TO THE LAND COURT OF QUEENSLAND

Further Supplementary Individual Expert Report – Groundwater conceptualisation and quality

Dr Matthew Currell

REGISTRY: Brisbane
NUMBER: EPA495-15
MRA496-15
MRA497-15

Applicant:	NEW ACLAND COAL PTY LTD ACN 081 022 380
	AND
Respondents:	FRANK AND LYNN ASHMAN & ORS
	AND
Statutory Party:	CHIEF EXECUTIVE, DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION

1. Introduction

[1] This supplementary report on the topics of groundwater conceptualisation and quality has been prepared in response to the re-opening of evidence in this matter, following new advice provided by the Independent Expert Scientific Committee for Large Coal Mining and Coal Seam Gas Development (**IESC**) in December 2016 (**IESC 2016 Advice**), after New Acland Coal (**NAC**) provided it with new material related to these topics. I have reviewed this material and the IESC's advice, as well as new project conditions contained in the approval decision of the Federal Minister for the Environment. My letter of instructions dated 8 February 2017 is included as Attachment A.

[2] My opinions regarding the work conducted by NAC on groundwater conceptualisation and quality up until June 2016 were outlined in the following reports:

- Joint expert report: Groundwater conceptualisation, quality and groundwater modelling (16/2/2016);[1]
- Individual expert report: Groundwater conceptualisation and quality (24/2/2016);[2]
- Supplementary joint expert report: Groundwater impacts of the proposed Stage 3 mine (11/05/2016);[3]
- Supplementary individual report: Groundwater conceptualisation and quality (06/05/2016);[4] and
- Second supplementary statement of evidence by Professor Werner and Dr Currell (02/06/16).[5]

[3] These reports contain a number of criticisms of the scientific work carried out under these topics by New Acland Coal to date, including:

- Inadequate field data to understand the hydrogeology of the site and surrounding areas, and the lack of a robust conceptual hydrogeological model of the region;
- Flaws and deficiencies in the way field data have been collected, interpreted, reported and incorporated into the conceptual and numerical models;
- Inclusion of data and/or features in the conceptual and numerical model for which the evidence base was questionable; and
- An inadequate monitoring program and baseline data to clearly detect potential impacts of the project on groundwater receptors and determine the degree of impact from future proposed mining activity.

[4] The IESC also pointed out many deficiencies of this kind in their advice on the project in 2014 and 2015, and I considered and referred to this advice when preparing my previous expert reports. Subsequently, the IESC provided further advice on the basis of additional reports provided to them by NAC in the second half of 2016. A report by SLR Consulting from January 2017 also details work recently done to assess the hydrogeological effects of faulting on the site, which I have reviewed.

[5] The primary focus of this report is whether, in light of the IESC 2016 Advice and the new materials provided by NAC, the issues previously identified in my expert reports have been

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[1] Exhibit 405, [NAC.0033].

[2] Exhibit 435, [OCA.0021].

[3] Exhibit 825, [OCA.0070].

[4] Exhibit 824, [OCA.0069].

[5] Exhibit 1116, [OCA.0116].

addressed, to the extent that NAC have produced a rigorous conceptual hydrogeological model, and a solid evidence base on which to:

a) make sound predictions of future impacts on groundwater from the project; and
b) detect and mitigate potential adverse impacts on groundwater users.

2. Materials used to prepare this report:

[6] This report made use of the following documents provided by NAC on February 4th, 2017 at the time of re-opening of the evidence:

- Department of the Environment and Energy 2017a. Decision of Minister for the Environment and Energy, Stage 3 Expansion of New Acland Coal Mine, Queensland (EPBC 2007/3423) (**EPBC Approval**).
- Department of the Environment and Energy 2017b. Statement of reasons for approval of a proposed action under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). 18th January 2017 (**Reasons**).
- IESC 2016, Advice to decision maker on coal mining project. IESC 2016-081: New Acland Coal Mine Stage 3 (EPBC 2007/3423) – Expansion (**IESC 2016 Advice**).
- Johnson, A. 2016. Letter from Chair of the IESC to Department of the Environment and Energy dated 21 December 2016 (**IESC Chair Conditions Letter**).
- SLR, 2016a. NAC03 Fault Hydrogeological Investigation Program, October 2016 Status Report. Report for New Hope Group 24 October 2016 (**SLR 2016a**).
- SLR, 2016b. NAC03 GMIMP [Groundwater Monitoring and Impact Management Plan], October 2016 Status Report. Report for New Hope Group: 24 October 2016 (**SLR 2016b**).
- SLR, 2016c. *NAC03* Landholder Make Good, October 2016 Status Report. Report for New Hope Group: 24 October 2016 (**SLR 2016c**).
- SLR, 2016d. New Acland Stage 3 Project Groundwater Model Update, Phase 1 Completion Report (Numerical Model Scoping Report). Report for New Hope Group: 24 October 2016 (**SLR 2016d**).
- SLR, 2017. New Acland Stage 3 Project Fault Hydrogeological Investigation Program, Drilling & Testing Report. Report for New Hope Group: 9th January 2017 (**SLR 2017**).

3. Summary of My Conclusions:

[7] In the IESC 2016 Advice, the IESC states that it believes most of the technical and scientific matters related to groundwater conceptualisation, modelling and quality that were raised in their 2015 advice "…have been addressed, or a process to address them is provided within the additional information provided by the proponent"[6].

[8] It is my opinion that the latter part of this statement ("or a process to address them is provided"), allows much of the proper scientific work required to underpin the conceptual and numerical hydrogeological modelling to remain incomplete, even while the question is answered in the affirmative by the committee. My analysis of the material provided to the IESC indicates that much of this work indeed remains incomplete. I disagree that the existence of a plan to conduct further data collection and modelling constitutes the necessary

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[6] IESC 2016, Advice to decision maker on coal mining project. IESC 2016-081: New Acland Coal Mine Stage 3 (EPBC 2007/3423) – Expansion.

scientific work required to provide confidence in the hydrogeological modelling, impact assessment and management strategies.

[9] In addition, the way this question was framed restricts the IESC's analysis to issues raised in the 2015 advice, ignoring potentially significant issues contained in its 2014 advice that have not been addressed, and additional issues identified in these proceedings by me or Professor Werner.

[10] While the information contained in the reports provided to the IESC does include some new hydrogeological data and analysis from the site, such as additional drilling, cross sections, slug tests, water level readings and a pumping test to explore the hydrogeological behaviour of one major fault, the information in the reports still predominantly outlines plans for work to be carried out in future, rather than a substantial body of new results that address the deficiencies pointed out in the IESC's 2014 and 2015 advice and the groundwater evidence heard in these proceedings. It therefore appears that the IESC have placed heavy reliance on future work that is yet to be completed, to address such deficiencies.

[11] Developing a plan to collect and analyse data is not the same as conducting this work, and does not constitute complete science in my view. Before scientific data (such as those used in a groundwater modelling and impact assessment program) have been collected, analysed and carefully scrutinised, one cannot claim to have satisfactorily answered the scientific questions of interest (e.g., what are the nature and magnitude of impacts most likely to arise as a result of the mine expansion?)

[12] The proposed groundwater model update (discussed in SLR 2016d) essentially foreshadows a full re-build of the conceptual and numerical hydrogeological models, including new sub-division of geological layers, new geological structure and faulting pattern, new hydraulic properties of faults and hydrostratigraphic layers, a new water balance as well as improved calibration data and greater rigour in the stochastic modelling process. Much of this work is badly needed to address flaws in the original AEIS conceptualisation and model. However, such a re-build, once carried out, can be expected to have major effects on model predictions and the impact assessment, which may render much of the AEIS obsolete and therefore require full re-assessment by potentially impacted parties. The presence of plans and a process to conduct this work give no indication of the outcome(s) a priori. The new conceptualisation and model would in such circumstances need to be thoroughly interrogated to ensure data gaps and errors such as those present in the AEIS are not again introduced into the new model.

[13] There has never been any question that processes and methods are available to NAC to collect and analyse the data necessary to produce a robust hydrogeological model and groundwater impact assessment. Such methods have been available to the proponent since they began mining on the site more than a decade ago. However, NAC's track record to date in the collection, analysis and reporting of hydrogeological data has been characterised by many methodological oversights, mistakes and reporting errors, as outlined in my previous expert reports and the IESC's advice of 2014 and 2015. The fact that there are future plans to collect additional data therefore also gives no assurance a priori that such problems won't be repeated in future, or that those identified to date will be addressed by new proposed activities and additional project conditions, following an approval decision. The limited technical work that is included in the new reports provided to the IESC (e.g. the Fault Hydrogeological Investigation Program Drilling & Testing report) does initially appear to be of better scientific quality than some of the earlier technical work in the AEIS. However, this is a small part of the considerable program of work that would be required to address all previous deficiencies outlined in the IESC's earlier advice, my previous expert reports and other issues identified in these proceedings.

[14] The opinions outlined in my original expert reports therefore remain largely unchanged, with some exceptions in cases where new hydrogeological data have been collected and analysed

in such a way as to address previous deficiencies in the proponent’s groundwater conceptualisation. These areas are discussed further below in more detail.

