decisions made where required.

The confidence level class assessment has been determined by assessment to key indicators in Table 2-1 of the AGMG. The model is assessed by Artesium as being a Class 2 model, and the reviewer agrees with this assessment.

Table 1 Australian Groundwater Modelling Guideline review checklist

Review questions		Yes/No	Comment
1. Planning			
1.1	Are the project objectives stated?	Yes	Project objectives are stated in Chapter 1 of the main report, describing the purpose of updating the groundwater model to support revised mine plans, inflow estimates and impact assessment.
1.2	Are the model objectives stated?	Yes	Model objectives are stated in Chapter 1, including simulation of groundwater inflows, drawdown, ZOI and support for impact assessment.
1.3	Is it clear how the model will contribute to meeting the project objectives?	Yes	Appendix A describes how model outputs (inflows, drawdown, ZOI) are used to address the stated project objectives.
1.4	Is a groundwater model the best option to address the project and model objectives?	Yes	Quantification of inflows, drawdown and spatial impacts requires a numerical groundwater flow model.
1.5	Is the target model confidence-level classification stated and justified?	Yes	Model confidence is discussed in Chapter 5, with justification based on data availability, calibration quality and uncertainty.
1.6	Are the planned limitations and exclusions of the model stated?	Yes	Model limitations and exclusions are discussed in Section 6.2 and Appendix A (Table 12-3).
2. Conceptualisation			
2.1	Has a literature review been completed, including examination of prior investigations?	Yes	Previous investigations and prior CloudGMS modelling studies are reviewed in Section 3.2.
2.2	Is the aquifer system adequately described?	Yes	Aquifer systems are described in Sections 2.5 and 4.3, including shallow and deeper fractured systems.
2.2.1	Hydrostratigraphy including aquifer type (porous, fractured rock ...)	Yes	Hydrostratigraphy is described in Sections 2.4 and 2.5, identifying porous surficial units and fractured bedrock aquifers.
2.2.2	Lateral extent, boundaries and significant internal features such as faults and regional folds	Yes	Geological extent and structures are described in Section 2.4 with reference to regional geology.
2.2.3	Aquifer geometry including layer elevations and thicknesses	Yes	Aquifer geometry and thicknesses are described in Sections 2.4 and 4 and illustrated in cross-sections.
2.2.4	Confined or unconfined flow and the variation of these conditions in space and time?	Yes	Confined and unconfined conditions are discussed in Appendix A (Table 12-1).
2.3	Have data on groundwater stresses been collected and analysed?	Yes	Mining-related stresses are described and analysed in Sections 3.3 and 3.4.
2.3.1	Recharge from rainfall, irrigation, floods, lakes	Yes	Recharge processes are discussed in Section 2.5, with implementation described in Appendix A.
2.3.2	River or lake stage heights	Partial	Surface water features are described; limited site-specific stage data are available.
2.3.3	Groundwater usage (pumping, returns etc.)	Yes	Mining dewatering and pumping stresses are described; no significant third-party usage identified.
2.3.4	Evapotranspiration	Yes	Evapotranspiration and climatic context are discussed in Section 2.2.
2.3.5	Other?	NA	No other groundwater stresses identified.
2.4	Have groundwater level observations been collected and analysed?	Yes	Groundwater level monitoring data are analysed in Section 3.5.

Review questions	Yes/No	Comment
2.4.1 Selection of representative bore hydrographs	Yes	Representative bore hydrographs are presented and discussed in Section 3.5.
2.4.2 Comparison of hydrographs	Yes	Observed hydrographs are compared spatially and temporally in Section 3.5.
2.4.3 Effect of stresses on hydrographs	Yes	Drawdown responses to mining stresses are discussed in Section 3.5.
2.4.4 Watertable maps/piezometric surfaces?	Yes	Watertable and potentiometric surfaces are presented in Chapter 4.
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	Partial	Density effects are discussed in relation to chemistry; barometric effects are not explicitly addressed.
2.5 Have flow observations been collected and analysed?	Partial	Limited direct flow observations are available; reliance is primarily on groundwater levels and inflows.
2.5.1 Baseflow in rivers	NA	Baseflow analysis is not presented.
2.5.2 Discharge in springs	NA	No springs identified within the study area.
2.5.3 Location of diffuse discharge areas?	Partial	Diffuse discharge is discussed conceptually; limited direct data available.
2.6 Is the measurement error or data uncertainty reported?	Yes	Data uncertainty is discussed in Appendix A, including uncertainty classifications.
2.6.1 Measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	Yes	Measurement uncertainty is discussed in Appendix A.
2.6.2 Spatial variability/heterogeneity of parameters	Yes	Parameter heterogeneity and uncertainty are discussed in Appendix A.
2.6.3 Interpolation algorithm(s) and uncertainty of gridded data?	Partial	Interpolation methods are described; uncertainty is discussed qualitatively.
2.7 Have consistent data units and geometric datum been used?	Yes	Consistent units and datums are used throughout the report.
2.8 Is there a clear description of the conceptual model?	Yes	The conceptual model is described in Chapter 4.
2.8.1 Is there a graphical representation of the conceptual model?	Yes	Conceptual cross-sections and diagrams are provided in Chapter 4.
2.8.2 Is the conceptual model based on all available, relevant data?	Yes	Conceptualisation integrates geological, hydraulic and hydrochemical data.
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Yes	Conceptual model aligns with stated objectives and confidence classification.
2.9.1 Are the relevant processes identified?	Yes	Key processes (recharge, dewatering, drawdown) are identified.
2.9.2 Is justification provided for omission or simplification of processes?	Partial	Simplifications are discussed but not always explicitly justified in one location.
2.10 Have alternative conceptual models been investigated?	No	Alternative conceptual models are not presented.
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Yes	Numerical model design reflects the conceptual model described in Chapter 4.

