May Patterson
Team Leader - Resource Assessments
NSW Department of Planning and Environment

Dear May,

Comments on Sutton Forest Quarries Pty Ltd – Environmental Impact Assessment

I am a practicing environmental engineer (B.E. Environmental Hons 1 and M.Eng.Sci Groundwater Studies) with 17 years of experience in hydrological studies and numerical groundwater flow modelling. I am a member of the International Association of Hydrogeologists (IAH) and Engineers Australia (IEAust). I have reviewed some of the Specialist Consultant Studies attached to the EIS. This includes the Groundwater Impact Assessment (Coffey 2016), the Surface Water Impact Assessment (SEEC, 2018) and the Biodiversity Offset Assessments (Niche 2018).

My understanding of the project EIS materials is that the proponent assesses:

1. During periods of below average rainfall, levels and flows in Long Swamp Creek and downstream Endangered Ecological Community (EEC) are naturally shallow, low and sustained primarily by baseflow;
2. The project will reduce stream flow and baseflow to Long Swamp Creek and EEC in an average year by some 59 ML/yr (34 ML/yr of runoff and some 19 ML/yr of regional groundwater baseflow);
3. These changes - the loss of some 24 Olympic sized swimming pools of environmental water each year– will have negligible impact on the biodiversity of Long Swamp Creek and EEC.

However, after reading the EIS I was none the wiser regarding:

1. The quantity of flow and water depths in Long Swamp Creek and EEC for average, below average or drought rainfall conditions both for baseline and predicted quarrying and post-quarrying conditions (i.e. potential changes to creek levels and flow-duration frequency curves);
2. The water needs of the species that comprise the Long Swamp Creek and EEC; nor
3. The project impacts upon Long Swamp Creek and EEC species, particularly when their water needs were naturally compromised during below average rainfall conditions or drought.

I also noticed that the numerical model predictions of baseflow volumes to Long Swamp were:

1. Not calibrated using either geochemical measurement methods or systematic measurements of streamflow and baseflow separation analysis (reducing confidence in the model predictions);
2. Sensitive to climate, e.g. a simulated 1.43 fold reduction in recharge as a fixed percentage of rainfall caused a 3.57 fold reduction in baseflow;
3. Reported without notes on sensitivity and uncertainty to various other assumed model inputs;
4. Not clearly quantified and reported for post-quarry scenarios; and
5. Based on placement of a no-flow lateral boundary condition that is mathematically 'too close' to the proposed southern boundary of the development (the model boundary should be moved further south to Stingray Swamp EEC or changed to a general head boundary condition).

In addition, I observed that impacts to shallow groundwater flow systems and their discharges to ecosystems were not quantified by the numerical model, mapped or clearly assessed. The proponent predicts some 50% of shallow groundwater infiltration does not reach the regional water table, there may exist hanging swamps on the valley slopes, and the proposed project will intersect, impact and interfere with shallow groundwater resources (probably by the time the excavation reaches an elevation of 650m AHD).

If the EIS does not contain clear reporting, discussion or assessment of the above quantities and processes for below average rainfall conditions and drought (when there will be negligible streamflow, naturally declining baseflows, and potentially water-stressed species of an endangered ecological community) and the predictive model has a number of limitations, how can there be confidence that the proponent's methodology to assess that biodiversity water-related impacts are indeed acceptable, the risks of impact are negligible and that any potential impacts from uncertainty in prediction are indeed manageable?

In addition to those gaps summarised above, during my review I became concerned that:

1. The groundwater monitoring system was insufficiently documented;
2. There was insufficient assessment of backfilled final void hydrogeochemical impacts;
3. Conceptual site geological, groundwater and surface water cross-sections were too simple;
4. Holistic figures and tables of the groundwater and surface water systems were not provided to clearly communicate the baseline, quarrying and post-quarry water balances for average, below average and above average rainfall conditions;
5. Areas of groundwater impact and potential groundwater impact were counted in the total 'potential biodiversity offset area' and might need to be excluded;
6. The quarry excavation footprint would capture more than the allowable harvestable right and therefore the resultant loss of runoff associated with the excavation and other onsite water storages must need to be specifically licenced.

Accordingly, I have some concern that the current EIS does not demonstrate a flow of relevant information from project hydrologists, hydrogeologists, numerical groundwater flow modellers and hydrogeochemists to project biodiversity experts, nor to NSW Government planners, regulators and state water managers to allow them to thoroughly execute their duties in the interests of the people of NSW. Predicted project impacts on baseflow and streamflow reduction and groundwater quality should to be presented in the context of below average rainfall and drought conditions. This is necessary to support management of flows and water quality into the drinking water catchment and for thorough assessment of biodiversity impacts, including to Endangered Ecological Communities. Therefore, in my opinion, it is too early to declare the impacts of the project negligible and that adaptive management can provide an appropriate level of protection for biodiversity.

