Coast and Country Association of Queensland Inc. & Ors
ats Hancock Coal Pty Ltd,

Land Court of Queensland Proceeding MRA713-13 & EPA714-13

Objection to Mining lease and Environmental Authority for Kevin's Corner Coal Mine

Expert report on groundwater impacts to the Land Court by Dr John Webb

Date: 29 April 2015

Degulla Lagoon, ~20 km north of proposed Kevins Corner Coal Mine.
Photo taken by J. Webb, 17 June, 2013

Contents

1 Introduction

1.1 Expert details, experience and qualifications

1.1.1 Name and address

[1] John Webb
Associate Professor in Environmental Geoscience
La Trobe University,
Melbourne, Victoria 3086

1.1.2 Qualifications

[2] BSc Hons (University of Queensland) 1973. Awarded First Class Honours
PhD (University of Queensland) 3/9/1982.

1.1.3 Experience

[3] I have over 30 years' experience in geology and 20 years' experience in hydrogeology, both in terms of practice and tertiary level teaching. I have supervised 31 PhD students, 4 MSc students and 86 Honours students in a variety of geological and hydrogeological projects. I have participated in over 40 consulting projects, and have been an invited member of 3 expert panels to assess groundwater and contaminated site management. Over the past 12 years I have acted as an expert witness in 8 court cases and tribunal hearings on hydrogeological and hydrogeochemical topics, including the Alpha Coal Mine Queensland Land Court appeal [MRA082/2013; EPA083-13] decided in 2014. I am currently acting as an expert in the Carmichael Coal Mine Land Court appeal [MRA/EPA428-14; MRA/EPA430-14; MRA/EPA432-14].

[4] Attachment A to this report is my curriculum vitae.

1.2 Background

[5] The Kevin's Corner Project (the Project) is a proposed open-cut and underground coal mine north west of the township of Alpha, approximately 340km south west of Mackay in the Galilee Basin, Queensland. The mining lease application is for 40 years with an annual extraction rate of around 45 million tonnes per annum Run of Mine (ROM) coal. The Project is situated in the Galilee Basin in the catchment of the Burdekin River, which flows into wetlands and the Great Barrier Reef, and the area of the Project and its surroundings is predominantly used for agriculture, particularly grazing. The thermal coal deposits for the Project are estimated to be 4.269 billion tonnes, within Mining Lease Application 70425 (MLA), which comprises approximately 37,380 hectares. Hancock Galilee Pty Ltd (Applicant) applied for an environmental authority (mining lease) (EA) under the *Environmental Protection Act 1994* (Qld) (EP Act) and a mining lease (ML) under the *Mineral Resources Act 1989* (Qld) (MR Act) for the Project on or about 18 December 2009. The Coordinator-General declared the Project a significant project for which an environmental impact statement (EIS) was required under the *State Development and Public Works Organisation Act 1971* (Qld) (SDPWO Act) on 11 September 2009. The Applicant undertook public consultation on an EIS in October 2011, a supplementary EIS (SEIS) in November 2012, an addendum to the supplementary EIS (AEIS) in

November 2011 and provided additional supplementary documentation to the Coordinator-General's evaluation report (Coordinator-General's Report) in early 2013, for approval under the SDPWO Act (together, the EIS documents). The Coordinator-General's Report on the Project under the SDPWO Act was delivered on 30 May 2013. The Coordinator-General recommended that the mine be approved subject to conditions. On behalf of Coast and Country Association of Queensland Inc. (CCAQ), an objection to the applications for a mining lease and an environmental authority was submitted by the Environmental Defenders Office (Qld) Inc. on 6 December 2013.

Because the proposed Kevin's Corner mine lies immediately to the north of the proposed Alpha mine, all material relevant to the impact of dewatering for the Alpha mine on groundwater is also relevant to the Kevin's Corner mine. The groundwater modelling for the impact of the two mines recognised this association and modelled both together.

1.3 Instructions

[6] On 9 January 2014, I was instructed by Michael Berkman, Solicitor, Environmental Defenders Office (Qld) Inc. on behalf of CCAQ to prepare a report setting out my opinion as to:

- whether there is sufficient information to form an adequate scientific basis for approval of the mine having regard in particular to potential groundwater impacts and the reasons for my view;
- whether, having reviewed all of the EIS documents, I agree with the conclusion of the Coordinator-General's assessment in relation to groundwater and the reasons for my view.
- whether, having regard to all of the available material, there are issues that should be examined in more detail or additional lines of inquiry in relation to groundwater that should be explored before approval is granted and the reasons for my view.

[7] Attachment B to this report is the letter of instructions, provided 9 January 2014, and emails provided to me on 9 December 2014 attaching the most recent version of the *Land Court Rules 2000* relevant to experts.

[8] I acknowledge that, prior to preparing this report, I was instructed on an expert's duty in accordance with rule 426 of the *Uniform Civil Procedure Rules 1999* and rule 24C of the *Land Court Rules 2000*. I understand and have discharged that duty.

[9] I also verify that no instructions were given or accepted to adopt, or reject, any particular opinion in preparing my report.

1.4 Methodology

[10] For this report, I examined the available geological and hydrogeological information in the EIS documents on the Alpha and Kevin's Corner coal mines; because they are immediately adjacent to each other, any information on one is directly relevant to the other. The conceptual geological model used in these reports (Figure 1), delineating the inferred subsurface location and arrangement of the strata, shows the modelled aquifer (CD-DE sandstones) dipping to the west, whereas the potentiometric surface of this aquifer, as shown by the water level data from bores in

the area screened within the CD-DE sandstones, dips to the east. The potentiometric surface (the height of the water level in bores) measures the groundwater pressure; groundwater always flows from areas of high hydraulic pressure to areas of low hydraulic pressure. Therefore groundwater flow in the aquifer must be towards the east, following the dip of the potentiometric surface, but in the opposite direction to the dip of the aquifer, which is towards the west, i.e. the groundwater is flowing up-dip. Typically, groundwater flows down the dip of an aquifer (this is true in the Great Artesian Basin (GAB) to the west of the study area and probably to the south of the proposed mine in the South Galilee proposed mine area; Heritage Computing 2013, Figure 3.9). The groundwater flow in the area of the proposed Alpha and Kevin's Corner coal mines flows in the opposite direction to that expected; there must be an explanation for this in the geological structure of the area, that involves a reconceptualization of the geologic framework that best fits all available data and accords with hydrogeologic principles. As Younger (2007) states, the structural framework must be evaluated before it is possible to begin analysing groundwater dynamics in any detail; the principal requirement is to understand how the aquifers/aquitards are disposed within the subsurface.

[11] Therefore I reinterpreted the geology of the area using the available 1:250,000 Jericho and Galilee geological maps (SF55-14 and SF55-10 respectively; Bureau of Mineral Resources 1973 and 1972 respectively), remote sensing data, particularly airborne radiometric data, a 2004 Landsat 5 image of the area, processed using ENVI software, and Google Earth images of the area. I followed the general principles of processing and applying remote sensing data to the interpretation of the surface geology, as detailed in general textbooks on the subject, e.g. Jensen (2007), Lillesand et al. (2008).

[12] I firstly recognised that some of the outcrop areas of the Rewan Formation, as shown on the 1:250,000 maps, coincide closely with areas on the radiometric image that have a distinctive pink colour (reflecting the potassium-rich clays that characterise this unit). I therefore delineated all areas on the radiometric image with this distinctive pink colour, and assigned them to the Rewan Formation. For the basal boundary of the Rewan Formation within the Alpha mine lease, I used Figure 4-6 in the Alpha Coal Project EIS volume 2, section 04 Geology, page 4-9.

[13] I then delineated the boundary between the Dunda Beds and the Clematis Sandstone. Both units are dominated by sandstone, but "generally…cliffs of Clematis Sandstone overlook.. rounded foothills of Dunda Beds. This physiographic distinction reflects lithological differences between the two units; the Clematis is quartzose, commonly… medium to very coarse-grained, whereas the Dunda Beds vary from quartzose to lithic, …. and are generally fine-grained" (Galilee geological map, Explanatory Notes, p. 11). Therefore, the base of the obvious sandstone cliff-lines represents the boundary between the Dunda Beds and the Clematis Sandstone, and the boundary had been previously mapped using this criterion on the 1:250,000 Jericho geological map. The base of the cliff-line is most easily identified using the Landsat 457 and PCA123 images, because the Dunda Beds and the Clematis Sandstone have different vegetation covers, which can be readily distinguished on these images; the cliff-line also often shows up as a thin white line on the Landsat 457 image.

[14] I then distinguished the overlying Tertiary laterite, which covers the underlying Permian and Triassic units in places. The laterite often has a distinctive appearance on the Landsat 457 and

Tasselled Cap (Brightness Greenness Wetness) images, because of its distinctive colour, mineralogy (dominated by ferric oxy-hydroxides) and vegetation cover. It is also evident on the PCA123 image.

[15] I mapped some small areas of Colinlea Sandstone on the eastern side of the area, by comparison with the 1:250,000 Jericho geological map. These are most easily distinguished using the Landsat 457 image.

[16] The overall geological map that I derived is similar in many respects to the 1:250,000 Jericho geological map. In particular, the correspondence between the basal Clematis Sandstone boundary on the two maps is often excellent. However, I could not verify the outcrops of Moolayember Formation previously mapped on the western side of the area, and I believe that these are most likely outcrops of Dunda Beds that have been misidentified. My geological map differs substantially from the 1:250,000 Galilee geological map; I believe this is because much of the Galilee geological map was based only on reconnaissance mapping or brief air photo interpretation, and has a limited reliability, as clearly stated in the map legend.

[17] From the detailed geological map of the area constructed using the remote sensing images, it was clear that the bedding along the crest of the Great Dividing Range was virtually horizontal over large areas, and appeared to dip gently to the east along the eastern flanks in Cudmore National Park. The broad north-south valley occupied by Lennox and Speculation properties separates two areas of broken topography, one of which is Cudmore National Park, with apparent eastwards dips on the eastern side. This suggested the presence of two anticline axes, running through each broken area, separated by a syncline in the valley. It appeared that the folds plunged very shallowly to the north from the topography. I then constructed three cross-sections; the section lines were drawn through points where I could accurately locate boundaries between lithological units (hence the section lines are not straight). For these sections I used the detailed geological cross-section available for the Alpha mine site, constructed using accurate drilling data for the depth of the coal seams and the base of the Rewan Formation. I also incorporated the bore data from Carr (1973). The sections were made in Adobe Illustrator, using the topography from the Shuttle Radar DEM (drawn using Global Mapper), and adding the geological boundaries that I had mapped, the detailed section through the Alpha lease, and the bore data from Carr (1973). I assumed that the sediments would have been dipping shallowly to the west before folding; therefore the fold limbs would be steeper on the western sides of the fold axes. I used consistent thicknesses for each unit; these were constrained by the outcrop boundaries I had mapped. I also ensured that all three cross-sections were consistent with each other and with the likely location of the fold axes.

[18] The geological model was assessed during a 6-day site visit to the area of the proposed Alpha and Kevin's Corner mines (14-19 June, 2013). Outcrops of laterite were closely examined, and coincided with where this unit was mapped, and the cliff-lines of the Clematis Sandstone were seen in the distance, again coinciding with where they had been mapped. An overflight of the entire area (extending as far north as the proposed Carmichael mine) in a light plane provided more insights. In particular, very shallow dips of bedding in the Clematis Sandstone, consistent with the folding proposed, were identified in the Cudmore National Park area. It should be noted that the very low dip angles in the area (<1°; see discussion below) are difficult to distinguish

close-up in outcrop; they are best seen from a distance and at an elevation; thus observation from a light plane is the easiest way to map them in the field. A further 4-day site visit (20-23 November 2014), this time to the area of the proposed Carmichael mine, enabled detailed inspection of the Dunda Beds on the ground, and a helicopter flight allowed close inspection from the air of outcrops of Clematis Sandstone, Dunda Beds and Tertiary laterite, as well as areas believed to be underlain by Rewan Formation.

[19] I have included a glossary of terms at Appendix C.