[15] In the subsequent sections of this report, I re-visit each of the main areas previously identified in my expert reports as containing data deficiencies, methodological problems and reporting errors, and examine whether these deficiencies have been addressed in the materials made available to the IESC since that time. Following this, I provide some analysis of the IESC 2016 Advice itself and then lastly, examine the new federal approval conditions, discussing whether or not these affect my opinions with respect to the adequacy of proposed monitoring and mitigation strategies.

4. My Opinion

4.1 Major deficiencies previously identified, and extent to which new data has addressed these

4.1.1 Local and regional geological structure

[16] An additional drilling program has been conducted to provide new information on the stratigraphic layering and geological structure of the site. This is described in the reports SLR 2016a, SLR 2016b and SLR 2017. As is clear from these reports, the new drilling has resulted in an updated understanding of layering in the Walloon Coal Measures, and the proponent proposes that on the basis of the drilling, a re-conceptualisation of the hydrogeology of the system (specifically the number of sub-layers in this aquifer) will be undertaken (see SLR 2016d). The drilling also aimed to determine better information about the occurrence and hydrogeological effect of faulting in the area (as discussed below in section 4.1.5 ‘faulting’). Geophysical data has also been collected in the form of a gravity survey, and this information is used to update the structural interpretation of the region (as shown in Figure 10 of SLR 2017). Additional geophysical information (magnetics data) has also been identified from a University of Queensland study (Babaahmadi and Rosenbaum, 2015[7]). This type of information was flagged in my original expert report as being missing from the groundwater conceptualisation and model presented in the AEIS.

[17] The new information and preliminary filling of these data gaps indicate that re-conceptualisation of the hydrogeology of the region is required – and indeed in SLR 2017 it is indicated that a new hydrogeological conceptualisation report is currently in preparation. This re-conceptualisation will require careful scientific review and interrogation. Following this, it is likely that a full re-build of the numerical groundwater model would also be needed on the basis of the updated conceptualisation (as is foreshadowed in SLR 2016d). These tasks are significant undertakings. A full re-build of the model would likely result in new predictions of impacts on groundwater, and different results than are presented in the AEIS. The revised impact assessment may thus render previous work obsolete and would therefore require proper scientific scrutiny.

4.1.2 Aquifer properties and inter-aquifer connectivity

[18] The new program of work conducted by SLR is in part designed to address previous deficiencies in the understanding of aquifer properties and inter-aquifer connectivity – one of the most important deficiencies pointed out in my original expert report and the IESC’s 2014 advice. A pumping test conducted in connection with the fault zone hydrogeological investigation (discussed further below) provides some new information about aquifer properties and inter-connectivity, although this is restricted to the various sequences within

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[7] Babaahmadi, A. and Rosenbaum, G. 2015. Kinematics of orocline-parallel faults in the Texas and Coffs Harbour oroclines (eastern Australia) and the role of flexural slip during oroclinal bending. Australian Journal of Earth Sciences, 62: 933-948.

the Walloon Coal Measures in the vicinity of one major fault investigated in that program. The new data does not assist in understanding connectivity between the coal measures and the Tertiary Basalts, Quaternary Alluvium or Marburg Sandstone.

[19] New monitoring bores have been drilled in connection with the fault zone investigation and revised groundwater monitoring and impact management plan (GMIMP) (SLR, 2016a & 2016b). These bores have been slug tested to provide further estimates of hydraulic conductivity (e.g. SLR, 2017 table 9). These tests produced some useful data regarding the possible ranges of hydraulic conductivity in the aquifers, and include some results that accord with previous data, and some that don't (e.g. one of the tests indicates K_h values in the Tertiary Basalt may be >50m/d at one location, although the report indicates this test will be repeated - see SLR, 2016b table 8). However, as was discussed previously in my individual reports, a slug test provides only an approximate estimate of hydraulic conductivity in the immediate vicinity of the well being tested, rather than the bulk hydraulic conductivity over a wide area (as is important on large sites such as mines). Slug tests also give no information about the storativity of the aquifer, the behaviour of the aquifer(s) under stresses such as long-term pumping or mine de-watering, or the inter-connectivity between different aquifer units.

[20] The pumping test outlined in the most recent report, SLR 2017, appears to be well-designed, and is an improvement compared to the original pumping tests carried out in the EIS (which were too short in duration to provide meaningful data). Analytical calculations were conducted to determine the appropriate pumping rate and duration, and observation bores were drilled in the coal sequences above and below that targeted by pumping. Both a step test and constant rate test were conducted. The constant rate test was conducted for a much longer period than previous aquifer testing – 72 hours rather than 6 hours previously. Recovery data was analysed as well as pumping data, as is appropriate.

[21] The pumping test data are used to provide revised estimates of transmissivity, hydraulic conductivity and storativity within the Walloon Coal Measures in its three major coal sequences (Tables 12 and 13 of SLR 2017). A number of different methods and assumptions were used to explore issues such as vertical hydraulic conductivity and the degree of 'leaky' behaviour between coal seams and the faults bounding the test region. These data are valuable and help to fill data gaps identified in the AEIS in my first individual report and the IESC's 2014 advice.

[22] However, despite the value of this additional work, the information and data gained should be viewed in the context of being useful only for a sub-area of the overall site, namely, the region of Walloon Coal Measures adjoining the major northwest-southeast trending fault targeted in the program. Also, the test only provides information about the hydrogeological properties of the Walloon Coal Measures, and does not provide any information about the connectivity between the coal measures and other key aquifers where landholder bores are located, such as the Tertiary Basalts and Marburg Sandstone. While it is flagged that there are future plans to investigate inter-aquifer connectivity further (as discussed below), these plans are limited in detail, and there is still a long way to go before the conceptualisation is complete from the point of view of understanding the inter-aquifer connectivity and aquifer properties of all the relevant units in the project area.

[23] It is also notable that the preliminary additional data obtained from the pumping test indicate that the values of hydraulic conductivity in the Walloon Coal Measures are significantly higher than estimates that were adopted as the mean values for the stochastic model calibration in the AEIS groundwater modelling (e.g. table 5.1 of Appendix F). For example, the median K_h values within the Acland Sequence based on the pumping test (SLR, 2017) are estimated to be 6.6m/day, and the bulk conductivity (including the inter-burden between coal seams) 1.3 m/day. This compares to mean input K_h values in the upper and lower WCM of 0.08 and 0.01 m/day for the stochastic modelling in the AEIS. These new field data are consistent with the horizontal hydraulic conductivity values for the Walloon Coal Measures

being at the upper end of the ranges reported in the OGIA regional model of the Surat Basin, and the ranges covered in the stochastic modelling for the AEIS (e.g., see Attachment 'AD6' of the Affidavit of Andrew Durick on 16/04/2016) [8]. This may be significant, as higher values of horizontal hydraulic conductivity (and therefore transmissivity) would result in drawdown propagating for greater lateral distances.

[24] Also of particular significance is the fact that, in this new technical work by SLR, it appears the proponent has decided on a new conceptualisation of the Walloon Coal Measures, and that in future this unit is proposed to be included in the modelling as a series of three aquifers corresponding to three coal sequences (Waipanna, Acland and Balgowan) separated by aquitards. This is a significant departure from the original conceptual model, which included only 'upper' and 'lower' WCM units. While it appears to me that this new conceptualisation is a more accurate representation based on the field data to date, the new conceptualisation would need to be carefully tested, and require a significant amount of new data to answer important questions such as the full horizontal and vertical extent of each of the three coal units (on the initial evidence it appears they are not always fully laterally continuous) and intervening aquitards, the degree of weathering in these layers, and the level of vertical connectivity across the sub-layers in the coal measures. This may lead to a substantially revised understanding of inter-aquifer connectivity and significantly affect predictions of groundwater impacts of the project. The preliminary analysis of the pumping test data indicates that there is some inter-connectivity between the different coal seams (e.g., some leakage is inferred based on the time-drawdown data).

[25] Some potentially important assumptions and possible methodological problems are also notable with respect to the pumping test analysis. For example, it is inferred (See SLR 2017 p. 16) that basalt intrusions (interpreted from gravity data and encountered in some of the drilling) do not impact the hydraulic behaviour of the aquifers, without any detailed investigation of the issue. It is also questionable as to why the pumping test was conducted on the downthrown side of the fault (i.e., the side opposite to proposed mining) rather than the up-thrown side, which is where drawdown would propagate due to mining. While it could be assumed that a similar response would be observed if the testing was conducted on the up-thrown side of the fault, this needs to be assessed with caution. The possibility that the pumping test results- and particularly the mis-match between the various solutions used in AQTESOLV and the observed drawdown data – may have been influenced by factors such as the basalt intrusions or well hydraulics issues, is also not considered or discussed. The production bore used in the test was constructed using slotted PVC, which may have had an impact on the efficiency of the well and the observed drawdown/recovery data (as opposed to using a stainless steel screen with custom-sized gravel pack). Assessing possible well hydraulics effects associated with bore construction should always be considered in a pumping test analysis, and it is not discussed in the reporting by SLR.

[26] These issues highlight that each time new data are collected and analysed, careful scrutiny is required to check assumptions and potential flaws in the work. Producing a plan for future data collection and analysis (as is emphasised in the IESC 2016 Advice) does not guarantee the quality of the data, applicability of the results or the extent to which new data fill knowledge gaps – this must be reviewed carefully, case-by-case.