On the matter of adaptive management, please note that the EIS does not document the time it takes for to stresses within the quarry to reach ecological receptors via the groundwater system. Note also that the proponent's specialist Cook (2018) found it necessary to state "*At this stage, with available monitoring data, it is considered premature to establish as set of absolute water levels, bore yields or water quality trigger values…*".

In conclusion - and given that absolute water levels are rarely an adequate trigger level for reliably detecting environmental impacts in a timely manner - I recommend more monitoring, more data analysis and further assessment work to complete the environmental assessment to support any water management plans that may be developed if the project is approved within the overall context of NSW Government's risk management-based assessment framework.

More detailed technical comments to support this submission are attached.

List of Attachments

Appendix A: Technical Commentary (Key Issues)
Appendix B: Technical Commentary (Detailed Comments)
Appendix C: Conceptual Model and Water Balance Recommendation
Appendix D: Numerical Model Domain Recommendation
Appendix E: EIS Recommendations

APPENDIX A – Technical Commentary (Key Issues)

1. SEEC (2018) estimate that the total harvestable right for the site at 14.8 ML. They suggest this right can be divided equally between Water Storage Dams A and B. However, this neglects consideration of the excavation area which will intercept rainfall and prevent runoff. Assuming an excavation / interception area of 47 Ha, a natural runoff coefficient of 0.08, and average annual rainfall of 902 mm, the excavation will harvest some 34 ML of runoff in an average year, more than twice the estimated harvestable right for the entire site. Will this overland flow water owned by the State be secured through a harvesting access licence or by some other means?
2. Areas that will be impacted by reductions in surface water flow, groundwater discharge and evapotranspiration appear to be mapped in the EIS as potential biodiversity offset areas. In my opinion, this is inappropriate. The offset maps should be revised based on updated hydrogeological assessment and mapping, consultation with ecohydrologists with expertise in groundwater use by trees, and where appropriate and safe to do so, on-ground ecological site survey to the north of the proposed excavation area between the 640m and 660m AHD contour lines.
3. Excavation through lenses of shale and perched aquifers in the Hawkesbury Sandstone Formation at approximately 650 m AHD to 660 m AHD during the first three (3) years of quarrying will impact escarpment vegetation communities as this groundwater evaporates or drains into or below the base of the proposed excavation. These impacts have not been quantitatively assessed as part of the EIS documents I reviewed.
4. The groundwater recharge retained and transmitted sideways by shallow sandstone - shale interbeds is not represented as geometry in the predictive groundwater model. This helps explain why Coffey (2016) arrived at a groundwater recharge estimate of 3.2% of average rainfall which is smaller than the relevant Water Sharing Plan (WSP) estimate.
5. For reference, the NSW Government Macro WSP for the Greater Metropolitan Region Groundwater Sources (NOW, 2011) estimated from a water resource management perspective using rainfall data from 1921 to 1995 that 6% of rainfall in Sydney Basin South infiltrates into the ground and that 50% of this water should be reserved for environmental purposes. It is unclear if this the basis for the estimate by Coffey (2016) and Cook (2018) that approximately one half of recharge provides base flow to watercourses with evapotranspiration and escarpment discharge consuming the remainder.
6. A clear and concise assessment of impact for average and below average rainfall years has not been presented. Presentation of quantitative water balance figures and conceptual cross-sections showing all components of the hydrological cycle and all groundwater flow pathways would allow decision makers to more easily review the surface water, groundwater and biodiversity impact assessments and thereby assess the merits of the proposal. For example, refer to Appendix C.
7. The Surface Water Impact Assessment (SEEC, 2018) predicts that after Stage 1 there would be no direct surface water runoff from the extraction area to Long Swamp Creek and that the processing and stockpiling areas would reduce runoff. This represents a 34 + 6 ML/yr (2%) reduction in flow into Long Swamp Creek for an average year. SEEC (2018) state this loss "*would be potentially offset by increases in infiltration to groundwater*", however, the Groundwater Impact Assessment by Coffey (2016) does not appear to consider the possibility of enhanced recharge, possibly because of in-pit evaporation effects, and predicts that baseflows to Long Swamp and Long Swamp Creek would be reduced by 0.052 ML/d (19 ML/yr). Therefore, the EIS prediction appears to be for a 59 ML reduction in flow within Long Swamp Creek and Long Swamp for an average year. Given the clearing of native vegetation elsewhere in the disturbance area, it appears the proposed project would alter the natural flow regime towards higher flows during wet periods and lower flows during dry periods. How will this impact Long Swamp EEC and Long Swamp Creek?