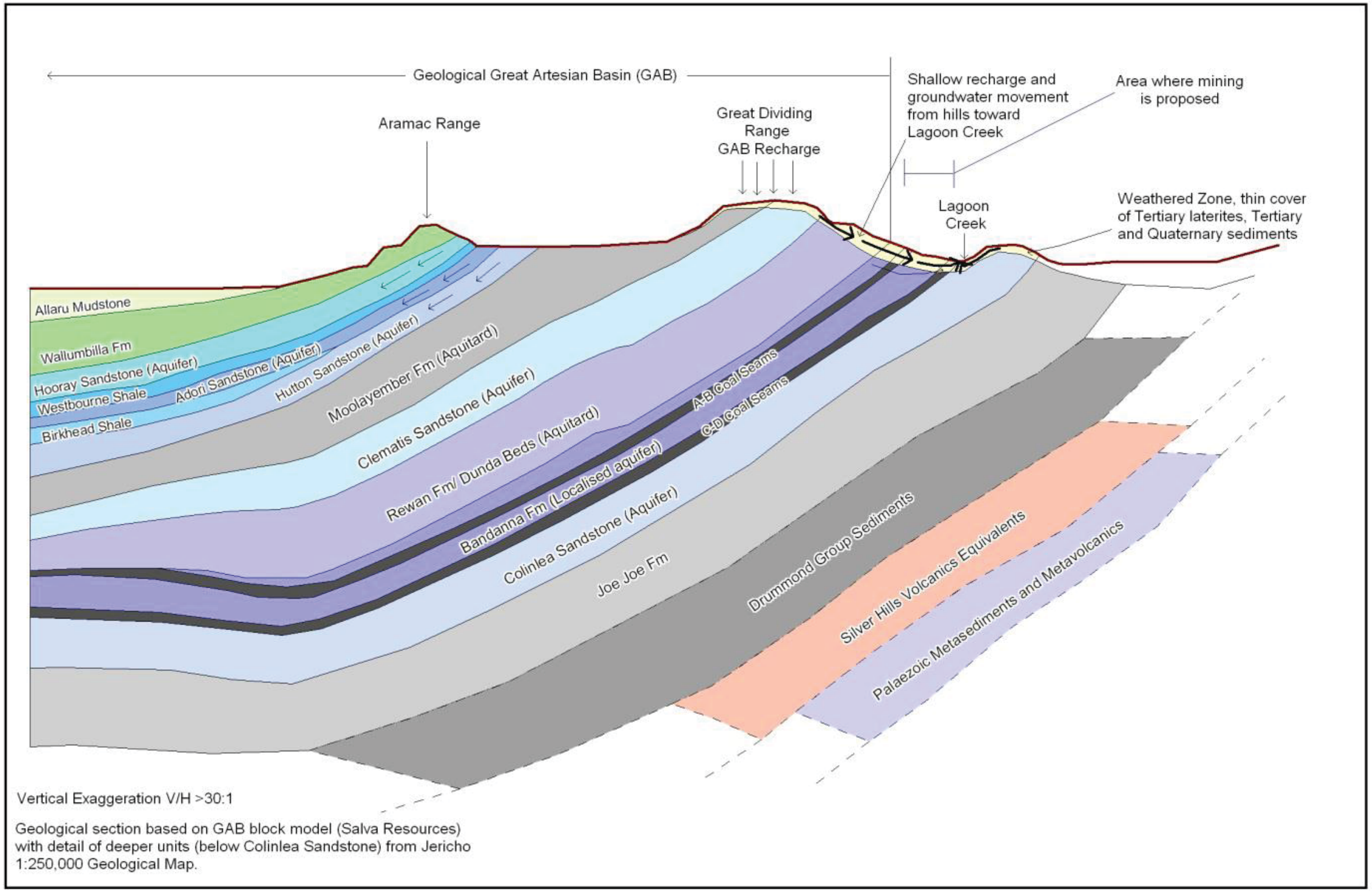


Figure 1(a): Conceptual geological model used in URS Groundwater Modelling Report for Alpha Coal Project 28 March 2012 (Figure 4-11 in that report).

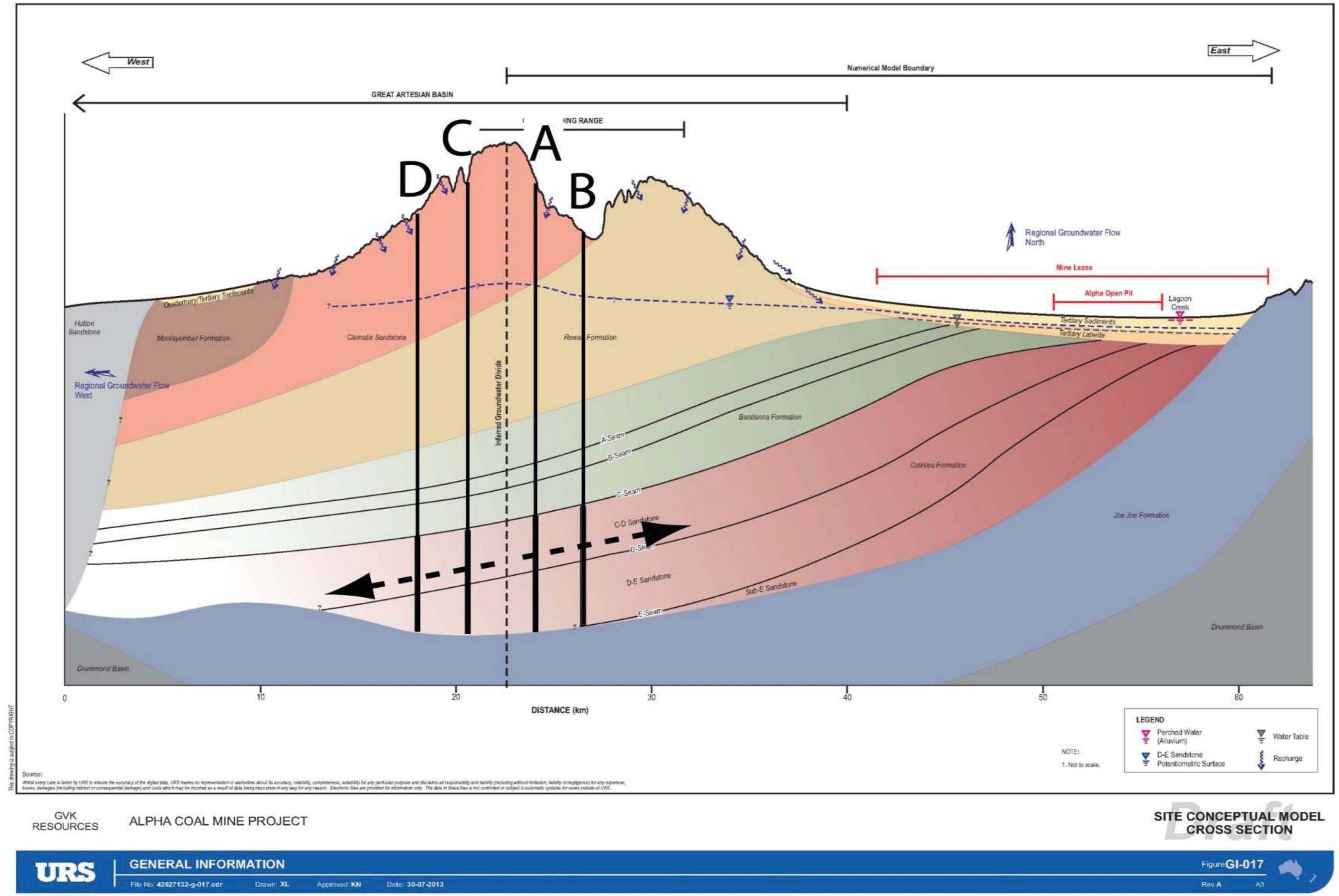


Figure 1(b): Conceptual geological model from Stewart (20/8/13, Figure 1), with additional annotations; bores A-D are all screened in the Colinlea Sandstone; dashed lines show groundwater flow directions in the Colinlea Sandstone that follow from the potentiometric surface for this aquifer shown in the diagram; further discussed in para 70).

Figure 1(c): Conceptual geological model, Galilee Coal Project (Heritage Computing Report, 2013); note similar shape of potentiometric surface for the Bandanna-Colinlea aquifer to Figure 1b.

1.5 Assistance

[20] The new conceptual geological and hydrogeological model in this report in part 3 below was developed entirely by myself using the available 1:250,000 geological map, airborne radiometric and magnetic data obtained from Geological Survey of Queensland, a 2004 Landsat 5 image of the area obtained from the Australian Greenhouse Office, and Google Earth images of the area downloaded by myself using Shape2Earth. The Landsat image was processed using ENVI software and all data was interpreted using the GIS program Global Mapper. The maps provided in Figures 2 and 3 were provided by CCAQ.

[21] As part of the preparations for this report, I examined the area around the Alpha and Kevin's Corner mine sites, including an overflight in a light plane, in the company of Dr Gavin Mudd, Faculty of Engineering, Monash University. I discussed my geological model with Dr Mudd, but he did not contribute to its development. I also spoke to some of the landholders in the area: Ian Hoch and Paola Cassoni of Glen Innes (who showed me laterite outcrops on Glen Innes property and outcrops of laterite along the road near the Hancock Alpha site office, pointed out cliffs of Clematis Sandstone in the distance, and discussed the groundwater quality) and Joanne Salmond of Degulla (who showed me Albro Spring and provided information on nearby artesian bores). The insights gained from this visit helped to inform my report.

1.6 References

[22] I referred to the following maps and reports in preparing this report:

- 1:250,000 Jericho geological map and the accompanying explanatory notes (SF55-14; Bureau of Mineral Resources 1972 and 1973 respectively);
- 1:250,000 Galilee geological map and the accompanying explanatory notes (SF55-10; Bureau of Mineral Resources 1972);
- Alpha EIS Volume 1 (20/12/2010):
  - Section 00 Executive Summary;
  - Section 01 Introduction;
  - Section 02 Description of the Project,
- Alpha EIS Volume 2 (05/11/2010):
  - Section 4 Geology;
  - Section 11 Surface Water;
  - Section 12 Groundwater,
- Alpha EIS Volume 4:
  - Appendix G Cumulative Impacts (05/11/2010),
- Alpha EIS Volume 5:
  - Appendix F1 Geomorphology Technical Report (09/2010);
  - Appendix F3 Site Water Management System and Water Balance Technical Report (14/09/2010);
  - Appendix F4 Surface Water Quality Technical Report (09/2010);
  - Appendix G Groundwater (14/09/2010);
  - Appendix J1 Geochemical Report (30/09/2010),
- Alpha Supplementary EIS Volume 2:

- Appendix I Coal Mine-Surface Water Summary (05/09/2011);
    - Appendix J Coal Mine-Geomorphology Technical Report (06/2011);
    - Appendix M Coal Mine-Surface Water Quality Technical Report (13/04/2011);
    - Appendix N Coal Mine-Groundwater and Final Void Report (05/09/2011);
    - Appendix O Coal Mine-Groundwater Bore Survey Report (28/07/2011),
- Additional Supplementary Documentation:
    - URS Groundwater Modelling Report (28/03/2012),
- Kevin's Corner EIS Volume 1 (31/10/2011)
    - Section 00 Executive Summary
    - Section 01 Introduction
    - Section 02 Description of the Project
    - Section 04 Geology
    - Section 10 Aquatic Ecology and Stygofauna
    - Section 11 Surface Water
    - Section 12 Groundwater
    - Section 16 Waste
    - Section 24 Hazard and Risk
    - Section 26 Decommissioning and Rehabilitation
- Kevin's Corner EIS Volume 2
    - Appendix J Subsidence Report (31/10/2011)
    - Appendix K Land Contamination (22/02/2011)
    - Appendix L2 Aquatic Ecology Assessment (09/2011)
    - Appendix L3 Stygofauna Assessment (09/2011)
    - Appendix M1 Fluvial Geomorphology Report (15/04/2011)
    - Appendix M2 Hydrology and Hydraulic Technical Reports (19/04/2011)
    - Appendix M3 Site Water Management System and Water Balance Technical Report (15/04/2011)
    - Appendix M4 Surface Water Quality Technical Report
    - Appendix N1 Grounwater Technical Report (22/09/2011)
    - Appendix N2 Groundwater Bore Survey Report (07/2011)
    - Appendix Q1 Geochemical Characterisation (07/09/2011)
    - Appendix X Cumulative Impacts (31/10/2011)
    - Appendix W Environmental Management Plan
- Kevin's Corner Supplementary EIS Volume 2
    - Appendix E Geochemical Assessment Coal and Mining Waste Materials (23/05/2012)
    - Appendix F Aquatic Ecology Assessment (05/2012)
    - Appendix K Revised Surface Water Hydraulics Report (12/06/2012)
    - Appendix L Groundwater Report (18/05/2012)
    - Appendix M Site Water Management (Basis of Design) Report (03/10/2012)
    - Appendix N Interim Subsidence Management Plan (03/10/2012)
    - Appendix O Interim Cumulative Impacts Assessment (03/11/2012)
    - Appendix S Cumulative Surface Water Impacts Assessment (03/11/2012)
- Coordinator General's Evaluation Report on the environmental impact statement (05/2013);

- Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining: Advice to decision maker on coal mining project - Kevin's Corner Coal Mine Project (2009/5033) (01/02/2013)
- Interim Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining: Advice to decision maker on coal mining project (20/6/2012);
- Alpha Coal Mine Environmental Management Plan (30/11/2012);
- Kevin's Corner Mine Environmental Management Plan (31/10/2011);
- Expert report to the Land Court in the Alpha Coal Mine objection proceedings by Mark Stewart (20/8/2013);
- Waratah Coal's China First Environmental Impact Statement: Volume 5, Appendix 14 – Groundwater (25/9/2010);
- Crosbie, R., et al. 2012, *New insights to the chemical and isotopic composition of rainfall across Australia*, CSIRO Water for a Healthy Country Flagship, Publication.
- Carr, A.F., 1973. Galilee Basin exploratory coal drilling – Wendouree area. Geological Survey of Queensland Record 1973/12.
- Smerdon B.D. and Ransley T.R. (eds), 2012. Water resource assessment for the Central Eromanga region. A report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment. CSIRO Water for a Healthy Country Flagship, Australia.
- Queensland Carbon Dioxide Geological Storage Atlas, 2009. Galilee Basin, pp 124-131.
- Heritage Computing, 2013. Galilee Coal project groundwater assessment for Waratah Coal Pty Limited. Report HC2013/7.
- Expert report to the Land Court in the Kevin's Corner Mine objection proceedings by Mark Stewart (17/10/2014);
- Carmichael coal mine and rail project: Coordinator General's evaluation report on the environmental impact statement, Appendix 1, Schedule H - Land and Rehabilitation (7/5/2014)
- Carmichael Coal Mine and Rail Project SEIS Mine Hydrogeology Report Addendum (24/10/2013)
- Jensen, J.R., 2007. Remote sensing of the environment, second edition. Prentice Hall Series in Geographic Information Science.
- Lillesand, T.M., Kiefer, R.W. and Chipman, J.W., 2008. Remote sensing and image interpretation, sixth edition. John Wiley & Sons.
- Younger, P.L., 2007. Groundwater in the environment: an introduction. Blackwell Publishing.