4.1.3 Groundwater flow patterns

[27] Groundwater contour maps are a fundamental aspect of a conceptual hydrogeological model, providing information about flow directions, hydraulic gradients, flow rates, recharge and discharge areas, and potentially, inter-aquifer connectivity. It is my opinion that a proper conceptual hydrogeological model of a site is not complete without such maps. This view was also expressed by the IESC in its 2014 advice, and is still yet to be addressed by NAC.

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[8] Exhibit 816 [NAC.0080], page 153.

[28] Despite new water level data having been collected in connection with the revised GMIMP (SLR 2016b) and the fault zone hydrogeological investigation, contour maps showing groundwater flow patterns in each major aquifer unit have still not been produced. This was requested in the IESC's 2014 advice, but not mentioned in its 2015 advice, so is not covered in the questions put to the IESC in 2016.

[29] Some new water level information has been collected in the monitoring bores drilled for the fault zone investigation program, as described in SLR 2017, in the form of raw water level readings presented in table format. Localised water level maps were also produced during the pumping test investigating fault hydraulic properties (e.g. Figures 17 to 20). This is valuable in the context of understanding the hydrogeological impact of one fault; however, this mapping is very limited in spatial extent. The conceptualisation therefore still suffers from a lack of water level mapping across the mining lease and surrounding areas in the various aquifers. I believe this is another of the basic building blocks of a conceptualisation which must be addressed before more complex aspects of the model can be properly developed.

[30] As outlined in my supplementary individual report, a previous attempt to map water levels around the site (by SKM in 2013) used a highly questionable method of displaying the data.[9] This information was inconclusive with regard to important questions such as the predominant groundwater flow direction(s) in each unit, the locations of recharge/discharge areas and the effect(s) of the current mine pits on groundwater flow patterns – all critical aspects of any groundwater conceptualisation.

4.1.4 Water balance, recharge & discharge

[31] From the IESC 2016 Advice it is clear that existing water usage by groundwater users (which may be up to 10 GL in the region) has still not been incorporated into the groundwater model, but that in the future NAC proposes to do this:

> "Improvement of the groundwater model's calibration in alluvial bores is proposed to be undertaken through incorporation of surrounding groundwater user abstraction rates in updated groundwater model predictions"[10]

[32] This is also noted in the groundwater model update report (SLR 2016d). This issue has been discussed at length in my previous expert reports and other evidence. The absence of groundwater usage within the AEIS model is a major oversight, and calls into serious question the water balance, a fundamental aspect of any hydrogeological model. Until the data is actually collected, presented and incorporated into the model, my opinion remains unchanged on this issue.

[33] Another important related issue that is still yet to be properly addressed, and which is not discussed in detail in the IESC's advice or the proposed model update (SLR 2016d), is improving estimates of groundwater recharge. This was pointed out in the IESC's 2014 advice but not mentioned in the 2015 advice. As pointed out in my supplementary groundwater report of 06/05/2016[11] the recharge rate used in the modelling to date is inconsistent with estimates conducted by Smitt et al. 2003 in the area, that were based on the chloride mass balance method. There is no evidence that this issue has been addressed or that there is a plan to better constrain recharge rates around the site, for example, using techniques described in Scanlon et al, 2002 (as was recommended by the IESC in 2014[12]). Recharge, like

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[9] Exhibit 826 [NAC.0083], soft page 27.

[10] IESC, 2016 p. 3.

[11] Exhibit 824, [OCA.0069].

[12] The IESC 2014 advice stated: "Modelling of recharge as a fixed percentage of rainfall is considered simplistic in a climate where evaporation exceeds rainfall for most of the year. As recharge is the largest inflow to the model, even small variations in recharge introduce large uncertainties in groundwater impact predictions. It is recommended that the magnitude of recharge be estimated using

groundwater usage, is a fundamental part of any water balance, and a key input to any groundwater model.

[34] Without a proper water balance that includes robust estimates of groundwater recharge and groundwater pumping by bores, as well as natural discharge to streams and evapotranspiration, the calibration of any numerical model is highly questionable, and estimates of aquifer parameters obtained on the basis of such calibration (with an incorrect water balance) should be viewed as highly uncertain. For this reason, along similar lines to the issue of inter-aquifer connectivity, updated water balance information (if collected and analysed appropriately) would likely lead to significantly revised predictions of impacts on groundwater arising from the project, requiring careful review and scrutiny.

4.1.5 Faulting

[35] The reports NAC03 Fault Hydrogeological Investigation Program, October 2016 Status report (SLR 2016a) and Fault Hydrogeological Investigation Program, Drilling & Testing Report (SLR 2017) contain additional information about the way in which faults have been mapped, more detail on the nature of the faulting (e.g. offset of strata, fault plane dips), and details of testing to determine the hydrogeological impact and hydraulic properties of faults. This new program of work focusses on one particular fault which occurs to the southwest of the project site, which has previously been inferred to act as a barrier to groundwater flow, and have a throw of approximately 50m. This fault is mentioned in the IESC 2016 Advice as an example that the new work by NAC has addressed previous deficiencies regarding conceptualisation of faulting in the groundwater model.[13] Less (if any) additional work has been conducted or is proposed for the many smaller faults located around the project site.

[36] The updated faulting investigation includes new information that was previously missing from the hydrogeological conceptualisation and model reports, such as:

- Cross sections across some of the faults (Figures 3 to 7 of SLR 2016a), showing offset of the strata in selected bore transects
- Water level monitoring conducted either side of the major fault (e.g. Fig. 10 of SLR 2016a and Fig. 15 of SLR 2017)
- A pumping test to examine the hydraulic properties and effect of the major fault on drawdown propagation, and identify any leakage induced by pumping (SLR 2017)
- Plans (and preliminary results) of a geophysical survey program to update the understanding of geological structure including faulting (SLR 2016a & SLR 2017).

[37] This additional work is valuable, and goes some way to addressing previous concerns regarding the conceptualisation of the major fault to the southwest of the mine. Based on the new information it indeed appears that this fault has a significant throw (as already documented in previous evidence), and it appears that the strata are fully disconnected either side of the fault plane – although the throw appears to cause alignment between two of the three coal sequences offset by the faulting (Figure 15 of SLR 2017). Other smaller faults around the site may not cause complete disconnection between layers, and can be expected to exhibit different hydraulic behaviour to this major fault. The pumping test conducted near the major fault indeed provides evidence that the fault acts as a barrier to groundwater flow, although not a complete barrier, as minor leakage was observed late in the test. It is important to note that such leakage would be expected to increase as the duration and extent of drawdown exceeds that of the pumping test (e.g. under mining conditions).

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methods other than model calibration (refer to Scanlon et al., 2002) and that a sensitivity analysis be undertaken to explore the robustness of the model predictions to variations in recharge rates."

[13] On page 2 of IESC, 2016: "The proponent's preliminary monitoring results show evidence that one fault acts as, at a minimum, a partial barrier to groundwater flow (SLR, 2016a)".

[38] The design, operation and analysis of the pumping test data is an improvement on previous pumping testing conducted on the site described in the AEIS. This time, the constant rate test was conducted for an appropriate time (72 hours) and flow rate (~6L/s) to obtain information about the aquifer(s) under stress, although not to the same degree that would be expected during mining. Water level patterns were mapped throughout the pumping test, and time-drawdown data were collected from the pumping and observation bores. These data were analysed using a range of possible analytical solutions, starting with the most basic solutions and moving to more complex solutions to obtain improved fit. This work is all appropriate for the purpose of understanding the hydraulic effect of the fault in question, and better constraining the transmissivity and storativity of coal sequences within the Walloon Coal Measures.

[39] However, the additional work only goes some way to addressing significant problems with the way faults were incorporated into the conceptual and numerical hydrogeological model of the site originally. There are still major problems and uncertainties with the conceptualisation of faults. These include:

(a) The observation that many of the faults in the AEIS numerical model don’t match the drilling and mapping data. This is yet to be resolved and incorporated into a new conceptual or numerical model of the site (see figure 1, below);

(b) That all faults were conceptualised as being either complete barriers to groundwater flow (with little field evidence to support this) or were included in the numerical model in such a way that does not allow the modeller to control precisely the hydraulic conductance across the fault plane(s). On the basis of the previous and new data, this conceptualisation is highly questionable;

(c) That alternative conceptualisations of the hydraulic properties of faults - such as faults acting as conduits for recharge and/or cross-aquifer flow - were never explored (and have still never been tested or considered in the modelling), despite field evidence suggesting this could be the case for some faults (e.g. WSA, 2013[14]);

(d) That there are multiple faults around the site which could have effects on the hydrogeological regime, but the recent work focusses predominantly on one large fault to the southwest of the site. The assumption that hydrogeological behaviour at this one fault is analogous to the behaviour to be expected at all faults is highly questionable. Thus far, there is no additional data to inform the hydraulic effect of the many other faults.

(e) That a decision was made to conduct the pumping test on the down-thrown side of the fault – which is not the side of the fault on which the proposed mine pits will be excavated. Hence, while the test provides evidence of the fault acting as a hydraulic barrier to an extent during drawdown propagation, the effect of the fault on drawdown propagating to a much larger magnitude (as expected during mining) and from the up-thrown side (the side from which drawdown would occur under proposed mining) is still uncertain.