8. The project groundwater model results show that baseflow to Long Swamp Endangered Ecological Communities (EEC) is highly sensitive to the amount of groundwater recharge. For example, a simulated 1.43-fold reduction in groundwater recharge to the calibration model caused a 3.57-fold reduction in baseflow to Long Swamp. Despite this sensitivity, however: (i) the model was not calibrated to streamflow monitoring and baseflow separation analysis data, (ii) no sensitivity tests were reported, and (iii) the impacts of the proposed project were only estimated for long-term average conditions and not for any pro-longed drought during which time impacts from quarrying activity would be more significant.
9. Groundwater capture by the proposed quarry is predicted to extend southwards into neighbouring catchments beyond the extent of the numerical model domain. For example, note how in Figure 23 on page 2-72 of Cook (2018) the 0.1m drawdown contour predicted by Coffey (2016) abuts the southern model boundary. Therefore, the model domain should be revised to assess the potential baseflow impacts to Stingray Swamp and/or Hanging Rock Swamp. The EIS should clearly report the cumulative impact of all quarrying and nearby groundwater pumping activity on all EECs. Refer to Appendix D for illustration.
10. A significant gap in the EIS reporting is the inputs, assumptions and predictions for the post-extraction groundwater regime. Are the post-operational impacts of the development (in perpetuity) the same as the predictions presented for Year 45?
11. The aquifer parameters and boundary conditions that have been selected for numerical modelling to explore impacts to baseflow in perennial sections of Long Swamp EEC appear poorly justified both with respect to the field measurement data and the predictions provided. Revisions and/or sensitivity tests to the horizontal and vertical hydraulic conductivity and storage values are required. Refer to the detailed commentary provided on subsequent pages for further information.
12. The proponent's assessment of negligible impact to EECs is, in my opinion, insufficiently justified. The proponent should be required to present a through analysis of groundwater - surface water interaction budgets with reference to scientific studies of ecosystem water requirements for EEC constituent species. For example, what are the operational or post-operational groundwater impacts from the proposed project in terms of swamp groundwater and surface water levels and flows? What changes in swamp water levels, flows and baseflows over various durations might cause undesirable ecological impacts? Might any of these impacts exceed thresholds for healthy EEC function?
13. The proponent's assessment that adaptive management can protect Long Swamp EECs does not appear to be tested through consideration of aquifer hydraulic diffusivity nor groundwater system time constants nor the time taken for pressure disturbances from mining or rehabilitation or remediation to move through the regional and perched aquifer systems. If the project did cause a problematic loss of water to any EEC, how long would it take to restore this lost water and offset the impact?
14. The proponent's specialist Cook (2018) stated "*At this stage, with available monitoring data, it is considered premature to establish a set of absolute water levels, bore yield or water quality trigger values…*" and appears to suggest that further monitoring work is required to understand the regional groundwater system before meaningful measures could be designed to protect it.
15. The current proposal is ultimately for quarrying down to 630 m AHD. The proponent's specialists suggest in cross-sections that this is approximately 14 m below the elevation of the regional water table elevation of 644 m AHD. However, given the aquifer cross-connections created by the long open exploration drill-holes in Hawkesbury Sandstone Formation and noting that some monitoring piezometers such as SFQ DDH1 recorded falling groundwater levels after being completed sometime after drilling, there is, in my opinion, a possibility that quarrying activity will intersect and drain some regional groundwater by the time the proposed excavation reaches approximately 650m AHD.
16. The design of the groundwater monitoring and recording network is insufficiently documented and there has been insufficient analysis of the collected groundwater level monitoring data. Refer to the detailed commentary provided on subsequent pages for further information.
17. While no final voids are proposed, the EIS provides a commitment to use onsite and offsite reject materials to backfill the quarry. Backfilling of the void will result in increased hydraulic conductivity, groundwater storage and recharge in the void compared to baseline conditions. Ultimately this will result in changes to the chemistry of groundwater flowing into Long Swamp Creek. In the EIS chapters I reviewed, I did not identify any groundwater flow modelling assessment of final groundwater levels within the backfilled void nor any reporting of a hydrogeochemical modelling assessment of these impacts upon Long Swamp Creek. A hydrogeochemical assessment is recommended to finalise the EIS and support development of a water management plan.

APPENDIX B – Technical Commentary (Detailed Comments)