Review questions	Yes/No	Comment
3.2 Is the choice of numerical method and software appropriate (Table 4-2)?	Yes	FEFLOW finite-element modelling is appropriate for the objectives.
3.2.1 Are the numerical and discretisation methods appropriate?	Yes	Unstructured finite-element discretisation is appropriate for complex geology.
3.2.2 Is the software reputable?	Yes	FEFLOW is a widely used and accepted groundwater modelling code.
3.2.3 Is the software included in the archive or are references to the software provided?	Yes	Software and version are referenced in Appendix A.
3.3 Are the spatial domain and discretisation appropriate?	Yes	Domain extent and discretisation are described and justified in Appendix A.
3.3.1 1D/2D/3D?	Yes	A three-dimensional model is used.
3.3.2 Lateral extent	Yes	Model extent encompasses mining areas and relevant receptors.
3.3.3 Layer geometry?	Partial	Layer geometry is described in Appendix A. Although the thickness of unconsolidated surface deposits are likely to vary spatially they have been simulated using a single layer with a constant thickness of 4 m. Where this unit is thicker than currently modelled (e.g. along creek lines) then assuming it is also saturated it will tend to limit lateral propagation of drawdown impacts within the shallow aquifer. This may be a partial explanation for the over-estimation of actual drawdown in and around Grants Open Pit (Section 3.5).
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Yes	Mesh refinement is applied in areas of interest.
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided into multiple layers to model time lags of propagation of responses in the vertical direction?	Yes	Vertical discretisation reflects stratigraphy and flow behaviour.
3.4 Are the temporal domain and discretisation appropriate?	Yes	Both steady-state and transient simulations are used.
3.4.1 Is it steady state or transient	Yes	Both steady-state and transient models are applied.
3.4.2 Stress periods	Yes	Stress periods are defined based on mine schedules.
3.4.3 Time steps?	Yes	Time steps are defined and described in Appendix A.
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Yes	Boundary conditions are described and consistent with the conceptual model.
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Yes	Boundary conditions reflect conceptualised flow boundaries.
3.5.2 Are the boundary conditions chosen to have minimal impact on key model outcomes? How is this ascertained?	Partial	Boundary placement is discussed; limited sensitivity testing presented.
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Yes	Recharge calculation is consistent with objectives and uncertainty discussion.
3.5.4 Are lateral boundaries time-invariant?	Yes	Lateral boundaries are treated as time-invariant.
3.6 Are the initial conditions appropriate?	Yes	Initial conditions are described in Appendix A.

Review questions	Yes/No	Comment
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?	Yes	Initial heads are derived from modelling and monitoring data.
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	Partial	Initial conditions are discussed; limited sensitivity assessment presented.
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	NA	Solute transport modelling is not undertaken.
3.7 Is the numerical solution of the model adequate?	Yes	Solution methods and solver are described and appropriate.
3.7.1 Solution method/solver	Yes	Direct solver (PARDISO) is used.
3.7.2 Convergence criteria	Yes	Convergence criteria are described in Appendix A.
3.7.3 Numerical precision	Yes	Numerical precision settings are described in Appendix A.
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?	Yes	Heads and inflows are used for calibration.
4.1.1 Groundwater head data	Yes	Groundwater head data are used for calibration.
4.1.2 Flux observations	Yes	Estimated actual mine inflows and water balances were also used for calibration.
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	Partial	Hydrochemistry supports conceptualisation but is not directly calibrated.
4.2 Does the calibration methodology conform to best practice?	Yes	Calibration approach aligns with accepted practice.
4.2.1 Parameterisation	Yes	Parameterisation is described in Appendix A.
4.2.2 Objective function	Yes	Calibration metrics and objectives are described.
4.2.3 Identifiability of parameters	Partial	Identifiability is discussed qualitatively.
4.2.4 Which methodology is used for model calibration?	Yes	Manual calibration supported by sensitivity testing.
4.3 Is a sensitivity of key model outcomes assessed against?	Yes	Sensitivity of key predictions is assessed through scenario testing.
4.3.1 Parameters	Yes	Key parameters are varied in scenarios.
4.3.2 Boundary conditions	Partial	Limited boundary condition sensitivity testing.
4.3.3 Initial conditions	Partial	Initial conditions sensitivity is limited.
4.3.4 Stresses	Yes	Mining stress scenarios are tested.
4.4 Have the calibration results been adequately reported?	Yes	Calibration results are presented in text, tables and figures.
4.4.1 Are the graphs showing modelled and observed hydrographs at an appropriate scale?	Yes	Hydrograph plots are appropriately scaled.
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Partial	Vertical gradients are discussed but not comprehensively demonstrated.
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Yes	Calibration statistics are reported in Appendix A.

Review questions		Yes/No	Comment
4.5	Are multiple methods of plotting calibration results used to highlight goodness of fit (robustly)? Is the model sufficiently calibrated?	Partial	Multiple plots are provided; robustness discussion is limited
4.5.1	Spatially	Yes	Spatial calibration plots are provided.
4.5.2	Temporally	Yes	Temporal calibration plots are provided and point to a relatively good match to observed seasonal fluctuations.
4.6	Are the calibrated parameters plausible?	Yes	Calibrated parameters are for the most part within plausible ranges, the only exception being specific yield which is below literature ranges.
4.7	Are the water volumes and fluxes in the water balance realistic?	Yes	Water balance results are realistic and discussed.
4.8	Has the model been verified?	No	Independent model verification is not documented.
5. Prediction			
5.1	Are the model predictions designed in a manner that meets the model objectives?	Yes	Prediction scenarios address stated objectives.
5.2	Is predictive uncertainty acknowledged and addressed?	Yes	Uncertainty is acknowledged and explored via scenarios.
5.3	Are the assumed climatic stresses appropriate?	Yes	Climatic stresses are consistent with historical data.
5.4	Is a null scenario defined?	Yes	Baseline/no-mining conditions are defined and used to predict Project impacts.
5.5	Are the scenarios defined in accordance with the model objectives and confidence level classification?	Yes	Scenarios align with objectives and confidence discussion.
5.5.1	Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	Partial	Since the observed groundwater level data set responses to development of the Grants Open Pit and the BP33 Box Cut then historic stresses on the shallow aquifer are similar to those expected in the future. On the other hand, there has been no historic extraction from the relatively fresh bedrock which will be intersected by underground operations at BP33.
5.5.2	Are well losses accounted for when estimating maximum pumping rates per well?	Partial	Well losses are discussed at a high level.
5.5.3	Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?	Yes	Prediction timeframes are consistent with calibration.
5.5.4	Are the assumed stresses and timescale appropriate for the stated objectives?	Yes	Stresses and timescales align with objectives.
5.6	Do the prediction results meet the stated objectives?	Yes	Prediction results address inflows and ZOI objectives.
5.7	Are the components of the predicted mass balance realistic?	Yes	Predicted mass balance components are reasonable.
5.7.1	Are the pumping rates assigned in the input files equal to the modelled pumping rates?	Yes	Assigned and modelled rates are consistent.