[40] Regarding the first issue (paragraph (a) above), it is clear that the inferred faults shown on the map in SLR 2016a and SLR 2017 are quite different from the pattern of faults in the AEIS model that was reviewed by the IESC in 2014 and updated in response to their advice. The maps below show a comparison of locations where faults were included in the model at this time (in orange), compared to those mapped in the recent SLR reports (SLR 2016a & SLR 2017):

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[14] Exhibit 817, [OCA.0063]

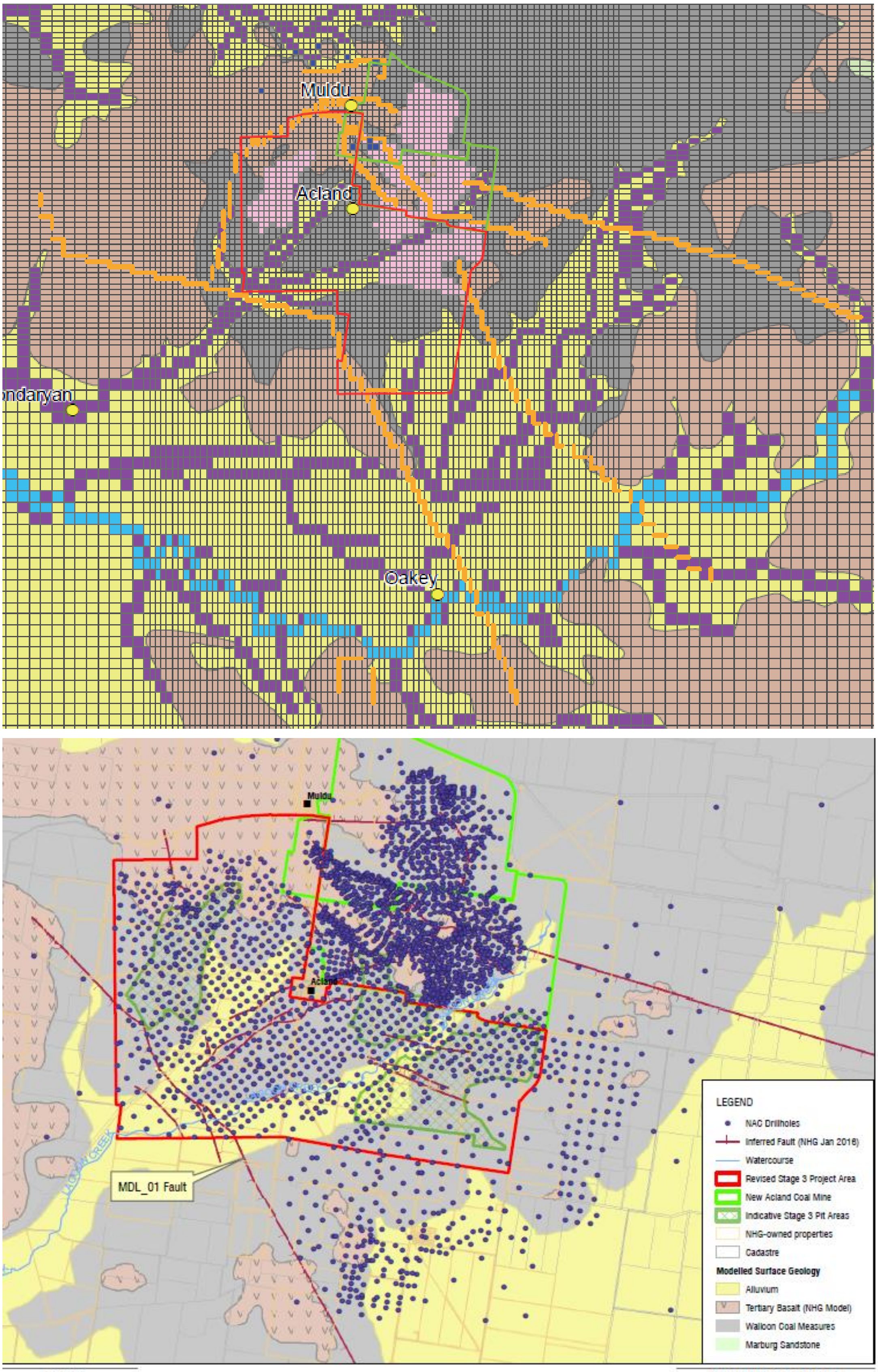

Figure 1 – Comparison of fault locations in the AEIS groundwater model following the IESC's 2014 advice (a) and immediately prior to IESC's 2016 advice (b).

[41] As can be seen from this comparison, a number of faults in the AEIS model occur in places where they are not mapped in the field, or with significantly different orientations and extent

(as discussed in my supplementary expert report of 6/5/2016[15]). Additional faults occur in the field mapping but are not included within the model. The map of faults included within the SLR 2016a and 2017 reports is in fact very similar to the map of faults that was provided to SKM during development of the original groundwater model prior to 2013:

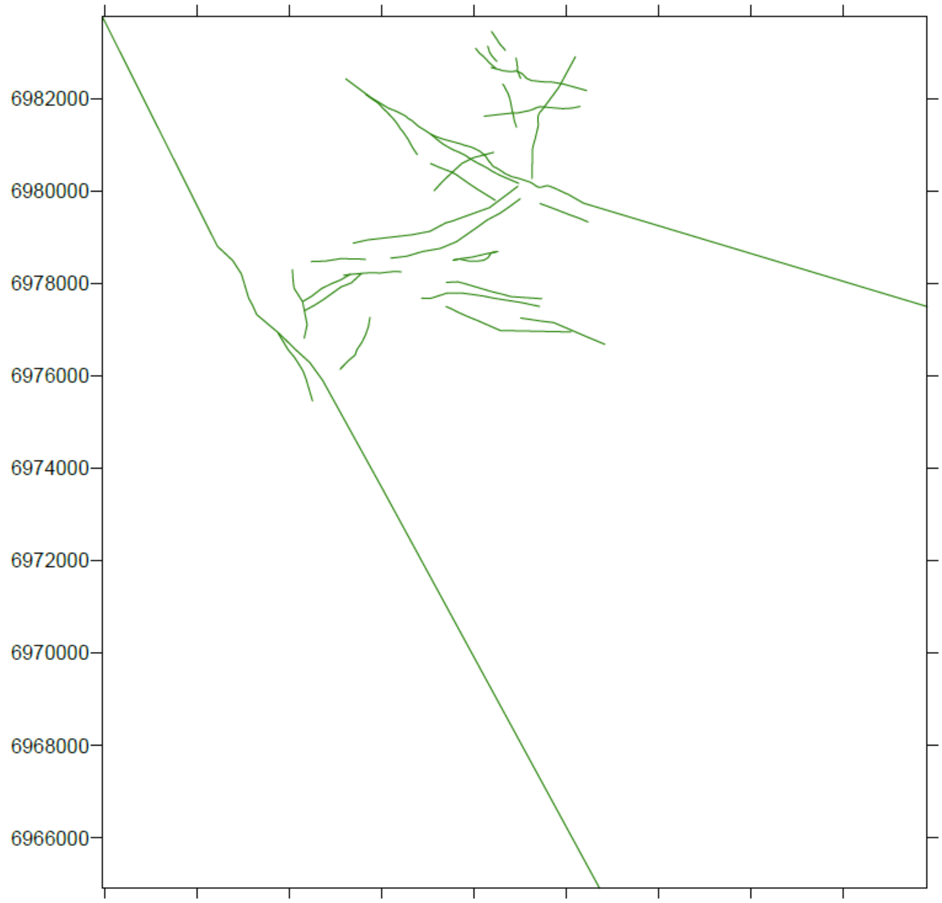

Figure 2 - Pattern of faulting provided by NAC to B. Barnett during development of EIS groundwater model (from Brian Barnett's statement of evidence, 10/05/2016[16]).

[42] Much of the mapping of the faulting pattern presented in SLR 2016a thus appears to have already existed and to have been provided to the consultants during development of the original groundwater model for the EIS and AEIS. It is thus not clear how much additional drilling (other than the new monitoring bores described in SLR 2016a and SLR 2016b) has taken place since the AEIS model to characterise the faulting pattern beyond that already provided (on the basis of coal exploration bore logs) during the initial groundwater model development.

[43] Importantly, the 'sensitivity analysis' of the effect of faulting presented in SLR 2016a still uses the previous conceptualisation of faults presented in 2014 and 15 (top image of figure 1) rather than a conceptualisation which has the faults located in the model where they were mapped in the field (the bottom image of figure 1, and figure 2, above). Consequently, the IESC's comment in 2016 that a *'Sensitivity analysis on the role of faulting has been undertaken within the groundwater model by removing the horizontal flow barriers that represented faults'* in my opinion gives a false impression that a rigorous sensitivity analysis of the effect of faulting has been conducted. The significant difference between the faulting pattern in the AEIS model and the actual field data will require (as foreshadowed in the SLR

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[15] Exhibit 824, [OCA.0069].
[16] Exhibit 826, [NAC.0083].

2016b report) a re-build of the hydrogeological conceptualisation with faults included in correct locations, with more appropriate hydraulic properties (and a range of possible properties tested in the modelling), before a thorough sensitivity analysis of the effects of faulting can be completed. The results of this sensitivity analysis will also be impacted by changes in the layering and hydraulic parameters of the aquifers in the model, and revised water balance. As with other aspects of the hydrogeological conceptualisation and model, it can be expected that this new conceptualisation would lead to significantly different predictions of groundwater impacts from the project compared to the AEIS, with significant implications for groundwater users.