A. Assessment of Ecological Impacts

1. Cook (2018) states at page xiii, paragraph 5, "*The numerical computer groundwater model predicts a maximum reduction of 0.052 ML/day in baseflow to Long Swamp Creek and Long Swamp over the 45 years of extraction. This equates to a reduction of 2.6% of the modelled baseflow which is considered to be a minimal impact and within the range of natural variation in flows for this type of GDE*". The proponent should elaborate with references to a surface water budget and the scientific ecological literature how a loss of 0.052 ML/d of water equates to a minimal ecological impact for this type of GDE.
2. Cook (2018) and Coffey (2016) estimate without reference that approximately 50% of recharge is lost as escarpment discharge and evapotranspiration. Niche (2018) report a project disturbance area of approximately 63 Hectares. If groundwater recharge is taken as 6% of incident rainfall as per the Water Sharing Plan estimate for the Greater Metropolitan Region Groundwater Sources – Sydney Basin South source, this yields an estimate for lost escarpment discharge and evapotranspiration of 0.050 ML/d.
3. A water loss of 0.052 ML/d equates to fifty-two thousand litres per day (52 kL/d). This is roughly the amount of water used by 80 Sydney dwellings per day, or the loss of one backyard swimming pool each day, or the loss of 7.6 Olympic sized swimming pools every year.
4. If flows in Long Swamp Creek are reduced by 52 kL/d:
   a. What will be the reduction in stream flow depth and stream flow velocity?
   b. What are these reductions as a percentage of average and drought stream flows and levels?
   c. What is the probability of a drought occurring that reduces water availability (baseflow) below some threshold from which constituent ecosystem species cannot recover?
5. If evapotranspiration and escarpment discharge north of the disturbance area is reduced by 50 kL/d:
   a. Will any hanging swamps be impacted? (note: the EIS appears to suggest these potential areas of impact were not surveyed because of heavy ground cover and inaccessible terrain)
   b. What will be the downgradient impact of the drawdown on Sydney Peppermint Forest and Scribbly Gum Woodland?
   c. What would be the upgradient impact (south of the excavation) on the Stringybark and Sydney Peppermint Forest?

6. Cook (2018) states at page xiii, paragraph 6, "*Maximum drawdown of the water table at the eastern end of Long Swamp of less than 0.1 m at the end of Stage 5, Year 28 with the same prediction at the end of Stage 7, Year 45. This amount of drawdown is not considered significant and within the range of natural variability*". Can the proponent elaborate with references to monitoring data, a surface water budget and the scientific ecological literature how a bulk-average drop of up to 10 cm in groundwater level below the swamp over a period of at least 18 years (and possibly in perpetuity?) equates to a minimal ecological impact for this type of GDE?

   For example, at page 8, Section 2.3, paragraph 3, Coffey (2018) notes the surface water depth at location WSL3 was approximately 50 cm during March/April 2014 (the measurement date was not specified in the modelling report). Monthly rainfall for March 2014 at Moss Vale was 190 mm (which is about 110 mm above average). Monthly rainfall for April 2014 was 42 mm (about 38 mm below average). What is the water level at WSL3 for average, below average and drought conditions? Is a 10 cm drop in groundwater level lasting at least 18 years insignificant for all of these climatic conditions? What was the water level at WSL3 on 23 July 2014 during Coffey's site visit when rainfall had been about 40 mm below average for four (4) consecutive months? How long does the 10 cm drop in groundwater last following closure and rehabilitation of the quarry?

The response should also address the limitations of the numerical model. For example, the numerical groundwater model is an Equivalent Porous Media (EPM) model that does not directly simulate groundwater flow in rock defects and relies on average, surrogate values of hydraulic conductivity and storage to predict approximate values of drawdown. Therefore, it would be reasonable to expect that drawdown within Long Swamp would be both smaller and larger than 10 cm depending on the location and the precise location of the more permeable groundwater flow pathways.

7. What are the water needs of the various species that comprise the Long Swamp and Creek EEC?, e.g.
    a. What is the critical stream-flow values and water depth required to maintain habitat for successful breading of the various constituent species?
    b. Can all species readily migrate to another location where water is available?
    c. How will the population decline if water availability is reduced?
    d. How long can the species survive without access to rainfall and baseflow?
8. Can all species comprising the EEC accommodate the reduced water availability caused by the proposed development during an extended drought?

B. Information Requirements for Adaptive Management

1. Cardno (2018) suggests, "*Any subsequent changes in swamp habitat, such as reduced soil moisture, vegetation die-back and changes in communities of aquatic plants should be correlated with any observed changes in groundwater levels and appropriate management actions taken to prevent or minimise any further change*".
2. It needs to be clarified that once quarrying has commenced, and if undesirable changes are observed, it would not be possible to prevent further undesirable reduction in baseflow to the Long Swamp Endangered Ecological Community (EEC) for quite some time. For example, if the quarry was instantaneously backfilled and groundwater levels beside the quarry were restored to pre-development levels, it will take time to restore baseflows to the swamps. What is this time? What mitigation scenarios, if any, would be practical and achievable for hanging swamps? What mitigation scenarios, if any, would be practical and achievable for downgradient perennial swamps?
3. Regarding timing of impacts, the EIS does not report the response time of the system to recover from disturbances or the impact beyond 45 years. The proponent should be required to report the hydraulic diffusivity of the perched and regional aquifers, calculate the groundwater system time constants and the long-term impacts into the future.
4. Hydrological and hydrogeological assessments, including modelling, can take quite some time to deliver. Prior to accepting that adaptive management could be successful, modelling predictions are required to demonstrate how long it might take for the system to recover to baseline conditions once quarrying and rehabilitation / mitigation was completed.
5. With access to a more complete assessment:
    - Ecosystem managers could develop more appropriate offsetting strategies.
    - Water managers developing the project Water Management Plan (WMP) may identify more appropriate mitigation and management strategies with more simplified monitoring and reporting requirements. In my experience, poorly planned field monitoring programs tend to be expensive and ineffective.