Review questions	Yes/No	Comment
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	No	No exceedance of expected river flows is indicated.
5.7.3 Are there any anomalous boundary fluxes due to superposition of head-dependent sinks (e.g. evapotranspiration on head-dependent cells (Type 1 or 3 boundary conditions))?	No	No anomalous boundary fluxes are reported.
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Yes	Recharge rates are less than rainfall.
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	No	No anomalous storage behaviour is reported.
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	Partial	Particle tracking is mentioned as a potential future option.
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Yes	Uncertainty is reported qualitatively and via completion of a scenario-based sensitivity analysis.
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	Partial	Scenario approach is used; formal optimisation is not presented.
6.3 Are the sources of uncertainty discussed?	Yes	Sources of uncertainty are discussed in Appendix A.
6.3.1 Measurement uncertainty of observations and parameters	Yes	Measurement uncertainty is discussed.
6.3.2 Structural or model uncertainty	Yes	Structural uncertainty is acknowledged.
6.4 Is the approach to estimation of uncertainty described and appropriate?	Yes	Scenario-based uncertainty approach is described.
6.5 Are there useful depictions of uncertainty?	Partial	Uncertainty is described; limited graphical depiction.
7. Solute transport		
7.1 Has all available data on solute distributions, sources and transport processes been collected and analysed?	NA	Solute transport modelling is not undertaken.
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?	NA	Solute transport modelling is not undertaken.
7.3 Is the choice of numerical method and software appropriate?	NA	Solute transport modelling is not undertaken.
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?	NA	Solute transport modelling is not undertaken.
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?	NA	Solute transport modelling is not undertaken.

Review questions		Yes/No	Comment
7.6	Are the solver and its parameters appropriate for the problem under consideration?	NA	Solute transport modelling is not undertaken.
7.7	Has the relative importance of advection, dispersion and diffusion been assessed?	NA	Solute transport modelling is not undertaken.
7.8	Has an assessment been made of the need to consider variable density conditions?	NA	Solute transport modelling is not undertaken.
7.9	Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?	NA	Solute transport modelling is not undertaken.
7.10	Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?	NA	Solute transport modelling is not undertaken.
7.11	Is the calibration based on meaningful metrics?	NA	Solute transport modelling is not undertaken.
7.12	Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?	NA	Solute transport modelling is not undertaken.
7.13	Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?	NA	Solute transport modelling is not undertaken.
7.14	Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?	NA	Solute transport modelling is not undertaken.
7.15	Does the report address the role of geologic heterogeneity on solute concentration distributions?	Partial	Geologic heterogeneity is discussed qualitatively.
8. Surface water–groundwater interaction			
8.1	Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Yes	SW–GW interaction is conceptualised consistent with objectives.
8.2	Is the implementation of surface water–groundwater interaction appropriate?	Yes	SW features are implemented via boundary conditions.
8.3	Is the groundwater model coupled with a surface water model?	No	No coupled surface water model is used.
8.3.1	Is the adopted approach appropriate?	Yes	Boundary condition approach is appropriate for objectives.
8.3.2	Have appropriate time steps and stress periods been adopted?	Yes	Time steps and stress periods are appropriate.
8.3.3	Are the interface fluxes consistent between the groundwater and surface water models?	Partial	Flux consistency is discussed qualitatively; no coupled model comparison.

5 Is the numerical model consistent with the conceptual model?

As the conceptual model has been iteratively revised during the calibration process to improve the match to the available data then the resulting numerical model is consistent with the conceptual model described in the Modelling Report (Artesium, 2026).

6 Is the model ‘fit for purpose’?

In terms of assessing whether or not the numerical model described in the Modelling Report (Artesium, 2026) is fit for purpose we have used the approach outlined in Hamilton et al. (2022)⁶ which is also used by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC)⁷. Hamilton et al. (2022) discuss whether a model is fit for purpose in terms of a trade-off between usability, reliability and feasibility. Useability relates to how and whether the model and results generated by the model can be used to inform decision making. Reliability considers both the likely reliability of model results and trust in the modelling process. Feasibility relates to the pragmatic aspects of delivering a modelling project given time and budget constraints.

In most respects the numerical model described in the Modelling Report (Artesium, 2026) is considered fit for the purpose of informing a groundwater impact assessment of the proposed BP33 mining operations. The model has been calibrated to both observed groundwater levels and estimated actual inflows to the existing Grants Open Pit and BP33 box cut. However, despite the relatively good fit achieved to these observations the calibrated model appears to over-estimate actual drawdown in the shallow aquifers around Grants Open Pit. As such the calibrated model is also likely to conservatively over-predict drawdowns in the shallow aquifers around the proposed BP33 box cut and underground mining operations and as suggested by the report authors should therefore be treated as a ‘worst likely case’.

A scenario-based sensitivity analysis has been undertaken to confirm the sensitivity of key model predictions to key model parameters including in particular specific yield. The calibrated specific yield values are considered to be towards the lower end of plausible ranges, as documented in the hydrogeological literature. As would be expected increasing the modelled specific yield by an order of magnitude (Scenario 1.4) results in a more constrained radius of influence which tends to reinforce the above statement that the current base (or expected) case drawdown predictions are likely to be over-predictions. It is noted, however, that key model predictions are not particularly sensitive to the specific yield or other parameters assessed. For instance, increasing the specific yield in all model layers by an order of magnitude results in a 25% reduction in the predicted maximum radius on influence (from 1,300 to 985 m) and a 57% increase in predicted maximum BP33 underground mine inflows (from 1,300 to 2,200 m³/d).