[44] Water level data were also used (prior to the pumping testing) to infer the hydraulic effect of the major fault. It can be seen from Figure 15 of SLR 2017 that there is a difference in water levels of approximately 5m across the fault zone (between bores GW19a and GW22b in the Acland sequence), which is significantly greater than the topographic elevation difference between the bores (approximately 2m), supporting the idea that this fault indeed significantly impacts groundwater flow patterns. The way these data have been represented is however questionable – they are shown as elevations on a cross section, rather than as elevation contours in map view (Figure 10 of SLR 2016a and Figure 15 of SLR 2017). It is still unclear why no proper water level maps of the major aquifers have been constructed to characterise the groundwater flow patterns around the site (as discussed above), including around faults. Proper water level contour maps would allow better determination of the impact of faulting on groundwater flow, including the many additional faults that are not the focus of the program described in SLR 2016a and SLR 2017.

[45] The completion of one appropriately designed pumping test to characterise the behaviour of a major fault is by no means an exhaustive scientific program to determine the overall effect of faulting on groundwater flow in the region, notwithstanding its value. There are many other field and lab-based techniques that can be used to determine the hydrogeological impact of faults, as shown in tables 1 and 2 below. Table 2 examines which of the investigative techniques available to explore fault zone hydrogeology have been used by NAC to date. Even including the recent work, only a sub-set of these techniques have been adopted (or are proposed in future).

Table 1 – Standard techniques used by geologists and hydrogeologists to determine the hydrogeological effects of faults, and analysis of whether these techniques have been adopted by NAC for the site.[17]

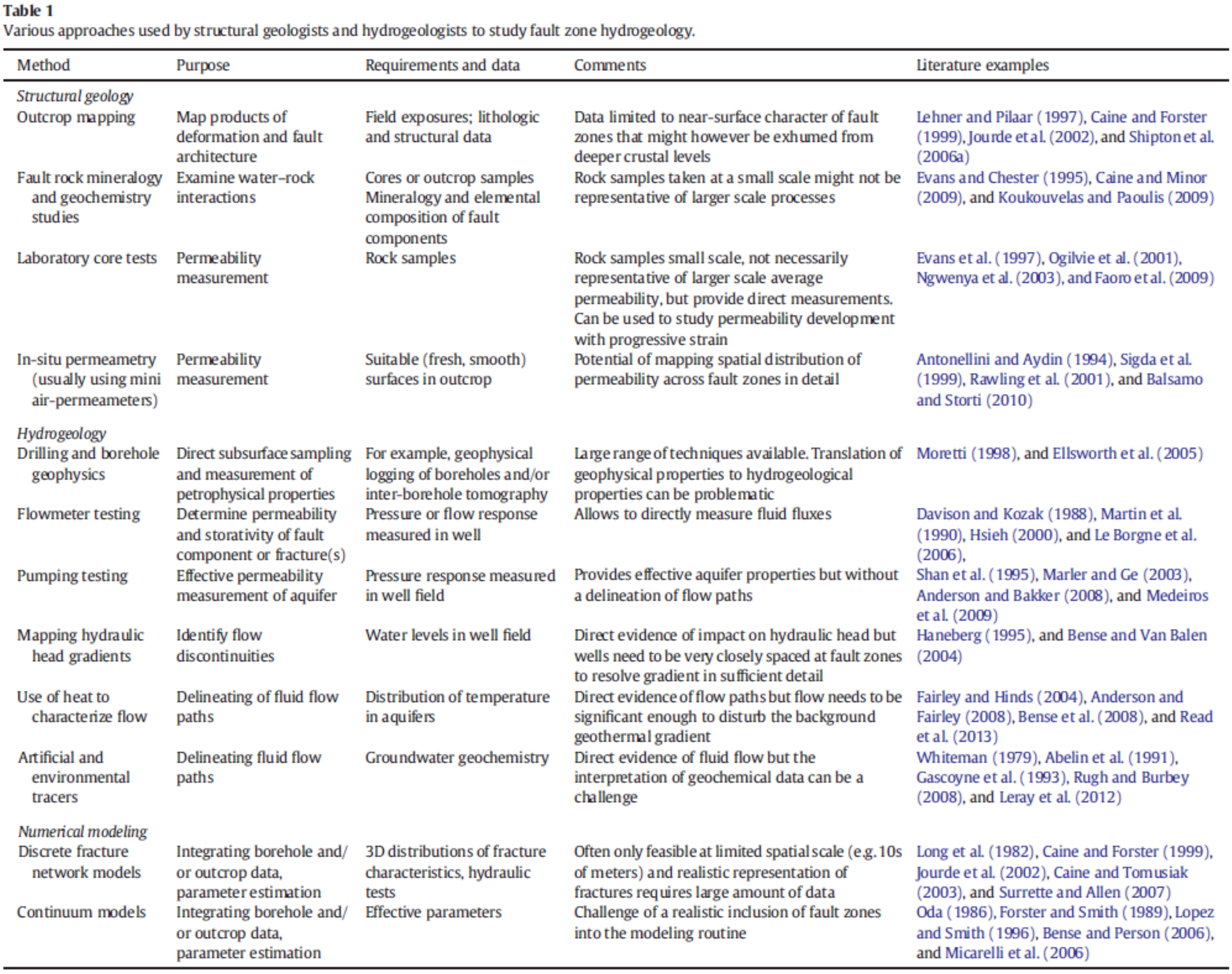

Table 1
Various approaches used by structural geologists and hydrogeologists to study fault zone hydrogeology.

Method	Purpose	Requirements and data	Comments	Literature examples
Structural geology				
Outcrop mapping	Map products of deformation and fault architecture	Field exposures; lithologic and structural data	Data limited to near-surface character of fault zones that might however be exhumed from deeper crustal levels	Lehner and Pilaar (1997), Caine and Forster (1999), Jourde et al. (2002), and Shipton et al. (2006a)
Fault rock mineralogy and geochemistry studies	Examine water–rock interactions	Cores or outcrop samples Mineralogy and elemental composition of fault components	Rock samples taken at a small scale might not be representative of larger scale processes	Evans and Chester (1995), Caine and Minor (2009), and Koukouvelas and Paoulis (2009)
Laboratory core tests	Permeability measurement	Rock samples	Rock samples small scale, not necessarily representative of larger scale average permeability, but provide direct measurements. Can be used to study permeability development with progressive strain	Evans et al. (1997), Ogilvie et al. (2001), Ngwenya et al. (2003), and Faoro et al. (2009)
In-situ permeametry (usually using mini air-permeameters)	Permeability measurement	Suitable (fresh, smooth) surfaces in outcrop	Potential of mapping spatial distribution of permeability across fault zones in detail	Antonellini and Aydin (1994), Sigda et al. (1999), Rawling et al. (2001), and Balsamo and Storti (2010)
Hydrogeology				
Drilling and borehole geophysics	Direct subsurface sampling and measurement of petrophysical properties	For example, geophysical logging of boreholes and/or inter-borehole tomography	Large range of techniques available. Translation of geophysical properties to hydrogeological properties can be problematic	Moretti (1998), and Ellsworth et al. (2005)
Flowmeter testing	Determine permeability and storativity of fault component or fracture(s)	Pressure or flow response measured in well	Allows to directly measure fluid fluxes	Davison and Kozak (1988), Martin et al. (1990), Hsieh (2000), and Le Borgne et al. (2006),
Pumping testing	Effective permeability measurement of aquifer	Pressure response measured in well field	Provides effective aquifer properties but without a delineation of flow paths	Shan et al. (1995), Marler and Ge (2003), Anderson and Bakker (2008), and Medeiros et al. (2009)
Mapping hydraulic head gradients	Identify flow discontinuities	Water levels in well field	Direct evidence of impact on hydraulic head but wells need to be very closely spaced at fault zones to resolve gradient in sufficient detail	Haneberg (1995), and Bense and Van Balen (2004)
Use of heat to characterize flow	Delineating of fluid flow paths	Distribution of temperature in aquifers	Direct evidence of flow paths but flow needs to be significant enough to disturb the background geothermal gradient	Fairley and Hinds (2004), Anderson and Fairley (2008), Bense et al. (2008), and Read et al. (2013)
Artificial and environmental tracers	Delineating fluid flow paths	Groundwater geochemistry	Direct evidence of fluid flow but the interpretation of geochemical data can be a challenge	Whiteman (1979), Abelin et al. (1991), Gascoyne et al. (1993), Rugh and Burbey (2008), and Leray et al. (2012)
Numerical modeling				
Discrete fracture network models	Integrating borehole and/or outcrop data, parameter estimation	3D distributions of fracture characteristics, hydraulic tests	Often only feasible at limited spatial scale (e.g. 10s of meters) and realistic representation of fractures requires large amount of data	Long et al. (1982), Caine and Forster (1999), Jourde et al. (2002), Caine and Tomusiak (2003), and Surrette and Allen (2007)
Continuum models	Integrating borehole and/or outcrop data, parameter estimation	Effective parameters	Challenge of a realistic inclusion of fault zones into the modeling routine	Oda (1986), Forster and Smith (1989), Lopez and Smith (1996), Bense and Person (2006), and Micarelli et al. (2006)

Table 2 – Description of techniques that can be used to determine the hydrogeological behaviour and impact of faulting[18] and analysis of which techniques have been applied to the project site to date.