2 Summary Report

2.1 Questions 1 and 3:

Is there sufficient information to form an adequate scientific basis for approval of the Kevin's Corner Coal Mine, having regard in particular to potential groundwater impacts?

Having regard to all of the EIS documents, are there issues that should be examined in more detail or additional lines of inquiry in relation to groundwater that should be explored before approval is granted?

[23] These two questions are most easily answered together. At present there is insufficient information to determine the overall groundwater impacts to the north of the Kevin's Corner Coal Mine.

[24] The groundwater modelling has significant shortcomings which need to be remedied by incorporating:

- A decreasing rather than constant head northern boundary (section 5 in the main report, particularly paragraphs 71 to 73);
- A no flow rather than constant head southern boundary (paragraph 70 in the main report);
- Infiltration of recharge primarily in particular areas along the Great Dividing Range (paragraphs 50-52 in the main report); and
- The revised geological model proposed here (see section 3 in the main report).

[25] The revised modelling will allow the impacts of the mining on areas to the north to be more accurately determined. At present these impacts are significantly underestimated and will extend much further north than presently modelled, potentially as far as the springs and lagoon on Degulla property, which could be negatively affected (see Figures 2 and 3 for locations of properties and surface water features in relation to the Kevin's Corner Coal Mine and other MLAs in the Galilee Basin).

[26] The modelling also needs to better consider the regional impacts of permanently removing a significant amount of groundwater from the Burdekin River basin, particularly in terms of the cumulative impacts from the Kevin's Corner, Alpha and other proposed mines on the eastern margin of the Galilee Basin in this area.

2.2 Question 2:

Having reviewed all of the EIS documents, do I agree with the Coordinator-General's assessment in relation to groundwater?

2.2.1 <u>Assessment</u>

[27] The Coordinator-General's Report contains the following comments bulleted below:

- *That "the updated groundwater models (as presented in the Groundwater Report, SEIS, Appendix L) provides for the comprehensive predictive analysis of groundwater impacts arising from both Kevin's Corner and the adjacent Alpha Coal mine over the life of these projects." (page 24)*

[28] I disagree. As detailed in paragraphs 73 to 77, the groundwater impacts to the north of the mine site are significantly underestimated, due to a lack of consideration of the effect of the mine dewatering on northwards groundwater flow.

- *That "Groundwater modelling presented in the SEIS (Appendix L) predicts no changes to groundwater levels in any of the model layers below the northern registered springs during the LOM or post mining." (page 30)*
- *And "I am satisfied that mine dewatering and depressurisation required for the project is unlikely to result in impacts on registered springs." (page 31)*

[29] It is true that modelling has not identified groundwater impacts outside the mine area extending as far as the springs to the north, but once the modelling is redone with the revisions suggested in section 2.1, the groundwater impacts are likely to prove much more substantial than presently modelled. This will be particularly true to the north, where decreased groundwater flow is likely to reduce artesian pressures and therefore decrease spring flows.

- *That "It is generally accepted that the Rewan Formation is a regional aquitard that prevents significant inter-aquifer transmission of water within and between basins" and "No major regional scale fold and fault structures have been mapped crossing or connecting any of the geological units within and adjacent to the mining lease area." (page 25)*

[30] My reassessment of the geology of the mine area and the recharge to the Bandanna/Colinlea aquifer shows that there are most likely higher permeability pathways through the Rewan Formation, and that there are broad, low angle folds affecting all Permian and Triassic stratigraphic units in the area. These revisions to the geological framework require re-evaluation of the overall conclusions of the Coordinator-General's Report with respect to groundwater.

2.2.2 Conditions and recommendations

[31] The Coordinator-General's Report specified 6 recommendations in relation to groundwater (Appendix 4, Recommendations 1-3 and 7-9) and 2 conditions (Appendix 3, Conditions 2 and 3). I agree with all of them; I have specific comments on some of them.

- *Recommendation 3 – GAB aquifer trigger levels*

[32] This is an important recommendation. However, although it specifies trigger levels that recognise an impact on the GAB aquifers, it does not specify any consequences if the trigger levels are exceeded, except that "the proponent must fully investigate and model the potential impact upon the Great Artesian Basin and obtain any necessary approvals". This is inadequate; a demonstrated impact on GAB aquifers requires a more detailed response.

- *Recommendation 7 – Regional water balance model*

The identification of linkages between formations, in terms of determining the regional interaction between surface water and groundwater, needs to take into account the revised conceptual geological model of the area presented here, and in particular if there are fault/joint controls on the springs that have not yet been determined.

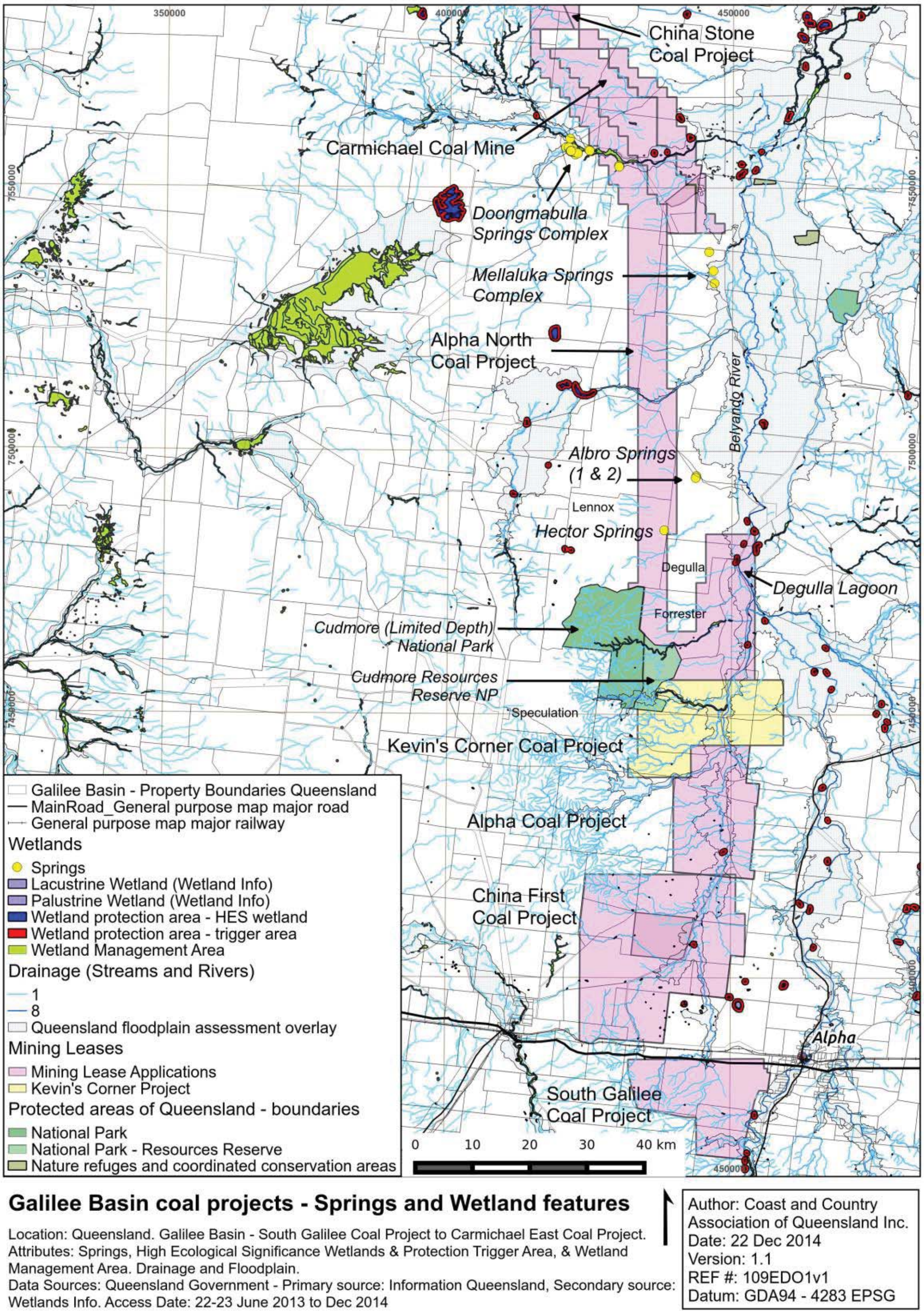


Figure 2: Galilee Basin coal projects – Springs and Wetland features, showing MLAs and property names

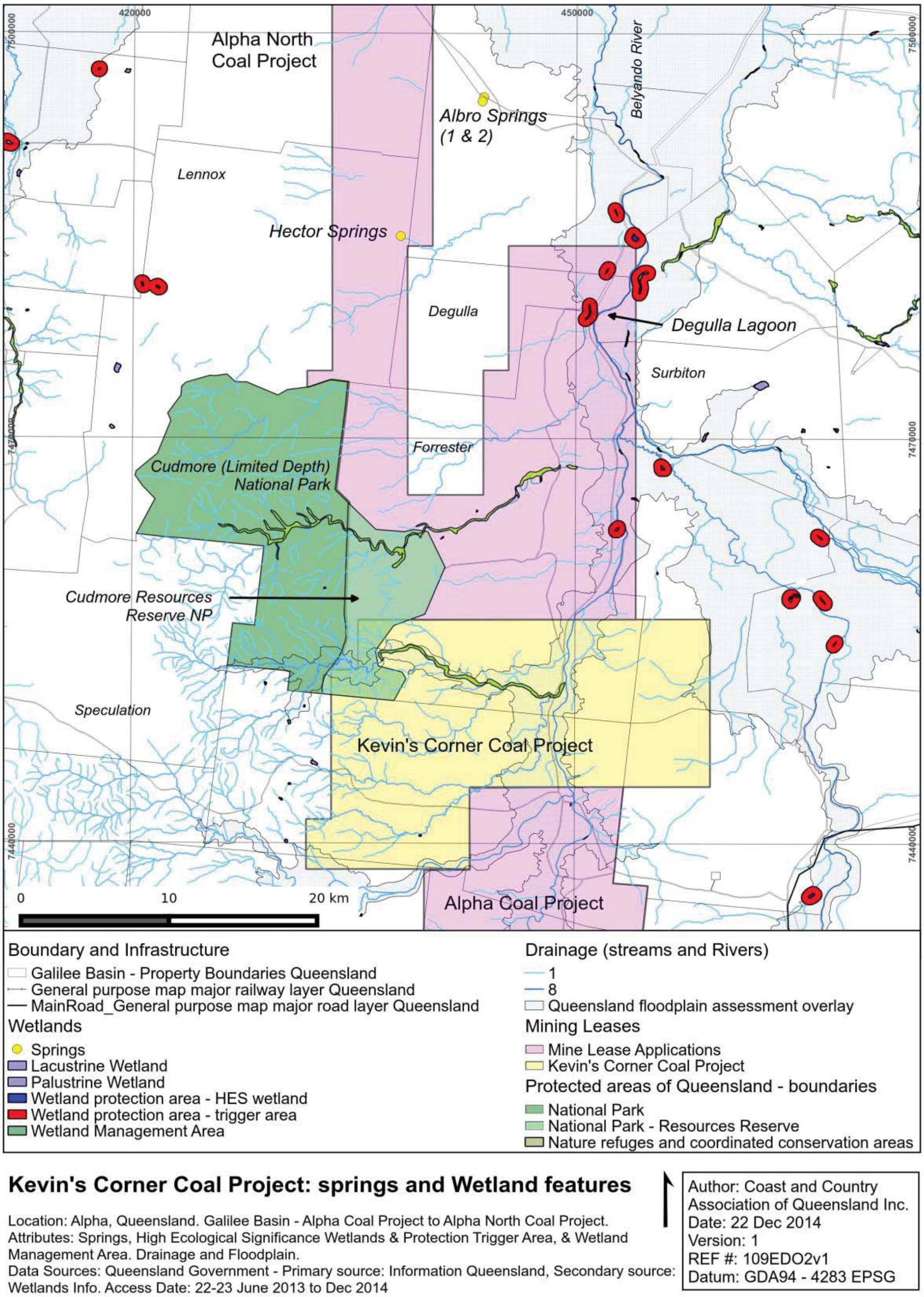


Figure 3: Kevin's Corner Coal Project –Springs and Wetland features, showing property names