C. Baseflow Measurement and Groundwater Model Calibration

1. The proponent should tabulate the available baseflow measurement data and clearly describe how this data was utilised to calibrate the groundwater flow model. The Australian Groundwater Modelling Guidelines suggest that when "*observations and measurements unavailable or sparsely distributed in areas of great*

interest" the resultant model has a Class 1 confidence level classification. A Class 1 confidence model is suitable for:

a. "*First pass estimates of extraction volumes and rates required for mine dewatering*";
b. "*Developing coarse relationships between groundwater extraction… and associated impacts*";
c. "*Understanding groundwater flow processes under various hypothetical conditions*".

2. A Class 2 confidence model is suitable for "*Prediction of impacts of proposed developments in medium value aquifers*" and "*Estimates of dewatering impacts for… excavations and the associated impacts*". A Class 2 model requires "*Streamflow data and baseflow estimates available at a few points*".

3. In 2004 the NSW Department of Infrastructure, Planning and Natural Resources (Pritchard et al., 2004) issued a report entitled *A review of the status of the groundwater resources in the Southern Highlands* in which the groundwater resources were stated to be "*highly valued*". To achieve a Class 3 confidence level classification streamflow and stage measurements need to be available along with "*reliable baseflow estimates at a number of points*".

4. On Page 8 at Section 2.3, paragraph 4 of Coffey (2016) it was reported that visual estimation of stream flow past Old Crossing in Long Swamp on 23 July 2014 was 4.3 ML/day. This streamflow was "*considered to have a large component of baseflow*" and "*Actual baseflow was likely to have been larger as other voids in the peat were observed*". It was also noted that July 2014 "*had been preceded by 4 months of below average rainfall (162mm)*".

   On Page 40 of Coffey (2016) it was reported that "*normalised to an annual period, incident rainfall at the Site over the calibration period was 1.43 times the long-term annual average*". On Page 41, Table 7 of Coffey (2016) the simulated baseflow to Long Swamp, Long Swamp Creek and tributaries for the calibration period (1.43 times above average rainfall conditions) was reported to be 7.19 ML/d. For long-term average climatic conditions, it was reported to be 2.01 ML/day (Page 43, Table 8 of Coffey, 2016). These predictions appear to be inconsistent with the observations.

   For example, if simulated baseflow for annual average rainfall conditions is 2 ML/day but observed baseflow during a below average rainfall period is upwards of 4 ML/day, then does the calibration of the groundwater flow model need to be revisited? For example, should long-term annual recharge to the regional water table be increased from 3.2% to at least 4.1% of rainfall to yield a prediction of long-term annual average baseflow of approximately 4 ML/day? Streamflow gauging data and baseflow separation analysis and/or groundwater hydrogeochemisty mass balance techniques are required to answer this question.

D. Simulated Aquifer Properties

1. Figure 5.9 on Page 40 of Coffey (2016) compares calibrated and observed hydraulic conductivity. Some simplifications to the calibrated hydraulic conductivity parameters are not sufficiently justified and the uncertainty this introduces would best be addressed by an alternate calibration scenario with higher recharge, refined geological layers and increased hydraulic conductivity, especially in the vicinity of the proposed quarry.

2. No calculations or working are presented by Coffey (2016) to justify the statement that "*For a volume of media comparable to the cell sizes used in the model, K varies from about 1 m/day at the surface to about 0.1 m/day at 100 m depth. The ratio of vertical K to horizontal K (Kv/Kh) is estimated to be about 0.01 to 0.02*".

3. Vertical hydraulic conductivity within 60 m of ground surface within the numerical model appears to be set approximately 0.5 to 2.0 orders of magnitude too low compared to aquifer testing interpretation results for GW051450 and the "Core Tests (friable sandstone)" data. Based on the field data there should be sandstone layers within the top 60 m of the model with vertical hydraulic conductivity greater than about 0.07 m per day.

4. Horizontal hydraulic conductivity below 60m of ground surface within the numerical model appears to be set about one order of magnitude lower than the aquifer test interpretation results for GW104765 and the

available "*Southern Highlands (specific capacity)*" data and two orders of magnitude lower than the "Southern Highlands (long-term pumping tests)" data.