Overall, the numerical model and results presented in the numerical Modelling Report (Artesium, 2026) are therefore considered to be fit for purpose on the basis that they are:

- Useable for the purpose of decision making, although should be treated as conservative with respect to the likely radius of influence of the historic and proposed mining operations in the shallow aquifer.
- Reliable. Whilst the calibrated parameters are non-unique and have not been fully optimised scenario based sensitivity analysis results suggest relatively constrained ranges of possible drawdown and inflow outcomes.
- Feasible. Although model run times are understood to be several hours a relatively good match has been achieved to the available groundwater level and estimated actual inflow data.

⁶ Hamilton SH, Pollino CA, Stratford DS, Fu B and Jakeman AJ, 2022. Fit-for-purpose environmental modeling: targeting the intersection of usability, reliability and feasibility. *Environmental Modelling and Software*, 148: 105278. Available [online]: <https://doi.org/10.1016/j.envsoft.2021.105278>.

⁷ Peeters LJM and Middlemis H, 2023. Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling, A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia, 2023.

Based on the findings of this review subsequent iterations of modelling work related to the Project should consider:

- Varying the thickness of model layer 1 (unconsolidated 'regolith' and alluvium) spatially based on site specific information, geological mapping and CSIRO regolith modelling results.
- Optimising the current calibrated model parameters using an automated calibration approach and allowing hydraulic parameters to vary spatially, within appropriate constraints, to fit the available observation data.
- Inclusion of observed drawdown (relative to initial readings in each observation bore) and vertical head differences as additional calibration targets.
- Completion of a predictive uncertainty analysis using a Monte Carlo based statistical approach such that the probability of different predictive outcomes can be quantified.

The primary aim of these additional items being to refine the current base (or expected) case parameters to address the current tendency for the model to conservatively over-predict actual drawdown and further quantify predictive uncertainty.

Yours faithfully,



Keith Phillipson
Senior Principal Modeller
Australasian Groundwater and
Environmental Consultants Pty Ltd

Attachment A

CVs



Keith Phillipson
Senior Principal Hydrogeologist

Education

- Bachelor of Science (Geography) with Honours, University of Bristol, 1992
- Master of Science (Water Resource System Engineering), University of Newcastle, 1994

Memberships

- International Association of Hydrogeologists, Member, Australian Chapter.

Employment history

2024	– Current	Australasian Groundwater and Environmental Consultants Pty Ltd Senior Principal Hydrogeologist
2019	– 2024	Australasian Groundwater and Environmental Consultants Pty Ltd Principal Hydrogeologist Team Lead
2014	– 2019	The Office of Groundwater Impact Assessment Director of Hydrogeology and Modelling
2007	– 2014	GHD Pty Ltd Principal Hydrogeologist
1999	– 2007	Entec UK Ltd Senior/Principal Hydrogeologist
1995	– 1999	Knight Piesold Ltd Hydrogeologist

Skills

Keith Phillipson is a senior principal hydrogeologist with over 30 years post graduate experience specialising in the use of groundwater models and other techniques to assess and manage the impacts of a wide range of developments on groundwater and surface water resources. In particular Keith has both undertaken and overseen a number of regional scale modelling studies focussed on assessing the cumulative impacts of large scale groundwater extraction for water supply, coal mining and coal seam gas production purposes. Drawing on his broad academic background and experience in a range of roles both within Australia and overseas Keith's skills include:

- extensive experience in the development and management of numerical groundwater flow modelling studies including integrated surface water and groundwater simulations to assess the impacts of a variety of groundwater extraction activities;
- development of detailed local and regional scale conceptualisations to support subsequent numerical flow modelling and other studies;

Skills (continued)

- technical input to and management of groundwater impact assessment activities for EIS studies undertaken in a number of jurisdictions including Australia (Queensland, New South Wales and Victoria) and Europe;
- assessment and modelling of surface water groundwater interactions;
- recharge estimation;
- expert witness and third party peer review of numerical modelling and EIS studies;
- presentation of technical outputs to a range of stakeholders including state regulators, the IESC, peer reviewers and non-technical audiences at public meetings;
- high level report writing skills; and
- academic training and extensive applied experience in both hydrogeology and hydrogeology.

Prior to joining AGE Keith directed hydrogeology and modelling research activities at the Office of Groundwater Impact Assessment (OGIA), an independent organisation responsible for assessing and managing the impacts of the Petroleum and Gas industry operating within the Surat Cumulative Management Area.

Areas of expertise and selected project experience

Groundwater Modelling and Water Resources

Narrabri Gas Project (NGP), Phase 1 Groundwater modelling (2023 onwards)

- Ongoing direction of NGP Phase 1 Groundwater Modelling activities to satisfy NSW State and Federal Approval conditions and further refine and improve the existing Project groundwater flow model developed for the Project EIS.

Inland Rail, Gowrie to Helidon Toowoomba Range Tunnel Groundwater Modelling (2023)

- Direction of activities related to revising an existing groundwater flow model of a rail tunnel through the Great Dividing Range northeast of Toowoomba to address client and regulator concerns relating to the previous modelling work.

WestConnex M4-M5 Link Tunnels, Landfill leachate migration assessment (2022)

- Direction of groundwater modelling activities aimed at quantifying the risk of landfill leachate migrating from abandoned landfills underlying the Sydney Park area towards the M4-M5 Link Tunnels. The primary aim of the work was to utilise additional datasets and learnings acquired during tunnels to improve current estimates of the risk of contaminated groundwater in the Sydney Park landfill area moving towards nearby tunnel infrastructure.

Surat Basin Acreage Development Shallow Groundwater Modelling Project (2020 onwards)

- Ongoing direction of a model based assessment of the impact of CSG activities on shallow groundwater systems in the north of the Surat Basin. Building on an existing regional scale model previously developed by this project will include development of a detailed simulation of strata present between the Walloon Coal Measures CSG reservoir and shallow alluvial systems which support aquatic GDEs in the area.