Technique	***Conducted by NAC on site?***	***Description of work by NAC***	***Has the technique been effective?***
Outcrop mapping	***Y***	Faults have been mapped at surface, and identified in section using bore logs and photos from mine pit walls	***Y***
Fault rock mineraology & geochemistry study	***N***	No specific analysis of fault zone material appears to have been conducted in connection to understanding the hydrogeological effect of the faults.	***N/A***
Laboratory core tests	***N***		***N/A***
In situ-permeability	***N***		***N/A***

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[17] From: Bense, VF et al. 2013. Fault zone hydrogeology. *Earth Science Reviews* 127: 171-192.

[18] Modified from Bense et al, 2013.

testing			
Drilling	***Y***	Drilling has been conducted in transects across a major zone of faulting to the southwest of the mine lease. This has confirmed previous interpretations of the strata offset across the major fault	***Y***
Borehole geophysics	***Partial***	Downhole geophysics is referred to in SLR 2017, although the precise data collection methods and results are not clear from the report. Surface geophysics has been conducted (gravity survey). The limited data presented shows that this is valuable in confirming the presence of one major regional fault	***Y***
Flowmeter testing	***N***		***N/A***
Pumping testing	***Y***	A pumping test on the downthrown side of one of the major faults has been conducted. The test showed that the fault acts as a barrier to groundwater flow in its immediate vicinity within one of the three coal sequences in the Walloon Coal Measures, but also allows some vertical and horizontal leakage	***Y***
Mapping hydraulic head gradients	***Partial***	Water level data across one of the faults has been used as a line of evidence to determine its hydraulic effects, and provides evidence the fault acts as a barrier. However, mapping of hydraulic head gradients is still yet to be conducted	
Use of heat to characterise flow	***N***		
Artificial and environmental tracers	***N***		
Discrete fracture network models	***N***		
Continuum models	***N***		

[46] As is clear from these tables, the techniques utilized to date, while valuable in relation to the fault studied in the recent program, are still a sub-set of the overall hydrogeological techniques available to explore this issue. Few if any of these techniques (other than drilling) have been used in relation to the many other faults, which are also likely to have significant impacts on the hydrogeology of the site (but not necessarily in the same way).

4.1.6 Groundwater quality

[47] Some limited new groundwater quality data have been collected in associated with the bores drilled for the fault zone investigation and revised GMIMP (SLR 2016a and SLR 2016b). Electrical conductivity and pH values were monitored and recorded during the development of bores for the fault zone pumping test. This provides no significant information in terms of

baseline concentrations of potential contaminants (such as metals) in groundwater around the site.

[48] There has also been a round of sampling for water quality in new monitoring bores described in the updated GMIMP (SLR 2016b). These data are valuable; however, one round of sampling is inadequate for establishing baseline variability of groundwater quality throughout the region. From the raw data in the appendix, it appears that elevated concentrations of aluminium (>5 mg/L) and iron (>10 mg/L) occur in some of the samples (those labelled 3686WB and 4090WB in the laboratory report), although it is not clear which bores these samples were taken from. Elevated aluminium and iron was a characteristic found in some sites during previous sampling in bores around the current mine, however no analysis or explanation for the cause of these elevated concentrations has been presented to date (they were assumed to be related to sampling error, as noted in the JER and my first expert report)[19]. The previous conclusion that these values represented sampling errors may need to be re-visited in light of new data indicating elevated levels of these elements in the recent sampling.

[49] My opinions regarding the adequacy of the water quality baseline data therefore remain essentially unchanged from my first expert report (16/2/2016).[20]

4.1.7 Monitoring network & conditions related to groundwater impacts

[50] Part of the new material provided to the IESC in 2016 includes a revised groundwater monitoring and impact management plan (**GMIMP**). This is an updated version of the GMIMP drafted for the AEIS and referred to in the draft environmental authority of 2015, which were examined and discussed in my first individual expert report (16/2/2016).[21] The network of monitoring bores installed recently is essentially what was proposed in the original GMIMP, as shown below (Figure 3). My opinions regarding the adequacy of this monitoring network are already outlined in my previous individual expert report and have not changed.

[51] In the revised GMIMP (SLR 2016b) it is acknowledged that the revision of the groundwater conceptualisation and modelling may lead to significantly different predictions of drawdown extent and magnitude as a result of the project. It is also acknowledged that this may require re-assessment of the adequacy of the monitoring network, and potentially drilling of new monitoring bores to account for the changes in drawdown predictions in future. As with the revision of the hydrogeological conceptualisation, model and impact prediction, this is a significant undertaking, and is a process that should not take place after approval to commence the mine expansion is given, as it requires detailed scientific review and input from groundwater users.

[52] Any new monitoring bores drilled as a result of revised groundwater conceptualisation and modelling would require an appropriate period for baseline monitoring, so that mining-related impacts could be clearly distinguished from other influences. Establishing a proper baseline for water levels in a multi-layered aquifer system requires presentation of time-series data in the form of groundwater hydrograhps, which then need to be carefully interpreted along with information about the rainfall patterns over the monitored period, groundwater usage, and the progress of mining in surrounding areas. Baseline data needs to be collected for a long enough period (e.g. multiple years spanning different climatic conditions) such that natural fluctuations in groundwater levels due to influences such as climatic variability and groundwater extraction can be clearly delineated, and any future mining-related impacts clearly separated from these influences. This also requires careful analysis of hydrographs to attribute trends in water levels to these possible causes. This was missing from the AEIS (as outlined in the first JER and my first individual expert report) and it is not addressed in the

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[19] Exhibit 405, [NAC.0033], p26 at paragraph 3.9.

[20] Exhibit 435, [OCA.0021].

[21] Exhibit 435, [OCA.0021].

new materials provided to the IESC. Baseline data has been collected in the form of manual readings following drilling of the new bores (one reading for each bore is presented), while water level monitoring using automated loggers is being conducted according to SLR 2016b, although results are yet to be provided. Again, these are a fundamental aspect of any sound hydrogeological conceptualisation, that are still yet to be properly addressed.

[53] It is proposed in the revised GMIMP that some of the drilled monitoring bores can be used for assessing vertical connectivity between aquifers (e.g. the Walloon Coal Measures and Tertiary Basalts, Quaternary Alluvium and Marburg Sandstone). However, as yet, no specific analysis of inter-aquifer connectivity has been presented, meaning this is still very much an open question. As discussed in my previous reports, this is of critical importance to the groundwater conceptualisation and impact assessment.

[54] The drilling program described in the report answers some outstanding questions regarding the hydrogeology of the area – namely, the area of alluvium adjacent to Lagoon Creek to the southwest of the mine was drilled, and as proposed by NAC and its groundwater experts during the first JER, the area was found to be un-saturated, and therefore no monitoring bore could be constructed.