5. An aquifer specific storage coefficient of 1 x 10^{-6} m^{-1} is assumed for all model layers and zones irrespective of geology and depth. While a value of 1 x 10^{-6} m^{-1} is consistent with a specific storage values for a confined sandstone aquifer, Cook (2018) interprets that parts of the aquifer are partially confined. Maps of the confined and unconfined status of each numerical model layer need to be provided for the start and end periods of the model calibration run (and each model scenario). Which model layers about the proposed excavation contain confined and unconfined groundwater for each scenario? Does this accord with the site observations?
6. An aquifer specific yield (drainable porosity) value of 2% is assumed for all model layers and zones, irrespective of location and depth while at page 17, paragraph 4, Coffey (2016) suggest that the "*total primary and secondary porosity that allows fluid flow ranges between 10% at the surface and 5% at depth*". While a specific yield of 2% might accord with short-term drainage rates from some sandstones with fine-grained inclusions, layers of clay and shale (that act as aquitards and basements for perched aquifers) and coarser grained sandstones will have a different specific yield value. Sensitivity testing of the specific yield value is warranted given the range of primary and secondary porosity values suggested by Coffey (2016) and the wide range of specific yield values for sandstone reported in the literature.

E. Groundwater Level Monitoring Network QA/QC

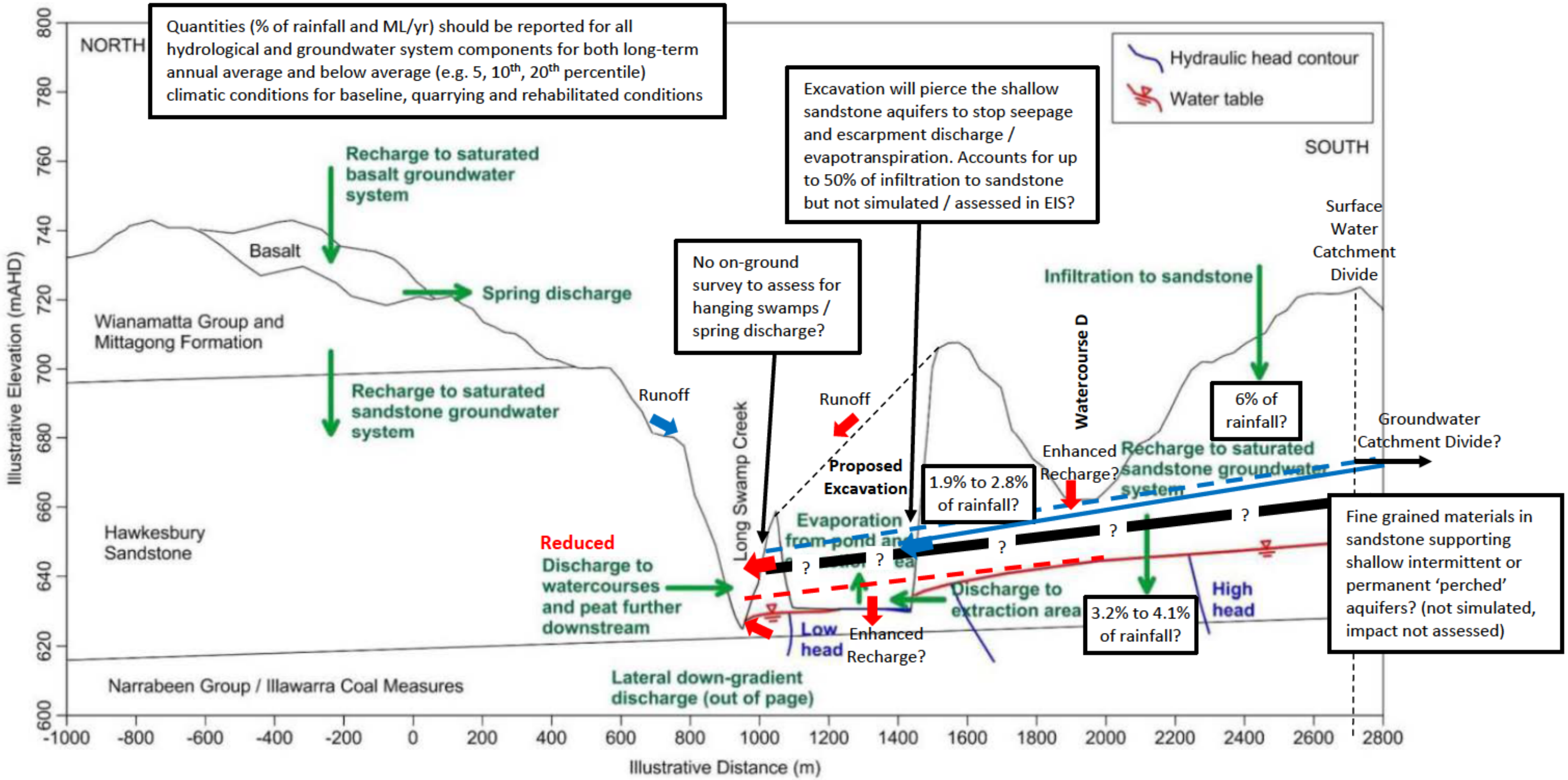
1. Are the monitoring wells that are instrumented to record groundwater level data every four hours open or closed to the atmosphere?
2. What is the make and models of the data loggers recording groundwater levels?
3. If the sensors are unvented, is there a barometric pressure sensor installed on site recording atmospheric pressure variations?
4. Is the data presented in the EIS corrected for barometric pressure?
5. How were the corrections for barometric pressure and manual dip measurements performed?
6. What survey method was utilised to record the monitoring bore casing elevations in m AHD and what is the vertical accuracy of that survey method utilised?
7. Within the EIS there is reference to damage to the monitoring network and repairs. What damage occurred and when, and what repairs have been undertaken?
8. Can all the raw uncorrected and corrected data be provided for independent analysis?