3 Conceptual Geological Model

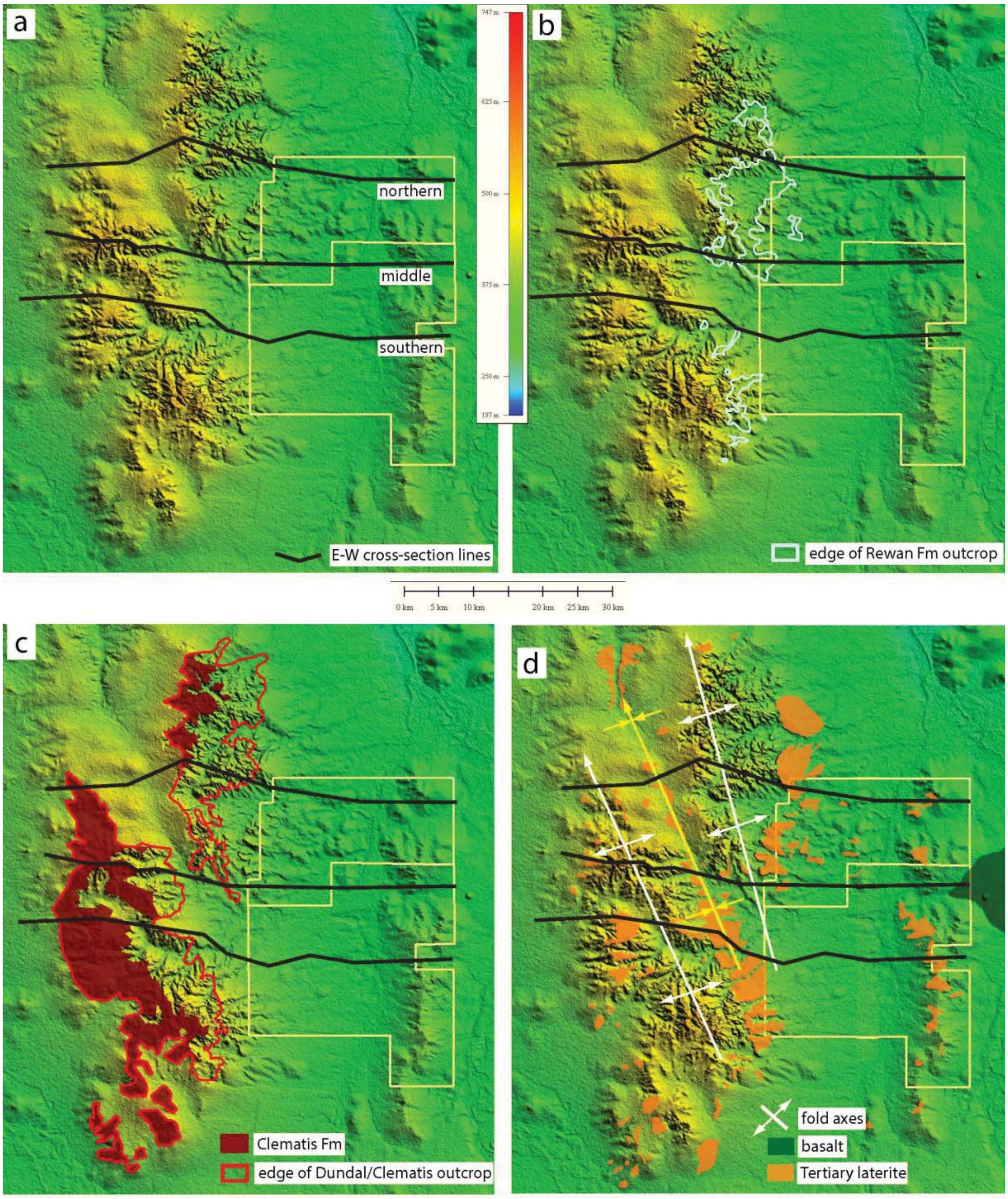
[33] The geology of the proposed Alpha and Kevin's Corner mine sites consists of a conformable sequence of Permian and Triassic strata (Joe Joe Formation, Colinlea Sandstone, Bandanna Formation, Rewan Formation, Dunda Beds and Clematis Sandstone, in stratigraphic order). These are overlain by Tertiary laterite (ferricrete), which consists either of a thin iron-cemented sandstone unconformably overlying the Permian-Triassic strata, or of a very strongly ferruginised weathering profile developed on these strata; the profile varies in thickness from a few centimeters to several meters. The Tertiary laterite covers the lower-lying parts of the area as a more or less continuous subhorizontal sheet, but has been partially removed by erosion from the hills. Quaternary unconsolidated sediments overlie the laterite, and range in thickness from absent to a few centimeters on the hills, to >10 m along the main creeks.

[34] The Permian and Triassic strata are stated in all the reports on the proposed Alpha and Kevin's Corner mines to dip uniformly at 0.5-2° to the west. The accurate geological cross-section of the proposed Kevin's Corner mine site provided in the SEIS (Fig. 4-8) is based on detailed drilling records, and shows that the dip of the coal seams is ~0.8°; the dip appears to be at a higher angle on the cross-sections because the vertical scale is exaggerated relative to the horizontal scale. Over the area of the proposed Alpha mine immediately to the south, the dip of the Permian strata is between 0.3° and 0.9° (based on the detailed geological cross-sections).

[35] My reinterpretation of the geology of the area shows that the Permian and Triassic strata in this area do not dip uniformly to the west, but have been folded into broad, low angle anticlines and synclines; axes trend south-southeast - north-northwest and plunge shallowly towards the north-northwest (Figure 4d). The crests of the anticlines approximately define the drainage divide of the Great Dividing Range in this area, which is a subtle topographic feature with a maximum of only 200 m of relief. Dips on the limbs of the folds are very shallow (maximum of a few degrees) and may be asymmetric (discussed further below).

[36] The folds converge towards the south-southeast (Figure 4d); to the south of the proposed Kevin's Corner and Alpha mine sites they probably merge, so that no folding is present, and the beds dip uniformly west. In the South Galilee proposed mine area, the groundwater appears to flow west down the dip of the Colinlea Sandstone (Heritage Computing 2013, Figure 3.9).

[37] The folding can be mapped from the Clematis Sandstone outcrops, which dip very shallowly to the east on the eastern flank of the Great Dividing Range in the Cudmore National Park area, as shown by the outcrop patterns evident on Landsat images of the area (particularly the RGB 457, Tasseled Cap RGB Brightness Greenness Wetness, and PCA RGB 123 images; Figures 5a, b, d), and visible from the air (Figures 6, 7). The broad valley occupied by the Lennox and Speculation properties (see Figures 2 and 3) defines the central syncline. The crests of these anticlines either side of this syncline have been breached by erosion, giving rise to areas of broken topography such as that within Cudmore National Park, and exposing not only the Clematis Sandstone, but also the underlying Dunda Beds and Rewan Formation (Figure 4b,c). As previously mentioned, the outcrop areas of the Rewan Formation can be clearly identified on the radiometric image of the area, because of their pink (high-potassium) signature (Figure 5c).



Geology of area around Alpha and Kevin's Corner mines

(constructed using the remotely sensed images, existing geological map, airborne radiometric and magnetic data and aerial observations during site visit)

Figure 4: Geology of area around Alpha and Kevin's Corner mines

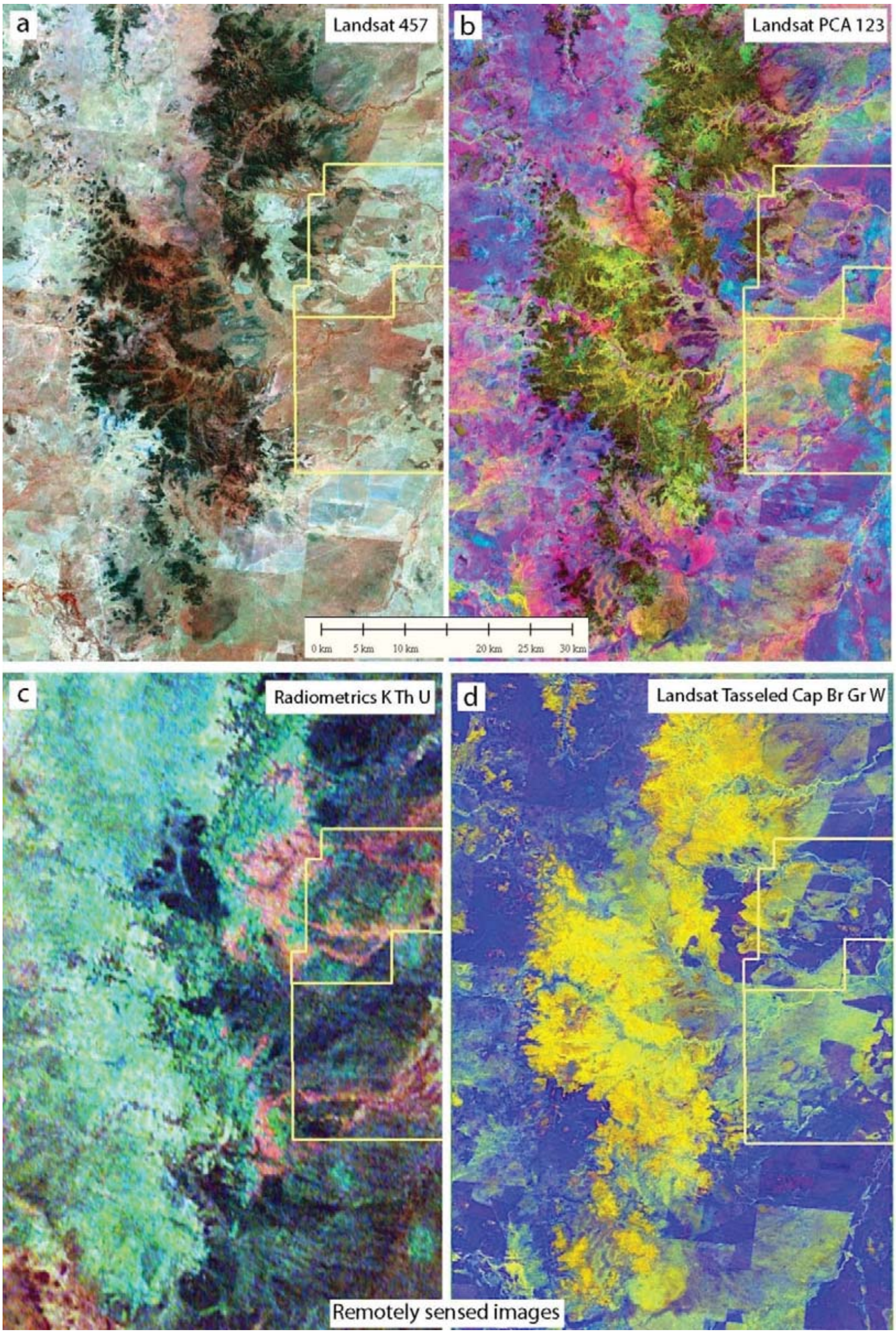


Figure 5: Remotely sensed images

[38] Because the Permian and Triassic sediments originally dipped shallowly westward, the effect of the folding has been to create asymmetrical folds in these strata, so that the anticlines have steeper western limbs (Figure 8; note the exaggerated dip because the vertical scale is much larger than the horizontal scale). As a result the Permian sediments dip westwards beneath the Lagoon Creek valley (as shown by all the cross-sections of the proposed Alpha mine and the bore data from Carr (1973), but on the eastern flanks of the Great Dividing Range they dip eastwards from the anticline axes beneath the crest of the range (Figure 8). The plunge of the folds towards the north-northwest and the convergence of the fold axes to the south means that there is a shallow northwards regional dip superimposed on the dip of the fold limbs; this is clearly evident as a shallow northwards dip of the Triassic strata north of Cudmore National Park (Figure 6).

[39] This folding is very similar to the broad open folds within the Great Artesian Basin and Galilee Basin sediments further west beyond the Great Dividing Range, as shown on the cross-sections in Queensland Carbon Dioxide Geological Storage Atlas (2009) and that accompanying the 1:250,000 Jericho geological map published by the Bureau of Mineral Resources in 1972. Smerdon and Ransley (2012, Fig. 5.6) identified an Eocene compressional event that folded the sediments of the Great Artesian Basin and underlying Galilee Basin.

[40] The conceptual geological model proposed here resembles that in Waratah Coal's China First EIS (Volume 5, Appendix 14, Groundwater), in that the latter identified an anticline beneath the Great Dividing Range to the west of the mine. The China First model was also based on the eastwards slope of the potentiometric surface in the Colinlea Sandstone.

Figure 6: Cudmore National Park, looking south; note the eastwards dip (towards the left on the photo) of the Clematis Formation outcrops in the middle left of the photo. Photo taken by J.Webb, 18/6/2013, from around 146.36 E, 22.79 S.

Figure 7: Cudmore National Park, looking southwest; note the eastwards dip (towards the left on the photo) of the Clematis Formation outcrops in the middle left of the photo, and the northwards dip of the Clematis Formation outcrops to the north (right of the photo). Photo taken by J.Webb, 18/6/2013, from around 146.58 E, 22.93 S.

4 Conceptual hydrogeological model

4.1 Aquifers

[41] The Bandanna Formation and Colinlea Sandstone can be regarded, approximately, as a single hydrogeological unit. The coal seams within the Colinlea Sandstone act as leaky aquitards, so that the lower sandstone beds (e.g. CD and DE sandstones) within the proposed mine site have storativity values characteristic of confined aquifers. The upper part of the Bandanna/Colinlea aquifer within the proposed mine site is unconfined. The conceptual hydrogeological cross-sections within the EIS reports show only the potentiometric surface of the CD sandstone; to the west of the proposed mine this lies within the Bandanna/Colinlea aquifer, suggesting that the potentiometric surface is close to the watertable within the Permian strata.