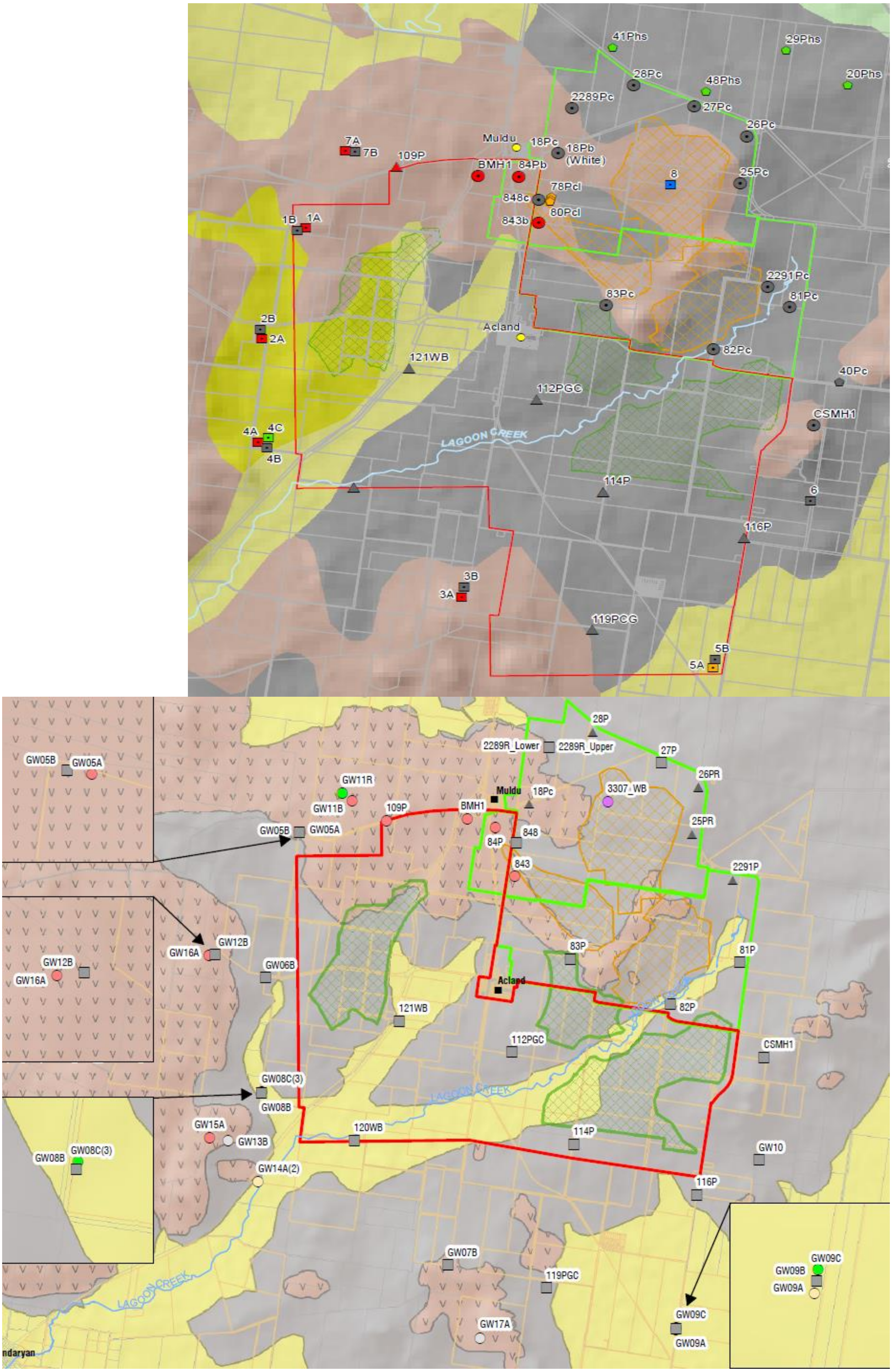

Figure 3 – Monitoring bores proposed in original GMIMP (2014) and the revised (2016) GMIMP

[55] The new conditions in the federal approval for the project mention the need for 'early warning' bores to detect drawdown before this propagates into areas where groundwater users have bores. This is a welcome condition, however, in order to have early warning bores there needs to be monitoring conducted along transects with multiple bores at greater and lesser distances from the proposed mine pits. In the case of the revised GMIMP (see figure 3, above), it can be seen that there is only a single 'ring' of bores constructed in most of the major aquifers (apart from the WCM, where there are multiple bores at different distances). In order for the 'early warning' system to be effective, there need to be at least two bores along a compass line, closer and further away from the mine (e.g. near the landholder bores) to assess early drawdown propagation before impacts reach receptors.

4.2 Analysis of the IESC's 2016 advice and conclusions

[56] The IESC's advice from December 2016 provides further opinion in response to two questions put to it by the Department of Environment and Energy, namely:

> "Question 1: Does the additional information reasonably address the technical/scientific matters raised in the Department's request for additional information dated 20 October 2016, and the key issues identified in the IESC advice (December 2015), or does it provide a robust process to address the uncertainties relating to those matters?"
>
> "Question 2: Does the proponent's revised groundwater modelling provide a reasonable prediction of the expected maximum range of groundwater drawdown for the proposed mine?"

[57] The nature of these questions means that the scope of the IESC's review was limited to assessing issues raised in its 2015 advice, and providing a broad (rather than detailed and specific) critique of the numerical modelling predictions made by the proponent. The scope of their assessment therefore does not (as I interpret) provide a comprehensive opinion on the major question of interest – namely, has the proponent produced rigorous conceptual and numerical hydrogeological models, and do these models and the data collected and analysed provide a solid evidence base on which to:

a) make sound predictions of future impacts on groundwater receptors from the project; and

b) detect and mitigate potential adverse impacts on groundwater users.

[58] In response to the first question put to them, the IESC state: "Most matters raised in the IESC's advice of 10 December 2015 have been addressed, or a process to address them is provided within the additional information provided by the proponent."

[59] After viewing the material that was provided to the IESC by NAC, it is clear that limited additional technical work (e.g. data collection and analysis) was conducted to address the issues raised in the 2015 (and 2014) advice - with the exception of some new data that is discussed above. The content of the new reports mostly describes plans to undertake additional work in future to revise the conceptualisation and numerical model. Consequently, many deficiencies previously pointed out by the IESC are yet to be satisfactorily resolved at this point in time, notwithstanding that plans are in place to address them in future and that the IESC have reviewed these plans.

[60] The major risks with this approach from a scientific viewpoint are:

a) A plan to collect and analyse data is not the same as actual collection and analysis of the data. Such plans are an important step in conducting a rigorous scientific investigation, however in themselves they give no guarantee that the data and its analysis will lead to a particular outcome. Without first completing the additional investigations, and subjecting these to rigorous scientific review, the groundwater impact assessment is incomplete.

b) Once revision of the conceptualisation and modelling of groundwater impacts occurs, on the basis of the proposed new data collection and interpretation activities, the predictions of impact would be expected to change significantly, meaning the implications of the project for groundwater users may be significantly different to what was presented in the EIS and AEIS. If the project is already approved, then the opportunities for independent scientific scrutiny of the project's impacts will be significantly reduced compared to during the environmental impact assessment.

c) The proponent's track record to date in the collection and analysis of scientific data has been characterised by many methodological flaws, oversights and reporting errors. Plans for future data collection give no assurance as to the rigour of the methods used to collect the future data, and its analysis and reporting. This means that until this work is completed and can be carefully scrutinised, uncertainty still exists with respect to the quality of any revised groundwater impact assessment.

[61] The further statement by the IESC in response to this question: "Matters that remain outstanding could be addressed through collection of additional data before and during operations" is in my opinion not particularly relevant to a scientific assessment of the conceptual and numerical groundwater models. There has never been any question that additional data can and should be collected; much of the content of my previous expert reports and the IESC's 2014 and 2015 advice highlight the types of data that should have been collected in order to produce a robust groundwater conceptualisation, model and impact assessment. This point has therefore never been in question, nonetheless, only limited data have subsequently been collected.

4.2.1 Potential oversights in the IESC's 2016 advice

4.2.1.1 Fit between observed and modelled water levels, and site water balance

[62] The IESC's 2015 Advice stated:

> "Application of appropriate methods and interpretation of model outputs: key conclusions Calibration hydrographs indicate the groundwater model has bias which results in frequent over-prediction of groundwater head in the alluvium **and Walloon Coal Measures** (emphasis added), when compared to observed data in monitoring bores. Updated modelling also predicts water levels within final voids will exceed the existing groundwater level, contributing to continued low confidence in the model conceptualisation and predictions."

[63] Professor Werner and I identified this issue as "not addressed" in the joint opinion with respect to the IESC's 2014 and 2015 advice, attached to the Supplementary Individual Expert Report of Professor Werner. The advice in 2016 on this particular issue however only mentions alluvial bores and does not mention the Walloon Coal Measures (or other aquifers), stating:

> "Improvement of the groundwater model's calibration **in alluvial bores** (emphasis added) is proposed to be undertaken through incorporation of surrounding groundwater user abstraction rates in updated groundwater model predictions. Further, the proponent proposes to consider adjusting the weighting values applied to groundwater user bores to improve groundwater model calibration in the alluvium (SLR, 2016d). This will enable the model predictions to better match modelled and observed water levels in the alluvium. The groundwater model update is stipulated under the Queensland Coordinator-General's Imposed Condition 12 (DSDIP, 2014)."

[64] It should be noted that when the groundwater evidence in this matter was heard in 2016, it was demonstrated that the poor match between water levels in the model and in monitoring bores was not just confined to the alluvium, or indeed the Walloon Coal Measures, but also extended to the Tertiary Basalts and Marburg Sandstone aquifers, where many land-holders in the surrounding areas have water supply bores. These other aquifers (apart from the alluvium) aren't mentioned in the 2016 advice.

[65] There is thus no evidence that the issue of poor calibration fit between modelled and observed water levels has been addressed in the new material provided to the IESC. As was noted in my supplementary expert report of 6/5/2016,[22] there are serious questions about the field data – particularly the mine pit inflow volumes in WSA (2013),[23] which were used as a key criteria for calibrating the numerical model, as well as the model's water balance (recharge rates and groundwater extraction volumes). These data are primary inputs that determine the predictions of water levels that a groundwater model will make. It is clear from the IESC's 2016 advice that updating of the water balance and collection of further calibration data is an aspect that is proposed to be dealt with by a future process, rather than having been addressed at this stage.

4.2.1.2 Faulting

[66] The 2016 IESC Advice states the following with regard to faulting, in light of the additional work detailed in SLR 2016a:

> "Evidence, characterisation and validation of the role of faulting within the project boundary have been provided. Geological mapping and drilling data provided by the proponent details the location, throw direction and strata offsets of four out of five faults within the proposed project area. The proponent's preliminary monitoring results show evidence that one fault acts as, at a minimum, a partial barrier to groundwater flow (SLR, 2016a)."

[67] As is clear in the AEIS (see Figure 1 above), the most recent version of the groundwater model in fact contains representations of many more than five faults within the project area. In this version of the model, all of these faults are represented as complete barriers to groundwater flow, or in a manner which doesn't allow the modeller to control their hydraulic behaviour (e.g. faults included as 'walls' with gaps selectively added between adjacent cells).

[68] Given this, the statement by the IESC that preliminary monitoring shows that "at least one" of the faults acts "as, at a minimum, a partial barrier to groundwater flow" does not provide confidence that the evidence base for conceptualisation of all faults in the model has been substantially improved, or that this conceptualisation has been properly interrogated and tested through collection of additional data and exploratory modelling, apart from the investigation focussed on the major fault to the southwest of the mine (SLR 2016a & SLR 2017).