F. Analysis and Interpretation of Groundwater Level Monitoring Data

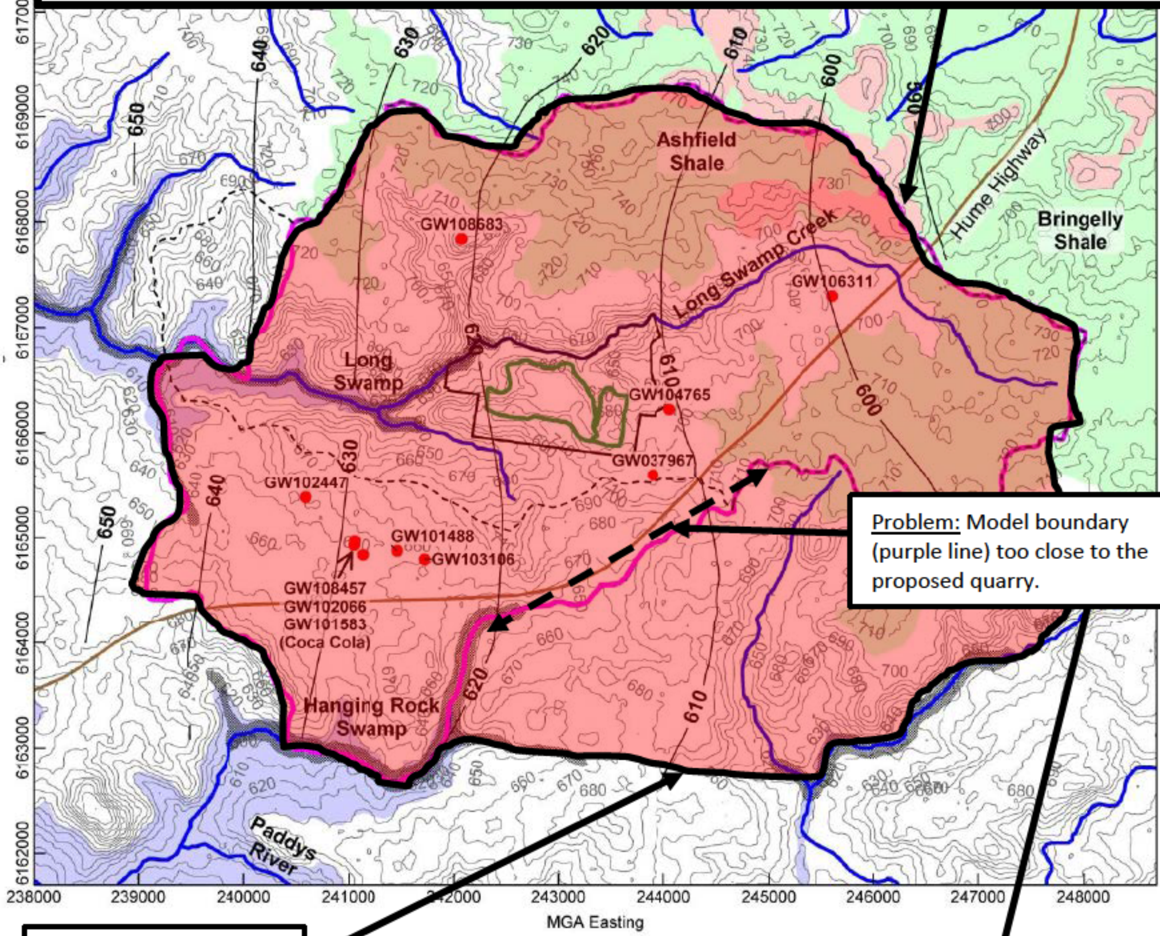
1. While high frequency groundwater level data has been collected at the site, it would appear this data has not been analysed with traditional hydrogeological data analysis techniques to estimate quantities like monitoring well barometric efficiency, aquifer confinement, aquifer specific storage, or aquifer specific yield (i.e. the properties that need to be known to develop model layers and a groundwater flow model to reliably predict project impacts).
2. The high frequency groundwater level time series needs to be analysed with frequency and time domain techniques to assess barometric efficiency, aquifer confinement and aquifer specific storage values.
3. The groundwater level fluctuations recorded following drilling should be analysed with the water table fluctuation analysis method to estimate the relationship between rainfall and aquifer storage.
4. Explanations need to be provided for the declines in groundwater level observed following the drilling of the long open boreholes as part of the resource exploration program and the more recent groundwater level monitoring