[42] The overlying Tertiary laterite is strongly iron-cemented and forms an aquitard that restricts downwards infiltration of rainfall into the groundwater in the Permian and Triassic formations. The laterite lies close to the surface (generally within a few meters) throughout the proposed mine area, and forms an impermeable base to some farm dams; these tend to be the ones that hold water. Farm dams entirely within the overlying unconsolidated Quaternary sediments generally leak. Therefore, the Tertiary laterite can create a perched watertable that may extend into the Quaternary sediments, particularly in the wet season; perched groundwater has been identified by drilling in the proposed mine area.

4.2 Groundwater quality

[43] The average salinity of groundwater in the area is 2000-3000 µS/cm; of 89 bores surveyed in the area for the EIS reports, 58% have a potential beneficial use of potable supply, and only 3% are so saline that domestic or stock use is precluded. As a result the groundwater is extensively used in the area for stock watering and domestic purposes; many properties depend almost entirely on this water source.

[44] Groundwater analyses from the different stratigraphic units (Stewart 20/8/13, Table 1) show that the groundwater in the alluvium and Tertiary strata is very saline (median 46000 and 27900 µS/cm respectively), whereas the groundwater in the underlying Permian units becomes less saline with depth, reaching a minimum of 1580 µS/cm (median) in the D-E sandstone within the Colinlea Sandstone. In Stewart 17/10/2014 (Table 5-7), different values are given for the groundwater salinities in these units: alluvium and Tertiary strata - median 1140 and 2750 µS/cm respectively, D-E sandstone - median 899 µS/cm. The reason for the difference is unclear; however, the overall trend of decreasing groundwater salinity with depth is the same.

4.3 Groundwater flow direction within the Bandanna/Colinlea aquifer

[45] The potentiometric surface of the CD sandstone within the proposed mine site dips shallowly to the east and northeast, despite the fact that the CD sandstone itself dips towards the west (Figure 8; note the exaggerated dip because the vertical scale is much larger than the horizontal scale). This apparently contradictory situation is explained readily by the folding of the Permian sediments. Along the crest of the range, where the anticline axes are located, the upper surface of the Bandanna/Colinlea aquifer is topographically higher than the subcrop of the CD sandstone within the mine site in the valley of Lagoon Creek (Figure 8), and an interpreted potentiometric

surface for the Bandanna/Colinlea aquifer from this high point towards the east is a continuation of the eastwards dipping potentiometric surface of the CD sandstone within the mine site.

[46] Therefore, due to the folding, the potentiometric surface of the Bandanna/Colinlea aquifer to the east of the crest of the Great Dividing Range in the mine area slopes to the east, and as a result groundwater flows eastwards (Figure 10a). The groundwater flow direction then swings northwards beneath the Lagoon Creek valley, following the topography as well as the low regional dip to the north.

[47] The potentiometric surface gets closer to the ground surface towards the north, until on Degulla property (Figure 3) there are artesian bores and springs.

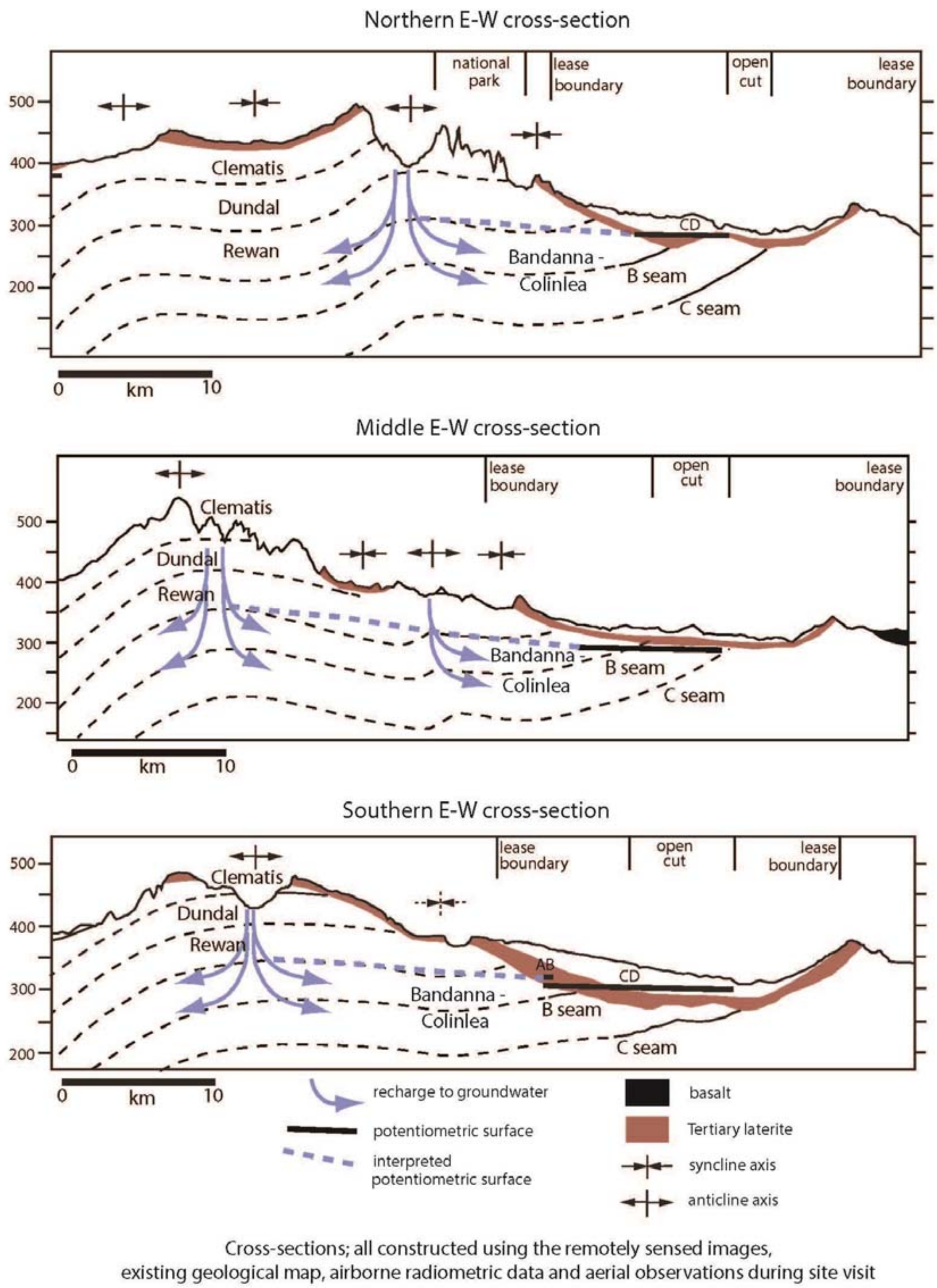


Figure 8: Cross-sections (vertical exaggeration x 45).

4.4 Recharge

[48] The Quaternary sediments covering much of the proposed mine area are often sandy, particularly at the surface, and absorb most rain events; there is little run-off and there are very few surface drainages that originate in this area. It is likely that the bulk of this surface recharge seeps down to the laterite layer, which probably develops a perched seasonal watertable, and is then removed by evaporation and transpiration. As a result, the salinity of groundwater in the Quaternary and Tertiary aquifers is relatively high. There is some recharge through the Quaternary and Tertiary units into the upper part of the underlying Permian sediments, as shown by the higher salinity of groundwater in the C-D sandstone, but this saline groundwater is not the main source of recharge for the D-E sandstone in the lower part of the Permian aquifer, because this aquifer contains fresher groundwater than that in the overlying beds.

[49] Instead the main recharge areas for the Bandanna/Colinlea aquifer in the proposed mine area are likely to be along the crest of the Great Dividing Range, where the anticline axes are located (Figure 8). Although the Bandanna/Colinlea aquifer does not outcrop in this area, there are probably extensional fractures present that have opened along the axes of the anticlinal folds; these fractures most likely initiated the erosion that formed the areas of broken topography along the anticline axes. There are a substantial number of NE-SW lineaments within the Clematis Sandstone outcrop areas that probably represent fractures that have developed along the folds. These fractures are likely to penetrate through the Rewan Formation, which would otherwise act as an aquitard. Stewart (17/10/2014, lines 45-47) states that there is no evidence of transmissive open faults or fractures within the Rewan Formation in the area, but parts of the Rewan Formation are quite transmissive, as shown by scattered high vertical hydraulic conductivity values of 0.3-1.2 m/day (Kevin's Corner EIS, 12 Groundwater, Table 12-30). Recharge may be greater where the Rewan Formation is exposed in the core of the eastern anticline, because the Rewan Formation is thinner there (Figure 8).

[50] Therefore the crests of the anticlines, which define the crest of the Great Dividing Range in this area, probably also mark the westwards limit of recharge to the mine area (Figure 10a). Because there are two anticline axes and two associated areas of broken topography, there are two separate recharge areas, one to the west of the Alpha lease, and one to the west and north of the Kevin's Corner lease.

[51] Recharge through the fractures around the anticline crests is slow, as shown by the lack of response in the potentiometric surface to seasonal variation in rainfall. Nevertheless, the potentiometric surface shows a relatively long term decreasing trend that matches the overall trend in rainfall over the same period (as demonstrated by the cumulative deviation from mean rainfall), confirming that recharge is due to local rainfall, and although low, is not negligible.

[52] The Kevin's Corner SEIS report on the hydrogeology of the mine area correctly noted that there is a groundwater divide to the west of the mine site, and that the majority of recharge within the study area is derived as diffuse recharge from the Great Dividing Range, but did not specify the recharge mechanism or the recharge areas.

[53] The relatively low salinity groundwater in the D-E sandstone in the Bandanna/Colinlea aquifer (median 899 or 1580 µS/cm) represents recharge that has occurred probably in the last few

thousand or tens of thousands of years. The low salinity does not relate to the aquifer composition; Stewart (17/10/2014, lines 1596-1598) states that the coarse quartz-rich sandstone will have limited salt contribution to the groundwater, but this is also true of the clay-rich units, because none of the minerals in these sediments contains significant levels of chloride, and water-rock interaction within these units cannot significantly alter the salinity. There is no significant chloride source in any of the sedimentary units apart from the chloride brought in through rainfall.

[54] The low salinity groundwater in the Colinlea Sandstone cannot represent connate water trapped in the sediments when they were deposited by Permian rivers over 250 million years ago, because the gradient of the potentiometric surface for the Bandanna/Colinlea aquifer is low but significant, and indicates that the groundwater system is dynamic and not static; the groundwater is moving slowly but continuously. Calculating the average linear groundwater flow rate in the Bandanna/Colinlea aquifer from Darcy's Law (v = hydraulic conductivity x hydraulic gradient / effective porosity), using hydraulic conductivity values of 0.05-1.5 m/day (URS report, Tables 7-3, 7-5 and 9-3), a hydraulic gradient of 0.001 (URS report Fig. 4-13) and an effective porosity of 0.1 (typical of porous sandstone), the velocity is 0.2-5 m/year (Stewart 17/10/2014, line 2457, quotes a velocity of 0.0028 m/year; it is not clear how this was calculated). Therefore, it would take thousands to tens of thousands of years for all groundwater in the aquifer within the mine site at present to flow northwards past the northern boundary of the site; any Permian groundwater flowed out of the system long ago.

[55] The amount of recharge can be estimated from the chloride (Cl) concentrations in groundwater and rainfall using the Chloride Mass Balance method (recharge = rainfall . Cl rainfall / Cl groundwater; e.g. Smerdon and Ransley 2012). This assumes that chloride is an unreactive tracer, that there is no chloride source in the aquifer apart from the chloride brought in through rainfall, and that all the chloride that arrives in rainfall ends up in groundwater, i.e. surface runoff is negligible. The greater chloride concentration of the groundwater is due to the effect of evapotranspiration in the soil during rainfall infiltration. From the median chloride concentration of groundwater in the area within the D-E sandstone in the Bandanna/Colinlea aquifer (170 mg/L; Stewart 17/10/2014, Table 5-7) and the likely chloride concentration of rainfall (~0.5 mg/L; Crosbie et al. 2012), recharge should average around ~2 mm/year, i.e. 0.3% of rainfall (mean annual rainfall is 662 mm). This compares with the calibrated recharge in the modeling EIS report of 0.1% of rainfall (apparently revised to <0.1% of rainfall in Stewart (17/10/2014, line 2456). Calculations of recharge to the intake beds of the Great Artesian Basin to the west of the mine site (Cadna-owie – Hooray Aquifer and equivalents), using the Chloride Mass Balance method, derived recharge values of <5 mm/year (Smerdon and Ransley 2012).

[56] The main recharge areas along the crest of the Great Dividing Range are the areas of broken topography as defined above. These have an area of ~400 km^2 and would, using a recharge of ~2 mm/year, provide recharge of ~780 ML/year. This recharge should equal the northwards groundwater flow through the Bandanna/Colinlea aquifer, because there is no groundwater flow out of this groundwater system to the east, west or south (as discussed below). This throughflow can be calculated from:

Throughflow = hydraulic conductivity x hydraulic gradient x cross-sectional area

Using a hydraulic gradient of 0.001 (URS report Fig. 4-13), the total thickness of sandstone in the Bandanna and Colinlea Formations of ~130 m (Table 4-2, URS report), the width of the model domain at the northern extent of drawdown of ~32 km, and hydraulic conductivity values of 0.05-1.5 m/day (URS report, Tables 7-3, 7-5 and 9-3), gives throughflow values of 76-2250 ML/yr. The postulated recharge of ~780 ML/yr lies within the lower end of these throughflow values. The calculated groundwater outflow from the steady state model (Stewart 17/10/2014, Table 5-5) is 192 ML/year.