Areas of expertise and selected project experience (continued)

Surat Cumulative Management Area (CMA) Underground Water Impact Reports (UWIR) 2016 and 2019

- Direction of conceptualisation and modelling activities associated with the 2016 and 2019 Surat CMA UWIR including the development of a range of novel modelling approaches and conceptualisation of the Surat CMA drawing on the extensive data hydrogeological data sets available for the area. Responsibilities in this role including: overall responsibility for the timely delivery and quality of hydrogeology and modelling deliverables; maintaining relationships with the CSG industry, other research organisations and federal organisations including the IESC; contract management; staff management; developing and managing departmental contractor budgets; directing research projects to the value of around AU\$2 million per annum; and managing review of OGIA deliverables through the Technical Advisory Panel. Lead technical author of the 2016 and 2019 Surat CMA Underground Water Impact Report and a number of associated technical reporting deliverables.

Improving Monitoring Techniques and Methods in the Surat CMA (2014)

- GHD Project Manager of a review of monitoring techniques and methods currently being adopted by CSG companies in the Surat CMA to fulfil the monitoring requirements as specified in the Surat CMA Underground Water Impact Report. In addition to completing a stocktake of the current methods adopted in the basin a series of 'best' practice recommendations was also provided to drive improved monitoring in the area.

Cape York Groundwater Resource Capacity Assessment (2014)

- Peer review of the proposed scope of work and outputs from the Cape York Groundwater Resources Capacity Assessment project undertaken by DNRM and DSITIA, including a detailed review of groundwater resource modelling output.

Arrow Surat Gas Project Groundwater Modelling input to the Supplementary Report to the Environmental Impact Statement (2013)

- Use of the OGIA Surat CMA and Condamine Alluvium groundwater flow models to assess the impacts of the Arrow Surat Gas Project. Keith provided project management and lead technical input to this commission which involved repeating much of the CSG impact assessment work reported in the Surat CMA UWIR but based on a revised Arrow Field Development Plan. 600 runs of the OGIA Surat CMA model were completed based on 200 alternative parameter sets in order to quantify the uncertainty associated with the impact predictions. Both the model runs, and detailed reporting were successfully completed over a period of less than three months.

Developing a Regional Groundwater Flow Model for the Surat Cumulative Management Area to assess the impacts of Coal Seam Gas Water Extraction (QWC17-10), Stage 1 and 2 (2010-2012)

- Initial review of existing models (Stage 1) followed by development of a new model of the Surat CMA in Stage 2. The Surat CMA area includes large parts of the Surat, southern Bowen and Clarence-Moreton basins. Calibration of the model was optimised using a parallel implementation of the PEST software suite. PEST was also used to assess the uncertainty associated with model predictions through the development of 200 alternative parameter sets. A key feature of this project was the adoption of a collaborative approach involving key input from staff at two consultancies the Queensland Water Commission. This enabled the modelling work to be completed within the challenging six month timeframe required to meet the QWCs reporting responsibilities under the Water Act.

Areas of expertise and selected project experience (continued)

Catchment Management Area Groundwater Modelling, Victoria (2008-2010)

- Project manager for the development of groundwater models of the Port Phillip, West Gippsland and East Gippsland Catchment Management Areas (CMAs) for the Department of Sustainability and Environment (DSE). These models were developed in accordance with the Murray Darling Basin Commission guidelines for groundwater model development and were also subject to ongoing review by external groundwater modelling specialists. The calibrated models were used by the DSE to assess the impacts of land use change on groundwater resources and by key stakeholders such as Southern Rural Water for groundwater resource management purposes.

Dubbo Groundwater Supply and Response Strategy, NSW (2009)

- Construction and calibration of a numerical groundwater flow model of the alluvial aquifer underlying the Macquarie River in the vicinity of Dubbo. Use of the calibrated model to optimise future groundwater development in the area and management responses to drought conditions.

Loy Yang Mine Groundwater Modelling, Victoria (2008)

- Development of a detailed nested model of the Loy Yang Mine. This model is set within the Latrobe Valley regional groundwater flow model allowing the impacts of abstraction from other adjacent mines on groundwater levels in Loy Yang to be assessed. The calibrated model is maintained and run by GHD on the behalf of Loy Yang Power to assess dewatering requirements and the sustainability of groundwater supply to the adjacent power station.

Anglesea Borefield Project, Victoria (2007)

- Development of a regional scale groundwater model to assess the potential yield of the Lower Eastern View Formation. This aquifer is being considered as a potential option to augment the existing supply to the Greater Geelong area. Key components of this study included an assessment of the impacts of the proposed development on nearby GDE sites which includes a number of freshwater pools and riparian marshes.

Regional Groundwater Modelling Studies, UK Environment Agency (1999-2007)

- Project manager of the 'Yare and North Norfolk' and 'Waveney and East Suffolk' groundwater investigation and modelling areas. The overall aim of these five year AU\$2.5m+ (fees) projects was to produce integrated groundwater and surface water models to support Environment Agency water resources decision-making for the next 20 years. Each project included extensive external review and stakeholder engagement (both internal government and external stakeholders including water companies) to ensure that the resulting numerical models were recognised as robust tools for decision-making in each area.
- Key features of these projects include the development of:
 - an Access database providing central storage and retrieval of all project data including document reviews;
 - a series of 'best practice' technical notes outlining the methodology used for all major tasks within the project;
 - a conceptual model of the groundwater and surface water processes operating in each area; and
 - construction and calibration of two 7 layer c2500 square kilometre numerical models on a 200 m grid.