Figure 12 Hydrogeological Conceptual Model

(after Coffey, 2016)



Minor Problem: Modellers assume no groundwater flow across surface water catchment divides, even despite the presence of groundwater pumping wells outside and near the chosen model boundary. The model calibration and cumulative impact assessment will therefore exclude the impact of these wells on baseflows to Long Swamp Creek. Consequently, the model calibration process results in different, surrogate values of recharge and hydraulic to reproduce observed heads and offset the groundwater capture that excluded from the simulation.



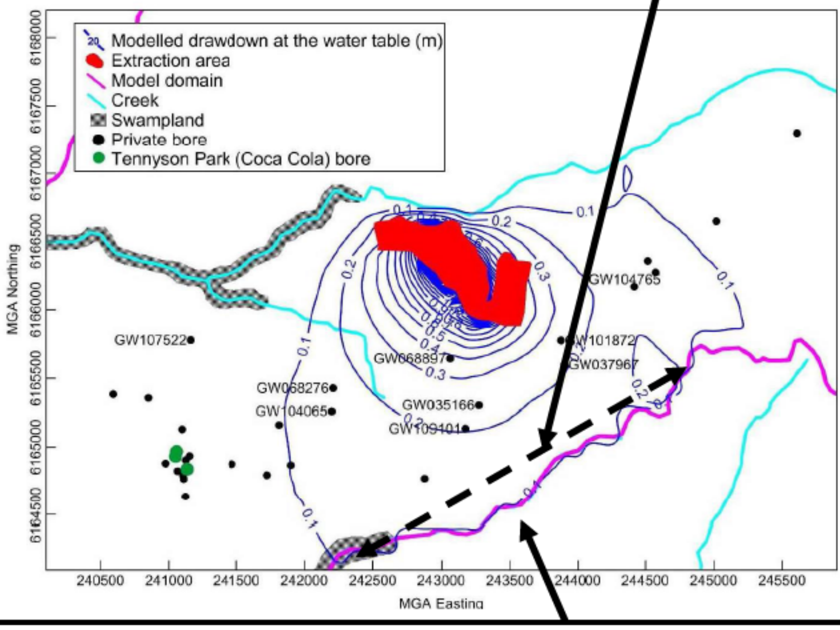
Problem: Model boundary (purple line) too close to the proposed quarry.

Solution:

1. Extend model boundary south and east to Stingray Swamp and report project impacts on Hanging Rock Swamp and Stingray Swamp baseflow.

2. Test sensitivity of model calibration to no-flow boundary assumptions with general head boundary conditions.

Figure 23 Predicted Long Term Drawdown – Year 28 (after Coffey, 2016)



Note how drawdown 'bunches' up against the no-flow boundary at the edge of the model domain. In reality this drawdown would extend further south-east towards and into the surface water catchments for Stingray and Hanging Rock Swamp.

APPENDIX E – EIS Recommendations

Further work, including sensitivity and uncertainty analysis, is required to complete the assessment and to verify the predictions of project impact and significance offered by the proponent. Some improvements to the project groundwater model setup and input data are recommended. Once the modelling has been revised and completed I would appreciate the opportunity to finalise my review commentary in accordance with the Australian Groundwater Modelling Guidelines.

Given that Cook (2018) appears to suggest that existing monitoring data is insufficient for establishing trigger levels, and since I interpret that excavation through perched aquifers will permanently disrupt groundwater availability to both upgradient and downgradient shallow ecosystems and cause drainage into and some mechanical unloading of rocks hosting the regional water table, I recommend that monitoring of groundwater levels and baseflows continue for a further three years prior to commencing any development. This will allow baseline conditions to be more thoroughly documented, analysed and understood; which in turn will allow for development of an improved groundwater model, and consequently development of appropriate trigger levels that incorporate improved understanding of natural variability.

I also recommend that further information be provided (including an adequately specified monitoring program) prior to accepting the proposition that, in future, adaptive managers could implement effective remedial action plans to rectify any unassessed or unpredicted undesirable outcomes to EECs. The aquifer hydraulic diffusivity and groundwater system time constants need to be reported. The time taken for pressure disturbances from quarrying, rehabilitation and any remediation to move through the regional and perched aquifer systems to restore swamp baseflows to (or close to) pre-mining levels should be reported.