[57] There are numerous statements through the various EIS hydrogeological reports that recharge is negligible/insignificant, and in the most recent modelling, "recharge was only applied to the shallow perched aquifer" (URS 2012, p. 85). Recharge to the Bandanna/Colinlea aquifer in the proposed mine area through the overlying laterite is probably small (apparently calculated as 19 ML/yr; Table 5-5). Stewart (17/10/2014, lines 1568-1571) states that "recharge to deeper Permian units occurs to the southwest of the site (along the Great Dividing Range)", and the Kevin's Corner SEIS states that recharge was "applied to topographically elevated areas of the Great Dividing Range" (p. 42), but in cross-examination in the Alpha Case on 30 September 2013 (Transcript - page 19 line 44 to page 20 line 22), Stewart identified that the recharge had been applied uniformly in the groundwater modelling across the entire layer of the model as a "top flux" boundary. In this case, the apparently preferred recharge value of 0.1% of rainfall (0.7 mm) for the modeling equates to a substantial recharge value as it has been applied to a large area; 0.7 mm of recharge across 1 km^2 results in 0.7 ML of recharge to groundwater, so this would equate to ~1700 ML/yr across the modelled area (~2500 km^2). This is much greater than the value of 19 ML/yr given in Table 5-5.

[58] The calculations in the present report show that recharge to the Permian aquifer along the crest of the Great Dividing Range is likely to be significant, and should be taken into account in the modelling. It is notable that modeling for other proposed mines in the area used relatively high recharge values (Stewart 17/10/2014, lines 2723-2729).

Figure 9: Google Earth image showing Degulla Lagoon and Belyando River

4.5 Discharge

[59] All creeks in the proposed mine area are ephemeral and flow only after heavy rain, when a perched seasonal watertable probably develops within the alluvium. Recharge to this watertable is probably through surface infiltration, which flows along on top of the laterite and may discharge to the creek. There is apparently little or no discharge from the Bandanna/Colinlea aquifer into Lagoon Creek in the mine area, because the potentiometric surface of the CD-DE sandstones is 12-22 m beneath the creek bed, and bores along the creek show that the water table lies at 3-9 m depth within alluvium, which is 15-20 m thick in the central area of the creek.

[60] However, the potentiometric surface in the Permian strata becomes closer to the ground surface northwards. The previous reports on the site noted that groundwater may be expected to contribute to surface water baseflow, especially to the north of the mine area, and that there is likely to be discharge to Sandy Creek.

[61] On Degulla property to the north of the proposed mine site (Figure 3), Albro Spring is a permanently flowing artesian spring, with extensive surrounding silica-cemented sediments and permanent swamp vegetation around the edges of the adjacent pool. Nearby bores show that the potentiometric surface of the Permian strata lies above the ground surface (Joanne Salmond, pers. comm.), so this spring is most likely fed by groundwater flow from the south within the Bandanna/Colinlea aquifer, i.e. it is a discharge area for groundwater flow from the area around

the proposed mines. There are three similar small springs further north (Mellaluka Springs Complex), that are attributed to artesian flow from the Permian aquifer (Carmichael SEIS Mine Hydrogeology Report Addendum). These three springs lie in a more or less straight north-south line, suggesting that they are located along a fault, and Albro Spring may also be located on a fault. Although Albro Spring lies at a small break in slope on the eastern side of the Great Dividing Range (the gradient upslope of the spring is ~0.7°), the fact that it is permanent indicates that it does not represent seepage from the colluvium along the flank of the range, which would be fed by seasonal rainfall.

[62] North-south faulting is evident in the Great Artesian Basin to the west of the proposed mine (Smerdon and Ransley 2012); these faults can have displacements of tens to hundreds of meters. It is notable that the likely faulting causing groundwater flow at Mellaluka Springs has a similar orientation.

[63] Mark Stewart (17/10/2014) states that there is no evidence of groundwater contribution to surface water within the model domain (lines 1854-1855), and little or no Permian aquifer groundwater – surface water interaction (lines 2783-2784). However, Albro Spring is located in the north of the model domain and is fed by groundwater flow; therefore there is substantial groundwater contribution to surface water in the north part of the modeled area.

[64] Also on Degulla property is a permanent lagoon adjacent to Belyando River (Figure 9); this is the only permanent surface water feature in the entire region. It did not dry up during the recent drought, and continued to provide drinking water to the nearby homestead. It is possible that this lagoon is groundwater fed.

4.6 Relationship to Great Artesian Basin

[65] Because groundwater flow in the area around the mine site is towards the east and north, i.e. away from the Great Artesian Basin, the Alpha and Kevin's Corner mine sites are not hydrogeologically part of the basin. There is a major groundwater divide along the crest of the Great Dividing Range in this area that acts as the eastern boundary of the Great Artesian Basin.

[66] The edge of the Great Artesian Basin is generally defined as the base of the Rewan Formation, but in the proposed mine area the outcrop limit of the Rewan Formation lies to the east of the groundwater divide along the crest of the range, and is therefore not the edge of the Great Artesian Basin in this area.

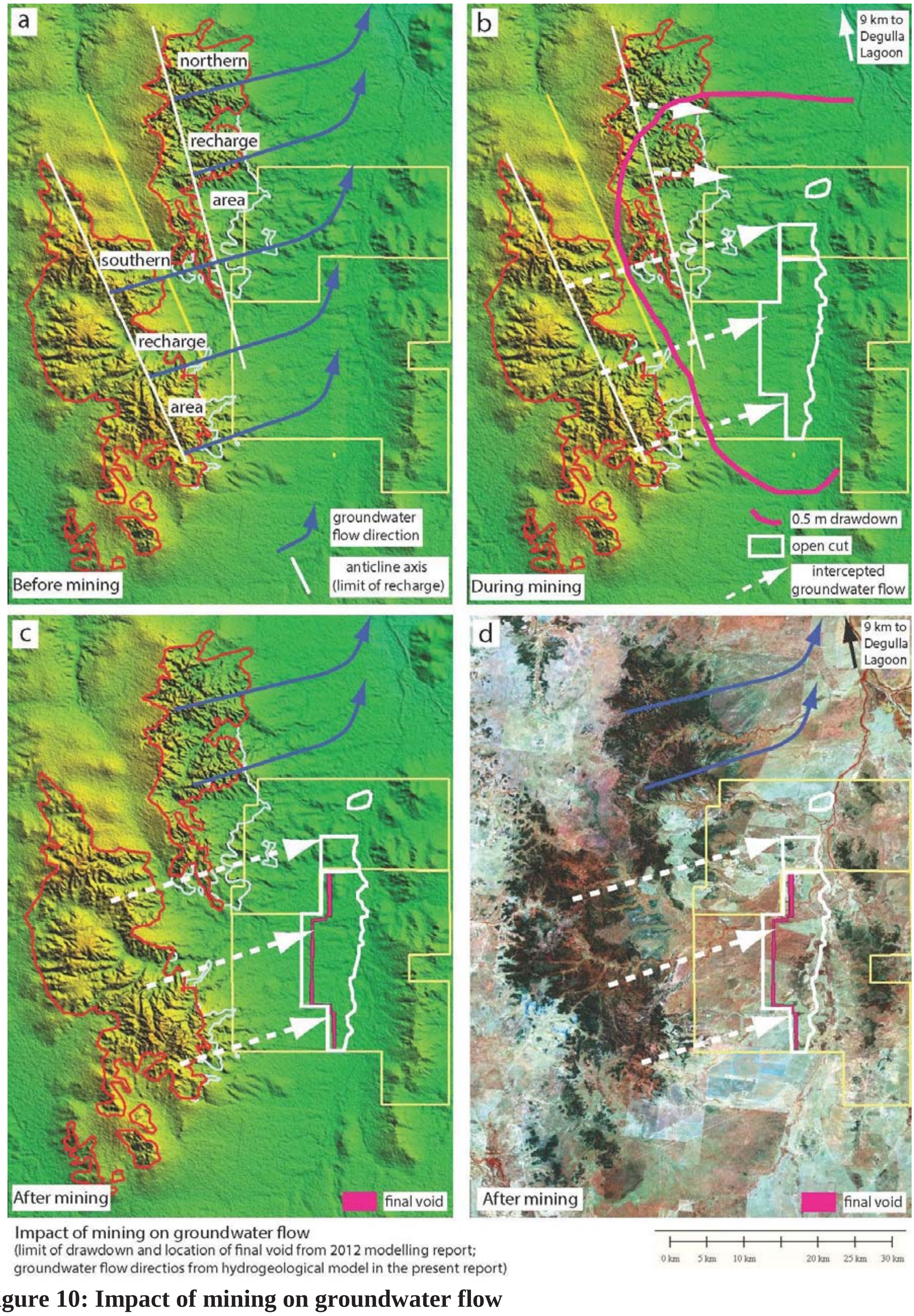


Figure 10: Impact of mining on groundwater flow

5 Modelling of the impact of the proposed Kevin's Corner mine on groundwater

[67] The most recent modelling of the drawdown of the potentiometric surface due to dewatering of the proposed Alpha and Kevin's Corner mines is based on no-flow boundaries along the eastern and western sides of the mine sites, and constant head boundaries to the north and south. The no-flow eastern boundary is the eastern limit of the aquifer, and is clearly correct.

[68] The western no-flow boundary is located along the Great Dividing Range, and assumes that the topographic head provided by the range is transmitted to the uniformly west-dipping Bandanna/Colinlea aquifer deep beneath. However, the overlying Rewan Formation, which is an aquitard where it is not penetrated by fractures, would prevent flow beneath the range into the aquifer. Even if the Rewan Formation was leaky at this point, it is extremely unlikely that there would be a groundwater divide within a uniformly dipping aquifer, because to the west of this divide, groundwater within the Bandanna/Colinlea aquifer must be flowing west, down the hydraulic gradient and down the westwards dipping bed, but to the east of the groundwater divide, groundwater within the Bandanna/Colinlea aquifer must be flowing east, down the hydraulic gradient but up the westwards dipping bed. Thus, the western no-flow boundary is very difficult to comprehend with the geological model used in the modeling study. Instead it is much more likely that the western boundary would be a variable (falling) head boundary, due to interception of groundwater flow through the aquifer by the mine sites upgradient. In this case the Alpha and Kevin's Corner mine sites would be hydrogeologically part of the Great Artesian Basin, and the groundwater extraction and interception for the mines would negatively impact on the groundwater resources of the basin. However, the geological model derived for this study, whereby the Great Dividing Range is a topographic and hydrogeological divide (because it is the axis of an anticline), means that the western boundary of the modeling is in fact a no-flow boundary. The fact that I agree that the western boundary of the modeling is a no-flow boundary in no way suggests that I agree with the geological model that underpins the hydrogeological modeling.

[69] The constant head southern boundary of the model was set ~ 40 km from the southern Alpha lease boundary, ~5 km north of the drainage divide at the head of Lagoon (Tallarenha) Creek. Groundwater data to the south in the Galilee and South Galilee coal projects shows that there appears be a groundwater divide coinciding with the drainage divide (Heritage Computing 2013, Fig 3.9), i.e. there is a no-flow boundary at this location. The modelling should replace the southern constant head boundary with a no-flow boundary along the divide. This will probably cause the drawdown cone due to dewatering around the mine sites to extend further to the south than presently modeled.

[70] Constant head boundaries in groundwater modeling should be set a sufficient distance from the disturbance being modelled (in this case the Alpha and Kevin's Corner mines) so that they do not influence the model outcomes. In the URS modelling, the constant head boundary to the north of the mine sites was located within the Bandanna/Colinlea aquifer 40 km north of the northern edge of Kevin's Corner mine, in an attempt to place the boundary beyond any impact of the mining on the groundwater levels in the Bandanna/Colinlea aquifer. In other words, the modelling assumed that at this boundary the groundwater levels remained constant, because any

groundwater flow intercepted by the mine formed only a minor portion of the groundwater flow at this point, i.e. groundwater flow at the boundary is derived almost entirely from areas to the north of the mine site. However, the groundwater catchment area for the Bandanna/Colinlea aquifer to the south of this northern boundary (extending to the western, southern and eastern no-flow boundaries) is ~3860 km^2, and the modeled cone of depression around both mines (taken as the 0.5 m drawdown contour) intercepts groundwater flow from an area of ~2800 km^2, i.e. ~75% of the groundwater catchment. This magnitude of interception means that groundwater flow northwards from the mine site will decrease substantially as a result of the mining.

[71] Therefore, the northern constant head boundary will become a variable (falling) head boundary with time. To the north of the boundary there will be continuing northwards groundwater flow, whereas to the south there will be southwards flow into the cone of depression due to mine dewatering. This will inevitably cause the hydraulic head along the northern boundary to decrease. Replacing the constant head boundary with a falling head boundary will most likely make the decrease in the level of the potentiometric surface north of the mine much more extensive than is presently modelled.

[72] The impact of the proposed mines on the groundwater will therefore extend much further north than presently modelled, and could easily reach Albro Springs on Degulla property, which would most likely dry up, and could also potentially impact on surface drainages, particularly Degulla lagoon, which is only 22 km north of the northern boundary of the Kevin's Corner lease. The drawdown will certainly negatively impact on the groundwater levels in the properties north of the mines (Forrester and Degulla – see Figure 3); both these properties are dependent on groundwater for stock watering.