Areas of expertise and selected project experience (continued)

National Groundwater Modelling System, UK Environment Agency (2006 – 2007)

- Representing the Anglian Region on a national Environment Agency project team tasked with overseeing development of a system for importing, storing and retrieving information from the Agency's various regional groundwater models. The system will be accessible to staff within the Agency as well as external consultancy staff who will be able to carry out user defined scenario runs of the models to investigate for instance the impact of new or revised abstraction licences or carry out drought predictions. This system was being developed by a team of specialist IT consultants employed by the Agency and hence the project team was responsible for developing a detailed specification for the system and testing of all aspects of the final product produced by the consultants. As one of two lead testers Keith's role on the project required intimate knowledge of:
 - all aspects of MODFLOW (including recharge and runoff model and post processing options); and
 - environment Agency procedures, data sets and staff roles and responsibilities.

Resource and Abstraction Management Framework v4, UK Environment Agency (2006 – 2007)

- Project manager of a two year c£ 300K (fees) project aimed at updating the Environment Agency's Resource and Abstraction Management (RAM) framework methodology to ensure consistency with the European Water Framework and Habitats Directives. In addition to reviewing output from resource assessments carried out using Version 3 of the framework the first year of the of the project included extensive consultation with technical staff and managers within the Agency. This consultation process involved a series of workshops to discuss the views of different teams of specialists within the Agency and guide development of the framework.

Groundwater Dependent Terrestrial Ecosystems Risk Assessment, UK (2007)

- Development of a risk assessment based methodology for prioritising investigation and further assessment of groundwater dependent terrestrial ecosystem sites throughout the UK.

Mining and Minerals Sector Experience

Narrabri Stage 3 Extension Groundwater Impact Assessment, NSW (2019)

- Technical lead for the Narrabri Stage 3 Extension Groundwater Impact Assessment. Work undertaken included development and calibration of an extensively revised groundwater flow model to assess the impacts of the proposed development on local groundwater resources.

Carmichael Coal Mine and Rail Project EIS / SEIS, Queensland (2011-14)

- Technical management of groundwater components of Environmental Impact Statement (EIS) and Supplementary Environmental Impact Statements (SEIS) studies of proposed mine and rail developments. Work undertaken included baseline monitoring network installation and development of a groundwater flow model to assess the impacts of the proposed development on local groundwater resources. Key components of this study included an assessment of the potential impacts on the nearby Doongmabulla GAB spring complex and the Carmichael River. As part of these studies Keith successfully acted as the GHD lead during detailed technical discussions with peer reviewers and both State and Federal regulators relating to the potential impacts of this high profile development.

Drake Coal Project EIS, Queensland (2011)

- Technical management of an assessment of the hydrogeological impacts of the proposed Drake Coal Project.

Shenhua Watermark Coal Project Feasibility Study, New South Wales (2011)

- Development of a groundwater flow model in order to assess inflows into the proposed open cut mine workings.

Areas of expertise and selected project experience (continued)

Whatley Quarry, Hanson Aggregates Ltd, UK (1999-2007)

- Project Hydrogeologist / Hydrologist for the Whatley 'super' quarry in southwest England operated by Hanson Aggregates, including development of procedures for data collection, storage and retrieval in line with best practice for the substantial groundwater and surface monitoring network.

Tara Tailings Dam Extension, Outokumpu, Ireland (1999)

- Hydrological and Hydrogeological impact assessment of the proposed Tara Tailings Dam extension in the Republic of Ireland. The project involved the development of groundwater flow and solute transport models. A post-audit review of these models was also undertaken as part of the planning conditions for the extension.

Skouries Gold Project, TVX Hellas, Greece (1998)

- Technical Manager of bankable pre-feasibility stage water management studies for a large mining development in northeast Greece. Development of 3D groundwater flow and site water balance models. Design, specification and supervision of a major multi-observation well pumping test and other hydrogeological data collection activities. Preliminary design of water management systems to control contaminated runoff from the site and provide sufficient water resources to meet the process water demand. Development of a project site water balance model in order to size components of the system and assess performance under extreme hydrological conditions.

South Crofty Closure Study, Environment Agency, UK (1998)

- Prediction of the quantity and quality of discharge from the abandoned South Crofty tin mine workings in southwest England and subsequent impact on surrounding water courses. Specification of post-closure monitoring.

Surface Water Experience

Building on his academic training in both hydrology and hydrogeology Keith has extensive previous experience in the surface water field. Including surface water monitoring network review and design, processing and correction of surface water data sets including rainfall, surface water flows and levels. He also has extensive experience with developing water balances for individual mine tailings facilities and overall mine sites and with developing rainfall/runoff simulations for water resource planning purposes or for use in integrated groundwater/surface water models. A selection of previous surface water projects are provided below.

Mine and tailings dam water balance studies, various clients, UK (1995 – 1999)

- Completion of tailings dam and mine water balance studies for numerous metalliferous mining projects in both Europe and Africa. Typical studies including the collation and review of hydrological data and the development of bespoke numerical simulations to predict long term levels and confirm required storage volumes for engineering design purposes.

Surface water and groundwater monitoring data review, Environment Agency South West region, UK (1996)

- Secondment to the South West region of the UK Environment Agency to undertake a comprehensive review of groundwater and surface water data collation and QA procedures including correction of erroneous data and review of the reliability of stage-discharge relationships used to derive flow from level data at surface water flow monitoring sites. Outline design of an additional permanent gauge for monitoring flow in tidal reaches.

Areas of expertise and selected project experience (continued)

Skouries Gold Project, TVX Hellas, Greece (1998)

- Preliminary design of water management systems to control contaminated runoff from the site and provide sufficient water resources to meet the process water demand. Development of a project site water balance model in order to size components of the system and assess performance under extreme hydrological conditions.

Whatley Quarry, Hanson Aggregates Ltd, UK (1999-2007)

- Project Hydrogeologist / Hydrologist for the Whatley 'super' quarry in southwest England operated by Hanson Aggregates, including development of procedures for data collection, storage and retrieval in line with best practice for the substantial groundwater and surface monitoring network.

Resource and Abstraction Management Framework v4, UK Environment Agency (2006 – 2007)

- Project manager of a two year c£ 300K (fees) project aimed at updating the Environment Agency's Resource and Abstraction Management (RAM) framework methodology to be applied to both surface water and groundwater extractions to ensure consistency with the European Water Framework and Habitats Directives. In addition to reviewing output from resource assessments carried out using Version 3 of the framework the first year of the project included extensive consultation with technical staff and managers within the Agency. This consultation process involved a series of workshops to discuss the views of different teams of specialists within the Agency and guide development of the framework.