[69] As discussed in section 4.1.6, the 'sensitivity analysis' with respect to faulting that is referred to by the IESC consists of a comparison of drawdown predictions from the pre-existing numerical model containing faults (in erroneous locations), and the same model with those faults removed (see figure 1). No predictions are yet available using faults in correct locations and/or with revised aquifer properties based on additional field data and re-conceptualisation of the hydrogeology, as is clearly required.

4.2.2 Unaddressed issues in the IESC's 2014 advice that were not raised in 2015

[70] Importantly, the IESC were only asked to address outstanding issues from their 2015 advice, and were not asked to again review outstanding matters from their 2014 advice. As is clear in

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[22] Exhibit 824, [OCA.0069].

[23] Exhibit 817, [OCA.0063].

the analysis of the IESC's 2014 and 2015 advice attached to my supplementary expert report,[24] there were many issues in the 2014 advice which were not addressed, and not all of these were re-visited in the 2015 advice. Consequently, there is a gap in what has been assessed between 2014 and 2016.

[71] A key example (as discussed above) is the lack of any water level contour maps produced for the various aquifers around the site. This was raised in the 2014 advice:

> "Model Documentation
>
> b. Several predicted drawdown maps are provided; however, the pre-development head patterns have not been presented. A qualitative comparison between observed and modelled potentiometric heads, in a series of maps, would enable better assessment of model reliability. Modelled heads in each layer need to be presented, across the entire model domain, and at intervals representing pre-mining, the proposed project's operational phase, immediately post-mining, and longer term, in order to evaluate the modelled spatial and temporal pattern of groundwater flow."

[72] No additional work has been done to address this matter, and it is not mentioned in the 2015 advice.

[73] A second example is the issue of inappropriate or poorly supported estimates of groundwater recharge used in the modelling (discussed above in section 4.1.4 of this report):

> "h. Modelling of recharge as a fixed percentage of rainfall is considered simplistic in a climate where evaporation exceeds rainfall for most of the year. As recharge is the largest inflow to the model, even small variations in recharge introduce large uncertainties in groundwater impact predictions. It is recommended that the magnitude of recharge be estimated using methods other than model calibration (refer to Scanlon et al., 2002) and that a sensitivity analysis be undertaken to explore the robustness of the model predictions to variations in recharge rates."

[74] This is another example of an issue that was rightly raised in the IESC's 2014 advice, has not been addressed and is not covered in the IESC's 2016 advice.

[75] For a full list of issues raised in the IESC's 2014 advice, and my opinion regarding whether these issues have been addressed, refer to Annexure C to my Supplementary Individual Report (06/05/2016).[25] None of the issues indicated there as 'not addressed' have in my opinion been fully addressed in the new materials provided by NAC since the time of that review.

4.2.3 Other issues identified as not being addressed by the IESC

[76] It should also be noted that the IESC were of the opinion that most, but not all of the issues they raised in their 2015 advice, have been addressed. A significant issue which the committee deems to still be un-resolved includes the way water quality in the mine voids is modelled:

> "The proponent has committed to update predictions of water level recovery within each of the three proposed final voids. However, a process to model and assess the potential local, long-term risks posed by gradual or rapid changes in water quality (e.g. salinity, pH, metals and toxicity) within the final voids has not been provided. Given groundwater modelling predicts that two of the three proposed final voids pose varying levels of risk of becoming groundwater sources to the environment, the proponent should provide details of potential measures to characterise, model, manage and monitor the potential long term water quality risks posed by final voids."

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[24] Exhibit 824, [OCA.0069].

[25] Exhibit 824, [OCA.0069].

[77] The modelling of water quality in mine voids is a significant issue, with major implications for long-term impacts of mining on groundwater quality in surrounding areas. The fact that this issue is not resolved to the IESC's satisfaction and/or that plans to address it are not clear is thus of major concern.

4.3 Analysis of Federal approval conditions

[78] The Federal Minister approved the project on January 18th 2017, and with this provided an updated list of conditions, including some relevant to groundwater – conditions 12 to 17.

[79] Many of these conditions are similar to those outlined in the Queensland Coordinator-General's report in 2014, such as the requirement for the proponent to submit a GMIMP that includes locations of proposed monitoring bores, baseline data and water quality triggers.

[80] Areas where there are new requirements or additional detail relative to the Coordinator-General's conditions are listed below; in each case I provide a brief opinion regarding whether these conditions are likely to significantly improve the prospects for detecting, avoiding and/or mitigating negative consequences of the project on groundwater.

13v – threshold triggers for early warning monitoring bores based on modelled impacts to water resources

[81] This condition is potentially valuable, if implemented correctly – e.g. provided enough early warning monitoring bores are included in each aquifer and the baseline data collected in these is sufficient to distinguish mining-related drawdown from other potential effects (see section 4.1.7 above). Based on the current monitoring network, outlined in the revised GMIMP (SLR 2016b) it is difficult to see how an 'early warning' system can be achieved, as there is only one complete ring of bores surrounding the proposed mine expansion. An 'inner' and 'outer' ring of monitoring bores would be required in order to meet this condition.

13vi – groundwater drawdown limits for impacts to the Oakey Creek Alluvium and Tertiary Basalt aquifers

[82] Similarly, this condition is potentially valuable, provided clear water-level baselines can be established for these aquifers in all relevant locations. It should be noted that drawdown itself does not give a precise indication of the actual volumetric impact of an activity on an aquifer[26]. This is of critical importance, given that these two aquifers are subject to new Sustainable Diversion Limits within the Murray Darling Basin Plan (2012), and from 2019 will have new extraction limits imposed, restricting the volume of licensed extraction that can be taken within the project region.

13ix - an outline of the proposed methodology to assess groundwater connectivity between each hydrogeological unit using nested bore arrays

[83] This is clearly a warranted requirement. However, information about the connectivity between each hydrogeological unit is to date still absent, despite drilling for the revised GMIMP having been completed. The condition doesn't provide detail regarding how vertical connectivity will be actually assessed – e.g. does the condition require that pumping tests to be conducted to assess hydraulic connection between all aquifers, or, is water level monitoring under pre-stress conditions considered sufficient? How many sites will be installed with nested monitoring bores to assess connectivity, and how many depths/aquifers will be monitored at each nested site? The number of nested sites in the revised GMIMP (SLR

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[26] This issue is discussed in: Currell, M. 2016: Drawdown triggers: a misguided strategy for protecting groundwater-fed streams and springs. Groundwater 54: 619-622.

2016b) is in my opinion not adequate for a proper assessment of inter-aquifer connectivity, as argued in my first expert report,[27] and this remains unchanged.

13A If monitoring reports, based on threshold triggers for early warning monitoring bores, indicate that a groundwater drawdown limit will be substantially exceeded, the Minister may:

- ***i. Require the approval holder to suspend mining operations***
- ***ii. Suspend or revoke an approval under section 144 and 145 of the EPBC act***

[84] This is an advance on previous conditions in the Coordinator-General's report. It is valuable for the option to suspend mining be available to the Minister. However, the condition doesn't necessarily provide great assurance to potentially impacted groundwater users, as the Minister (whoever that may be at the time such an impact occurs) has the discretion to require suspension of mining or not, and 'substantially exceeded' is a subjective term.

14. The Minister may submit the GMMP to the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) or other independent expert to review before making a decision on whether to approve it under condition 12.

[85] Again, this is a valuable condition, but appears entirely optional as it will be at the discretion of the Minister at the time.

16. The approval holder must undertake groundwater model reviews in accordance with the requirements of the conditions imposed by the Queensland Coordinator-General under section 54B of the State Development and Public Works Organisation Act 1971. The reviews must address all matters raised in the December 2015 and 2016 lESe advice in regards to groundwater modelling. In addition, groundwater model reviews must be undertaken by a suitably qualified expert and must include:

- ***i. validation of the existence and nature of faulting and its potential effect on the predicted lateral extent of groundwater drawdown;***
- ***ii. updated groundwater resource user abstraction data;***
- ***iii. a review of predicted volumetric impacts to a groundwater resource; and***
- ***iv. ongoing model evaluation including comparison between observed and modelled heads for each formation, across pre-mining, operations, postmining and long term phases.***

[86] As discussed above, the deficiencies identified in the conceptual hydrogeological model, numerical model and groundwater impact assessment to date would require a full re-build of the conceptual and numerical models. The revised modelling would likely produce significantly different predictions of impacts to groundwater, which in turn would have a significant bearing on the design of monitoring and mitigation strategies. Therefore the timing of the proposed revision of the groundwater modelling to include the issues identified in this condition (and others) is critical. In my view this re-build of the model and re-assessment of impact predictions would need to take place before the project is granted any further approval to proceed, as the revised predictions would require significant scientific scrutiny, and the associated impacts would require careful consideration by all potentially affected parties.

5. Declaration

[87] In accordance with rule 24F(3) of the *Land Court Rules 2000* (Qld), I confirm the following:

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[27] Exhibit 435, [OCA.0021].

a) the factual matters stated in the report are, as far as I know, true;
b) I have made all enquiries considered appropriate;
c) the opinions stated in the report are genuinely held by myself;
d) the report contains reference to all matters I consider significant;
e) I understand the duty of an expert to the court and have complied with that duty;
f) I have read and understood the *Land Court Rules 2000* on expert evidence; and
g) I have not received or accepted instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.

M Currell

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Signature

9 March 2017