[73] The 0.5 m drawdown cone due to dewatering at both Kevin's Corner and Alpha mines is modeled to extend ~55 km north-south (Fig. 5-6, Stewart 17/10/2014). Modelling of the cumulative impact of the Kevin's Corner, Galilee and South Galilee mines by Heritage Computing (2013, Figs 5.14, 5.15) predicted a drawdown cone extending well over 100 km north-south. In particular, the dewatering associated with the Galilee and South Galilee mines will remove almost all groundwater flow into the Kevin's Corner and Alpha leases from the south. The steady state model for the Kevin's Corner and Alpha leases has groundwater inflow to the area of 175 ML/yr (Table 5-5, Stewart 17/10/2014). This is almost all derived from the south, and virtually all of it will disappear if the Galilee and South Galilee mines go ahead.

[74] The cone of depression due to dewatering by both the Alpha and Kevin's Corner mines will divert groundwater flow directions towards the pits and intercept almost all groundwater flow from the two proposed recharge areas along the Great Dividing Range (Figure 10b). From the most recent modelling, the preferred estimate of groundwater ingress to the proposed mine sites (both Alpha and Kevin's Corner) is 176 GL over 30 years, which is equivalent to 5900 ML/yr, i.e. far greater than the estimates of recharge and groundwater flow (< 800 ML/yr). Therefore the loss of groundwater attributable to the mine dewatering is very significant. The most recent EIS hydrogeological report acknowledges "that groundwater resources will be "mined" from the Galilee Basin sediments and will be permanently lost" and that "changes in groundwater levels and pressures as a result of mining will permanently alter groundwater flow patterns and levels"

(URS 2012, pp151 and 162). This groundwater will no longer flow into the system that contributes to groundwater flow beneath the Belyando River, and ultimately, the Burdekin River.

[75] It should be noted that all the hydrogeological EIS/SEIS/AEIS reports on both the Alpha and Kevin's Corner proposed mine sites state that because the Rewan Formation is an effective hydraulic barrier, it limits the westwards propagation of the cone of depression due to mine dewatering. However, although the presence of the Rewan Formation prevents upwards propagation of the dewatering effects into the units overlying this aquitard, it has no effect whatsoever on westwards propagation of the cone of depression within the Bandanna/Colinlea aquifer, as modelling of the cone of depression shows. As a result the cone of depression extends westwards to close to the groundwater divide along the crest of the Great Dividing Range.

[76] When mining of the Alpha and Kevin's Corner leases is complete, a final void will remain at the western edge of the open cut (Figures 10c, d). Modelling shows that this will cause a cone of depression drawing groundwater flow almost radially toward the void (due to negative climate balance), with the lake water in the final void becoming progressively more saline over time due to evaporation, and the surface of the lake equilibrating at about 250 m AHD, always below the potentiometric surface for the CD sandstone to the east, west and south (the modelling suggests that there will be groundwater outflow to the north). The void will permanently intercept ~70% of groundwater flow from the probable recharge areas defined in this study. The final mine void will therefore cause a permanent lowering of the potentiometric surface to the north of the mine, and any resulting deleterious effects on the springs, surface drainages, Degulla lagoon and local agricultural groundwater use will be permanent. This can be easily overcome by filling the final void, and thereby allowing the groundwater system to re-establish (approximately) the pre-mining configuration. The ground surface over part of the open-cut area would be probably several meters lower than before mining commenced, and would have to be graded so that it did not divert Lagoon Creek, but the impact on the groundwater system would be much less than leaving a final void.

[77] At the proposed Carmichael mine, the Co-ordinator General's report specified in the conditions for the project's EA (Appendix 1, Schedule H) that the voids should be partially filled and revegetated to above the usual groundwater level. This partial filling of mine voids at the end of mining operations means that groundwater levels are anticipated to be at around the base of the voids post closure. A similar condition should be applied to the Kevin's Corner mine.

6 Conclusions

[78] The main conclusions of this report can be summarised as follows:

- The groundwater modelling has significant shortcomings which need to be remedied by incorporating a decreasing rather than constant head northern boundary, a no flow rather than constant head southern boundary, and infiltration of recharge primarily in particular areas along the Great Dividing Range; and
- The geological framework underpinning the modelling needs to be revised to incorporate the broad, gentle folding across the area.

7 Confirmation

I confirm that:

(a) the factual matters stated in the report are, as far as I know, true; and
(b) I have made all enquiries considered appropriate; and
(c) the opinions stated in the report are genuinely held by myself; and
(d) the report contains reference to all matters I consider significant; and
(e) I understand the duty of an expert to the court and have complied with that duty; and
(f) I have read and understood the Land Court Rules 2000 as far as they apply to 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.

Assoc Prof John Webb

29 April 2015

Attachment A - Full Curriculum vitae

Personal Details

Name: John Allan WEBB
Business address: Environmental Geoscience, La Trobe University Victoria, 3086, Australia
Phone (03) 9479 1273 Fax (03) 9479 1272
Email john.webb@latrobe.edu.au
Date of birth: 1953
Nationality: Australian

Academic Qualifications

BSc Hons First Class (Queensland) 1973. Awarded University of Queensland medal
PhD (Queensland) 1982.

Professional Appointments

2005-present *Associate Professor*, Environmental Geocience, La Trobe University
1992-2004 *Senior Lecturer*, Department of Earth Sciences, La Trobe University
1986-1991 *Lecturer*, Department of Earth Sciences, La Trobe University
1981-1985 Tutor and *Senior Tutor*, Department of Geology, University of Melbourne

Professional Organisations

1994 to present - member, International Association of Hydrogeologists (committee member, Victorian division, 2007-2013)
1974 to present - member, Geological Society of Australia
1989 to present - member, Australia / New Zealand Geomorphology Research Group

Key Experience

I have extensive experience as a hydrogeologist and hydrogeochemist, both in terms of teaching the subject at a tertiary level and as a consultant. I have supervised 31 PhD students, 4 MSc students and 86 Honours students in a variety of geological, hydrogeological and hydrogeochemical projects. On average I have supervised 3.5 honours students each year since 2007, and I am currently supervising 8 PhD students (5 of them full-time).

I have participated in a number of consulting projects, and have been an invited member of 3 expert panels to assess groundwater and contaminated site management. Over the past 12 years I have acted as an expert witness in 8 court cases and tribunal hearings on hydrogeological and hydrogeochemical topics, including the Alpha Coal Mine Queensland Land Court appeal [MRA082/2013] decided in 2014.

Teaching

I have taught courses in hydrology, hydrogeology and water geochemistry at undergraduate and postraduate level since 1987, both at La Trobe University and RMIT, and teach into courses at

University of Melbourne. The courses use practical exercises based on real datasets and include excursions to sites of interest.

I also teach courses on landscape and climate change, and remote sensing and GIS, as well as organising seminars and projects for undergraduate environmental science students.

Research

Hydrogeology

Groundwater management, including its influence on dryland salinity is one of the major problems facing agriculture across southern Australia. I have led a group at La Trobe University researching the hydrogeology of this topic in western and central Victoria for over 6 years, involving 6 PhD students and 11 Honours projects. The projects have been financially supported by the National Centre for Groundwater Research and Training, Department of Environment and Primary Industries Victoria, Glenelg-Hopkins and Wimmera Catchment Management Authorities, Goulburn-Murray Water and several landcare groups, as well as Australian Institute for Nuclear Science and Energy. The results have been presented at numerous national and international conferences, published in Journal of Hydrology and Hydrogeology Journal, and have been actively used in management and location of good quality groundwater resources in the area.

My hydrogeological research profile was recognised when I was invited to be a member of program 4 (Groundwater-Vegetation Interactions) within the National Centre for Groundwater Research and Teaching; this project is also supported by the Victorian Department of Primary Industries, who contributed over $250,000 to the instrumentation of the field sites. This major project is on the effect of climate and land use change on surface and groundwater resources in western and central Victoria, and has received over $250,000 in additional funding from the Groundwater Centre.

Remediation of acid mine drainage

Acid mine drainage (AMD) is generated when sulphide minerals, usually exposed by mining, are exposed to the atmosphere and oxidise, releasing acidity and dissolved heavy metals. AMD must be neutralised before it can leave a site, and this process generates a sludge which has to be disposed of. My research on AMD has concentrated on neutralisation using limestone, particularly anoxic and open limestone drains (Silvana Santomartino's PhD project), increasing the chemical stability (resistance to leaching) of neutralisation sludges (Danny McDonald's and Wendy Stanford's PhD projects). Results of these projects have been presented at international conferences and published in Environmental Science and Technology and Applied Geochemistry. We are currently researching improvements to AMD neutralisation techniques; 1 honours student and 3 PhD students are currently working on this topic.

Supervision of Postgraduate Students

1. David Cantrill, 1989 (Dept of Botany, University of Melbourne) – An Albian coniferous flora from the Otway Basin, Victoria

2. Mark Ellaway, 1990 (Dept of Geography, University of Melbourne) – Karst hydrochemistry at Buchan, eastern Victoria
3. Tom Bernecker, 1993. A sedimentation model for the Siluro-Devonian Chillagoe Formation in the Mungana area, North Queensland
4. Jon Kelly, 1999. Diagenesis and origin of glauconite in Victorian Tertiary sediments
5. Michael Martin, 2000. Heavy mineral analysis of Cretaceous sediments, northwest W.A.
6. Alan Partridge, 2000. Cretaceous and Tertiary palynology and geological history of the Gippsland Basin
7. Stan Lithco, 2003. The karst water chemistry of the cenotes and springs of the Lower Southeast of S.A.
8. Christian Ihlenfeld, 2004. Isotopic and trace element study of seasonal changes in travertine deposition, north Qld.
9. Barton Smith, 2004. Landscape evolution and geomorphology of arid zone lunettes and gypsum dunes in NW Victoria and western NSW.
10. Sue White, 2005. Karst and landscape evolution in parts of the Gambier Karst Province, southeast S.A. and western Victoria.
11. Silvana Santomartino, 2005. Use of anoxic mine drains to remediate acid mine drainage.
12. Darren Bennetts, 2006. Dryland salinity of the basalt landscape around Hamilton, western Victoria.
13. Danny McDonald, 2006. Stability of treatment sludges using synthetic acid rock drainage.
14. Gresley Wakelin-King, 2007. Landscape evolution and geomorphology of an arid zone stream near Broken Hill.
15. Matthew Edwards, 2007. Dryland salinity of Mt William Creek, upper Wimmera catchment.
16. Matthias Raiber, 2009. Dryland salinity of the basalt landscape east of Hamilton, western Victoria.
17. Yohannes Yihdego, 2012. Effect of climate and landuse change on watertables and lake levels in western Victoria.
18. Sarah Hagerty, 2013. Groundwater resources and salinity associated with granites in the Upper Wimmera catchment.
19. Alex Fink, 2014. Mineralogy and origin of Lightning Ridge black opal.
20. Fahmida Perveen, submitted. Affect of timber plantations on surface and groundwater resources and quality in western Victoria.
21. Fiona Glover, submitted. Inland acid sulphate soils in the Corangamite region, western Victoria. (80%)
22. Josh Dean, submitted. Effect of land use change on surface and groundwater resources and quality in western Victoria
23. Matej Lipar, submitted. Origin of solution pipes in Quaternary aeolianites of southern Australia.
24. Sanjeeva Manamperi, current. Effect of climate change on episodic groundwater recharge across the north Victorian plains.
25. Bruce Gill, current. Application of 3D geological modelling to groundwater management
26. Tim Robson, current. Groundwater – surface water interactions at Lake Tutchewop, northern Victoria.
27. Farah Ali, current. Secondary mineral precipitation from acid mine drainage
28. Wendy Stanford, current. Remediation of acid mine drainage using the magnetic sludge process

29. Rakhshan Roohi, current. Use of remote sensing to estimate evapotranspiration
30. Michael Sephton, current. Use of alkalinity-producing covers to prevent the release of acid mine drainage from waste rock and tailings
31. Shannon Burnett, current. Deposition of sand sheets across southeastern Victoria during the Last Glacial Maximum.

Publications since 2000

Refereed journal papers

1. White, S. and Webb, J., 2014. The influence of tectonics on flank margin cave formation on a passive continental margin: Naracoorte, southeastern Australia. *Geomorphology*.
2. Dean, J.F., Webb, J.A., Jacobsen, G., Chisari, R., and Dresel, P.E., 2014. Biomass uptake and fire as controls on groundwater solute evolution on a Southeast Australian granite: aboriginal land management hypothesis. *Biogeosciences*, 11, 4099–4114.
3. Lipar, M, and. Webb, J.A., in press. Middle – Late Pleistocene and Holocene chronostratigraphy and climate history of the Tamala Limestone, Cooloongup and Safety Bay Sands, Nambung National Park, southwestern Western Australia. *Australian Journal of Earth Sciences*
4. Camporese, M., Daly, E., Dresel, P.E., Webb, J.A., 2014. Simplified modeling of catchment-scale evapotranspiration via boundary condition switching. *Advances in Water Resources*, 69, 95-105.
5. Gill, B.C., Webb, J.A., Wilkinson, R. and Cherry, D., 2014. Irrigator response to groundwater resource management plans in Victoria, Australia. *Journal of Hydrology* 518, 83–93.
6. Adelana, M., Dresel, E., Hekmeijer, P., Zydor, H., Webb, J.A, Reynolds, M. and Ryan, M., 2014. A comparison of streamflow, salt and water balances in adjacent farmland and forest catchments in south-western Victoria, Australia. *Hydrological Processes*
7. Burnett, S., Webb, J.A. and White, S., 2013. Shallow caves and blowholes on the Nullarbor Plain, Australia - flank margin caves on a low gradient limestone platform. *Geomorphology,* 201, 246-253.
8. Yihdego, Y., Webb, J.A., 2013. An empirical water budget model as a tool to identify the impact of land-use change on stream flow in southeastern Australia. *Water Resources Management*, 27, 4941-4958.
9. Webb, J., Finlayson, B.L. Cochrane, G., Doelman, T. and Domanski, M., 2013. Silcrete quarries and artefact manufacture in the Central Queensland Highlands, Eastern Australia. *Archaeology in Oceania*, 48, 130-140.
10. Kappen, P. and Webb, J.A., 2013. An EXAFS study of arsenic bonding on amorphous aluminium hydroxide. *Applied Geochemistry* 31, 79–83.
11. Doerr, S.H., Davies, R.R., Lewis, A., Pilkington, G., Webb, J.A., Ackroyd, P.J., Bodger, O., 2012. Origin and karst geomorphological significance of the enigmatic Australian Nullarbor Plain ‘blowholes’. *Earth Surface Processes and Landforms*, 37, 253-261.
12. Dresel, P.E., Hekmeijer, P., Dean. J.F., Harvey, W., Webb, J.A. and Cook, P., 2012. Use of laser-scan technology to analyse topography and flow in a weir pool. *Hydrology and Earth System Sciences*, 16, 2703-2708.