Groundwater Dependent Terrestrial Ecosystems Risk Assessment, UK (2007)

- Specification of appropriate groundwater and surface water monitoring systems to confirm impacts on highly sensitive terrestrial GDEs in East Anglia.

Regional Groundwater Modelling Studies, UK Environment Agency (1999-2007)

- The integrated nature of these models developed for the UK Environment Agency required collation, review and processing of both groundwater and surface water data sets. Rainfall, evaporation and river flow and river level monitoring networks were all reviewed prior to extensive data checking and gap filling. The QA'd climate data were then used as input to daily soil moisture based rainfall runoff calculations and the flow and level data used calibrate modelled estimates of total flow (i.e. groundwater baseflow, runoff and interflow) at each gauging station.



James Barratt

WA Region Manager | Principal Hydrogeologist

Education

- M.Sc. in Hydrogeology, North West University (South Africa), 2015 – 2017.
- Bachelor of Environmental Science (Honours) – Hydrology and Hydrogeology, North West University (South Africa), 2014.
- Bachelor of Environmental Science – Geology and Geography, North West University (South Africa), 2011 – 2013.

Employment history

Jan 2022 – Current	Australasian Groundwater and Environmental Consultants Pty Ltd WA Region Manager
Jul 2021 – Dec 2021	Australasian Groundwater and Environmental Consultants Pty Ltd Senior Project Hydrogeologist
Nov 2020 – Jun 2021	Australasian Groundwater and Environmental Consultants Pty Ltd Project Hydrogeologist
Sept 2020 – Oct 2020	Independent Consultant Hydrogeologist & Groundwater Modeller
Apr 2017 – Aug 2020	Exigo Sustainability Pty Ltd Hydrogeologist & Groundwater Modeller
2012 – 2014	School for Biological and Environmental Sciences Student Tutor- and Academic Assistant

Skills

James Barratt has several years' experience as a project manager and hydrogeologist and has worked on groundwater modelling, field data collection and analysis, and hydrogeochemical investigations in South Africa and across Africa before joining AGE in 2020. At AGE, James focusses on managing multidisciplinary projects and regularly completes technical tasks including field data collection, groundwater conceptualisation models, analytical- and numerical groundwater modelling, and technical reporting. James's is also experienced in conducting desktop studies, hydro- and geochemical analysis and interpretation across various sectors including mining, agriculture, industry, and residential developments.

James has broad project management skills which include activities such as:

- design and implementation of drilling programs;
- managing fieldwork data activities;
- purchasing and maintaining field equipment;
- liaison with regulatory bodies regarding site permits;
- budget reconciliation and management; and
- proposal preparation and report writing.

Areas of expertise and selected project experience

Project management

- Wodgina Lithium Project, Pilbara, Western Australia (2024): Project management of a supervised drilling and pumping test programme along with the development of a conceptual; and numerical model. This work was completed to improve the mine's water supply security and undertake a H3 level hydrogeological assessment to support a 5C application.
- Ngualla Rare Earth Project, Tanzania (since 2023): Project managed a multidisciplinary team including geologists, geophysicists, environmental advisors, and hydrogeologists with various field data collection activities including geophysical surveys for groundwater exploration, supervised drilling and pumping tests, and baseline water quality monitoring. The project also included all reporting on the updated environmental management plans, and conceptual; and analytical modelling to inform the groundwater assessments and management plans.
- Ken's Bore Iron Ore Mine and Marillana Project, Pilbara, Western Australia (2022 to 2024): Project management numerous supervised drilling and pumping test programmes along with data QA/QC and bore census of regional bores. Trial large-scale infiltration tests (> 20 L/s) were also completed as part the field activities.
- Hercules Project, Goldfields, Western Australia (since 2024): Project managed the planning, design, and execution of supervised drilling and pumping tests to inform the groundwater assessment required for the Mining Proposal and Mine Closure Plan for the proposed open pit and underground mine.
- Meteor Down South Coal Mine, Bowen basin, Queensland (since 2020): Project managed numerous annual compliance reviews, updated conceptual model, development of the numerical groundwater model, and various iterations of the mine's Progressive Rehabilitation and Closure Plans' groundwater assessments.
- Onslow Iron Project Haul Road, Pilbara, Western Australia (2023): Managed the field data collections including supervised drilling and pumping test programme along with data QA/QC, and direct liaising with pastoralists and traditional owner groups to obtain access to drilling and testing locations.
- Polokwane Smelter Complex, South Africa (2018 to 2020): Project managed a multidisciplinary team including geophysicists, environmental advisors, geochemists, hydrologists, and hydrogeologists with various field data collection activities including geophysical surveys for contaminant plume tracking and mapping, routine water quality monitoring, geochemical waste sampling and characterisation, and supervised drilling and pumping tests. The project also included an updated conceptual model, development of the numerical groundwater model, and modelling of closure management and mitigation to inform the smelter complex's closure environmental and closure liabilities.
- Lurio Graphite Project, Mozambique (2018 to 2019): Project management of a surface and groundwater resource assessment and geochemical waste characterisation which included field surveys and sampling, followed by conceptual; and analytical modelling, and technical reporting. The drilling also included the designing of surface and groundwater abstraction systems from flood-prone riverine and alluvial deposits.
- Karowe Diamond Open Pit and Underground Mine, Botswana (2017 to 2020): Project managed a multidisciplinary team including geophysicists, geochemists, and hydrogeologists undertaking various field data collection activities. These activities included geophysical surveys for groundwater exploration, supervised drilling and pumping tests of deep (>500 m) and angled (~60°) production bores, geochemical waste sampling and characterisation, and conceptual- and analytical modelling. The field data collection activities were completed to inform the underground mine's feasibility studies and environmental impact assessments, and operational mine dewatering requirements and pit slope stability.
- Kisanfu Mine and Lupoto Project, Democratic Republic of Congo, (2017 to 2020): Project managed a multidisciplinary team including geophysicists, hydrologists, and hydrogeologists undertaking various baseline assessments and field data collection activities including geophysical surveys for groundwater exploration, supervised drilling and pumping tests, and dewatering existing open pits using barge pumps. This work was completed to inform the conceptual- and numerical groundwater modelling completed for the projects' dewatering and impact assessments.

Areas of expertise and selected project experience (continued)

Hydrogeological analysis and modelling

- Kanowna Belle Gold Mine, Goldfields, Western Australia (since 2021): Analysis and interpretations of groundwater monitoring datasets, updated the conceptual model, and development of a numerical groundwater model to assist with TSF seepage; and site-wide groundwater management.
- Wodgina Lithium Project, Pilbara, Western Australia (2024): Analysis of field data including drilling observations and pumping tests, development of a conceptual; and numerical groundwater model to predict the groundwater impacts from borefield abstraction on the receiving environment, and H3 level reporting.
- Wonmunna Iron Ore Project, Pilbara, Western Australia (2023): Field supervision of drilling activities, updated the conceptual model, and developed analytical models; and H2 level reporting to support an amended 5C application.
- Meteor Down South Coal Mine, Bowen basin, Queensland (since 2020): Completed numerous annual groundwater compliance reports, updated the conceptual model, and development of a numerical groundwater model with an uncertainty analysis as part of the conditions outlined of the Associated Water Licence and EPBC approval conditions. The numerical groundwater model also informed the mine's Progressive Rehabilitation and Closure Plans' groundwater assessments.
- Laguna Agnes Water, Queensland (since 2021): Developed an integrated surface and groundwater conceptual model and analytical water balance, completed an environmental impact assessment, and providing input during legal proceedings.
- Beetaloo Sub-basin Groundwater Assessment, Northern Territory (2022 to 2023): Completed numerous reviews and groundwater assessments to inform groundwater storage estimations supporting groundwater abstraction licence applications.
- Mount Thorley Warkworth, Hunter Valley, New South Wales (2020 to 2022): Completed the development of a conceptual and numerical model for a Groundwater Impact Assessment as input to an EIS seeking to approve an underground mining expansion.
- Lemington Underground, Hunter Valley, New South Wales (2021): Developed the conceptual model and compiled the impact assessment reporting for a proposed underground water storage facility.
- Rolleston Open Cut, Queensland (2020 to 2021): Updated of the numerical groundwater using MODFLOW-USG to fulfil the condition of the Associated Water Licence.
- Bowen Basin, Queensland (2020): Annual Groundwater Monitoring Report to fulfil the condition of the Associated Water Licence.
- Karowe Diamond Mine, Botswana (2018 to 2020): Lugeon packer testing, data analyses, and numerical modelling using FEFLOW of the open pit and proposed underground block cave mining for the feasibility study compliant with JORC.
- Mphahlele and Magazynskraal Open Pit and Underground PGM Mines, South Africa (2019 to 2020): Developed the conceptual and numerical models of the open pit extension and proposed underground bord and pillar mining complexes to inform the feasibility studies.
- Zandhevel Phosphate Mine, South Africa (2018 to 2020): Developed the conceptual and numerical models of the planned open pit as part of the groundwater impact assessment informing the EIS. A mine closure assessment was also completed that included a risk assessment of the groundwater and hydrogeochemical management and mitigation measures.
- Tshiping Water User Association, South Africa (2017 to 2019): Developed a regional (~7,000 km²) historical and current conceptual model and analytical regional groundwater reserve and balance model.
- Yanfolila Gold Mine, Mali (2018): Specialist groundwater input into the Business Plan Optimisation and slope failure assessments. Review and updated the conceptual models, and mine dewatering and depressurisation plans as part of the assessment.

Areas of expertise and selected project experience (continued)

Hydro- and geochemical assessments

- South Kalgoorlie Operations (SKO), Goldfields, Western Australia (since 2022): Developed a hydrogeochemical conceptual model to inform a source-pathway-receptor analysis assessing return and recycled water from in-pit TSFs.
- Polokwane Smelter Complex, South Africa (2018 to 2020): Development of an integrated hydrogeochemical and hydrogeological conceptual- and numerical flow and mass transport model to assess mass transport migration from waste facilities.
- Pilanesberg Platinum Mine, South Africa (2017 to 2020): Completed numerous waste characterisations, developed and numerical reactive geochemical model, and developed an integrated hydrogeochemical and hydrogeological conceptual- and numerical flow and mass transport model to assess mass seepage from a TSF.
- Shire Valley Transformation Programme, Malawi (2018): Development of a hydrogeochemical conceptual model and salt mass balance to assess salinity build-up in soils during large-scale irrigation projects in low-lying areas.
- Marikana PGM Mine, South Africa (2018 to 2019): Development of an integrated hydrogeochemical and hydrogeological conceptual; and numerical flow and mass transport model to assess whether an in-pit TSF needed to be lined prior to construction to mitigate mass transport migration and contamination risks.
- Lurio Graphite Project, Mozambique (2018 to 2019): Designed and implemented source-pathway; receptor investigations that included isotopic and hydrochemical tracers to inform cost-risk-benefit analyses; as well as waste characterisation and geochemical modelling.
- Zandvliet Wastewater Treatment Works (2019): Conducted sampling and analysis of hydro; and geochemical data for domestic waste assessments based on legislative requirements utilising a risk-based approach.
- Kansanshi Mine, Zambia (2017 to 2018): Completed field sampling of surface and groundwater; analysis and interpretation of the hydrochemical and isotopic data; developed a conceptual model including a key focus using a source-pathway-receptor analysis; and reporting to inform a water tracing assessment.

Training

- First Aid and CPR (current).
- 4WD advanced training (current).
- Utilising PHREEQCi for Aqueous Reactions (Mills Water 2019).
- Microsoft Excel Advanced (Udemy 2019).
- FEFLOW 7.2 Advanced Groundwater Modelling Principles (DHI Oct 2018).