13. Yihdego, Y. and Webb, J. A., 2012. Modelling of seasonal and long-term trends in lake salinity in south-western Victoria, Australia. *Journal of Environmental Management*, 112, 149-159.
14. Cochrane, G.W.G., Habgood, P.J., Doelman, T., Herries, A.I.R. and Webb, J., 2012. A progress report on research into the stone artefacts of the southern Arcadia Valley, central Queensland. *Australian Archaeology*, 75, 98-103.
15. Robson T.C. and Webb J. A., 2011. Late Neogene tectonics in northwestern Victoria: evidence from the Late Miocene-Pliocene Loxton Sand. *Australian Journal of Earth Sciences* 58, 579–586.
16. Shaqour, F., White, S. and Webb, J.A., 2011. Geotechnical characterization of geomaterial blends with zeolitic tuffs for use as landfill liners. *Bulletin of Engineering Geology and the Environment*, 70, 691-697.
17. Glover, F., Whitworth, K.., Kappen, P., Baldwin, D., Rees, G., Webb, J., Silvester, E., 2011. Acidification and buffering mechanisms in acid sulfate soil (ASS) wetlands of the Murray-Darling Basin, Australia. *Environmental Science and Technology*, 45, 2591–2597.
18. Yihdego, Y. and Webb, J. A., 2011. Modelling of bore hydrographs to determine the impact of climate and land use change in a temperate subhumid region of southeastern Australia. *Hydrogeology Journal*, 19, 877-887.
19. Webb, J.A., Gardner, T.W., Kapostasy, D., Bremar, K.A. and Fabel, D., 2011. Mountain building along a passive margin: Late Neogene tectonism in southeastern Victoria, Australia. *Geomorphology* 125, 253-262.
20. Liu, L., Field, J., Weisskopf, A., Webb, J., Jiang, L., Wang, H. and Chen, X., 2010. The exploitation of acorn and rice in Early Holocene Lower Yangzi river, China. *Acta Anthropologica Sinica*, 29, 12-32.
21. Kakuwa Y. and Webb, J., 2010. Evolution of Cambrian to Ordovician trace fossils in pelagic deep-sea chert, southeastern Australia. *Australian Journal of Earth Sciences*, 57, 615-625.
22. Holmes, W.B.K., Anderson, H. and Webb, J.A., 2010. The Middle Triassic megafossil flora of the Basin Creek Formation, Nymboida Coal Measures, New South Wales, Australia. Part 8. The genera *Nilssonia*, *Taeniopteris*, *Linguifolium*, *Gontriglossa* and *Scoresbya*. *Proceedings of the Linnean Society of New South Wales*, 131, 1-26.
23. Webb, J.A., Grimes, K.G. and Lewis, I., 2010. Volcanogenic origin of cenotes near Mt Gambier, Southeastern Australia. *Geomorphology* 119, 23–35.
24. Domanski, M., Webb, J.A., Glaisher, R., Gurba, J., Libera, J. and Zakoncielna, A., 2009. Heat treatment of Polish flints. *Journal of Archaeological Science*.
25. Edwards, M.D. and Webb, J.A., 2009. The importance of unsaturated zone biogeochemical processes in determining groundwater composition, southeastern Australia. H*ydrogeology Journal*,
26. Raiber, M., Webb, J.A. and Bennetts, D., 2009. Strontium isotopes as tracers to delineate aquifer interactions and groundwater salinisation in the basalt plains of southeastern Australia. *Journal of Hydrology*, 367, 188-199.
27. Gardner, T., Webb, J.A., Pezzia, C., Amborn, T., Tunnell, R., Flanagan, S., Kapostasy, D., Merritts, D., Marshall, J., Fabel, D and Cupper, D., 2009. Episodic intraplate deformation of stable continental margins: evidence from Late Neogene and Quaternary marine terraces, Cape Liptrap, southeastern Australia. *Quaternary Science Reviews*, 28, 39-53.

28. Parker, K.E. and Webb, J.A., 2008. Estuarine deposition of a mid Viséan tetrapod-bearing unit, Ducabrook Formation, central Queensland. *Australian Journal of Earth Sciences*, 55, 509-530.
29. Webb, J.A. and Domanski, M., 2008. The relationship between lithology, flaking properties and artefact manufacture for Australian silcretes. *Archaeometry*, 50, 555-575.
30. Raiber, M. and Webb, J.A., 2008. Development of the Streatham Deep Lead System in Western Victoria: Implications for Tertiary tectonism and landscape evolution. Australian *Journal of Earth Sciences*, 55, 493-508.
31. Webb, J.A. and Spence E., 2008. Glaciomarine Early Permian strata at Bacchus Marsh, Central Victoria – the final phase of Late Palaeozoic glaciation in Southern Australia. *Proceedings of the Royal Society of Victoria*, 120, 373-388.
32. Wakelin-King, G.A. and Webb, J.A., 2007. High-energy mud floodplains, low-energy sand channels: sediment transport and deposition in a drylands mud-aggregate river. *Journal of Sedimentary Research*, 77, 702-712.
33. Domanski, M. and Webb, J.A., 2007. A review of heat treatment research. *Lithic Technology*, 32, 153-194.
34. Santomartino, S.L. and Webb, J.A., 2007. Estimating the longevity of limestone drains in treating acid mine drainage containing high concentrations of iron. *Applied Geochemistry*, 22, 2344-2361
35. Birch, W.D., Mills, S.J., Schwendtner, K., Pring, A., Webb, J.A., Segnit, E.R., Watts, J.A., 2007. Parwanite: a new hydrated Na–Mg–Al-phosphate from a lava cave at Parwan, Victoria, Australia. *Australian Journal of Mineralogy*, 13, 23-30.
36. Webb, J.A., Ford, A. and Gorton, J., 2007. Influences on selection of lithic raw material sources at Huizui, a Neolithic/Early Bronze Age site in northern China. *Bulletin of the Indo-Pacific Prehistory Association*, 27, 76-86 http://ejournal.anu.edu.au/index.php/bippa/article/viewFile/36/31
37. Kakuwa, Y. and Webb, J., 2007. Trace fossils of a Middle-Late Ordovician pelagic deep ocean bedded chert in southeastern Australia. In Ichnology at the Crossroads: A Multidimensional Approach to the Science of Organism-Substrate Interactions, edited by Bromley, R.G., Buatois, L.A., Mangano, M.G., Genise, J.F. and Melchor, R.N. *SEPM Special Publication* 88, 267-276.
38. Bennetts, D.A., Webb, J.A., McCaskill, M. and Zollinger, R., 2007. Dryland salinity processes within the discharge zone of a local groundwater system, *Southeastern Australia. Hydrogeology Journal*. (30%), 15, 1197-1210.
39. Wakelin-King, G.A. and Webb, J.A., 2007. Threshold-dominated fluvial styles in an arid-zone mud-aggregate river: the uplands of Fowlers Creek, Australia. *Geomorphology* 85, 114-127.
40. Tweed, S.O., Leblanc, M., Webb, J.A. and Lubczynski, M.W., 2006. Remote sensing and GIS for mapping groundwater recharge and discharge areas in salinity prone catchments, southeast Australia. *Hydrogeology Journal* 15, 75-96.
41. Webb, J.A. and Mitchell, M.M., 2006. Stratigraphy and palaeoflora of the Triassic Council Trench Formation, Central Victoria. *Proceedings of the Royal Society of Victoria*, 118, 113-127.
42. McDonald, D. M., Webb, J. A. and Taylor, J. 2006. Chemical stability of acid rock drainage treatment sludge and implications for sludge management. *Environmental Science and Technology*, 40(6), 1984-1990.

43. Webb, J.A. and James, J.M., 2006. Karst evolution of the Nullarbor Plain, Australia. In Harmon, R.S. and Wicks, C.M. (eds), Karst geomorphology, hydrology and geochemistry - a tribute volume to Derek C. Ford and William B. White. *Geological Society of America Special Paper* 404, 65-78.
44. Gardner, T.W., Webb, J.A., Davis, A.G., Cassell, E.J., Pezzia, C., Merritts, D.J. and Smith, B., 2006. Late Pleistocene landscape response to climate change: eolian and alluvial fan deposition, southeastern Victoria, Australia. *Quaternary Science Reviews*, 25, 1552-1569.
45. Bennetts, D.A., Webb, J.A., Stone, D.J.M. and Hill, D.M., 2006. Understanding the salinisation process for groundwater in an area of south-eastern Australia, using hydrochemical and isotopic evidence. *Journal of Hydrology*, 323, 178-192
46. Vos, I.M.A., Bierlein, F.P. and Webb, J.A., 2005. Geochemistry of Early-Middle Palaeozoic basalts in the Hodgkinson Province: a key to tectono-magmatic evolution of the Tasman Fold Belt System in northeastern Queensland, Australia. *International Journal of Earth Sciences*, 95, 569-585.
47. Paine, M., Bennetts, D.A., Webb, J.A., and Morand, V., 2004. Nature and extent of Pliocene strandlines in southwestern Victoria and their application to late Neogene tectonics. *Australian Journal of Earth Sciences*, 51, 407-422.
48. Nash, D. J., McLaren, S. J. and Webb, J. A., 2004. Petrology, geochemistry and environmental significance of silcrete-calcrete intergrade duricrusts in the central Kalahari, Botswana. *Earth Surface Processes and Landforms*, 29, 1559-1586.
49. Santomartino, S.L. and Webb, J.A., in review. Comparison of methods for acid sulphate soil and sediment analysis. *Australian Journal of Soil Research*.
50. Ihlenfeld, C., Norman, M.D., Gagan, M.K., Drysdale, R.N., Maas, R. and Webb, J.A., 2003. Climatic significance of seasonal trace element and stable isotope variations in a modern freshwater tufa. *Geochimica Cosmochimica Acta*, 67, 2341-2357.
51. Musgrave. R.J. and Webb, J.A., 2003. Palaeomagnetic analysis of sediments in the Buchan Caves, southeastern Australia, provides a pre-Late Pleistocene date for landscape evolution. In Sasowsky, I.D. and Mylroie, J.E. (eds), *Studies of Cave sediments*, 47-70. Kluwer.
52. Gouramanis, C., Webb, J. A. and Warren, A. A., 2003. Fluvio-deltaic sedimentology and ichnology of part of the Silurian Grampians Group, western Victoria. *Australian Journal of Earth Sciences*, 50, 811-825.
53. Kelly, J.C., Webb, J.A. and Maas, R., 2001. Isotopic constraints on the genesis and age of autochthonous glaucony in the Oligo-Miocene Torquay Group, southeastern Australia. *Sedimentology*, 48, 325-328.
54. Doelman, T., Webb, J.A. and Domanski, M., 2001. Source to Discard: Patterns of Lithic Raw Material Procurement and Use in Sturt National Park, Northwestern NSW. *Archaeology in Oceania*, 36, 15-33.
55. Webb, J.A., 2001. A new marattialean fern from the Middle Triassic of eastern Australia. *Proceedings of the Linnean Society of New South Wales*, 123, 215-224.
56. Torrence, R., Pavlides, C., Jackson, P. and Webb, J., 2000. Volcanic disasters and cultural discontinuities in Holocene time, in West New Britain, Papua New Guinea. In McGuire, W.J., Griffiths, D.R., Hancock, P.L. and Stewart, I.S. (eds). The archaeology of geological catastrophes. *Geological Society, London, Special Publications*, 171, 225-244.
57. Marshallsea, S.J., Green, P.F. and Webb, J.A., 2000. Thermal history of the Hodgkinson Province and Laura Basin, Queensland: multiple cooling episodes identified from apatite

fission track analysis and vitrinite reflectance data. *Australian Journal of Earth Sciences*, 47, 779-797.

58. Domanski, M. and Webb, J.A., 2000. Flaking properties, petrology and use of Polish flint. *Antiquity*, 74, 822-832.

Refereed papers in conference proceedings

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2. Glover, F., Webb, J.A. and Silvester, E., 2011. Factors influencing inland acid sulphate soil formation in southeastern Australia. *7th Australian Workshop on Acid and Metalliferous Drainage, 21-24 June 2011, Darwin, Proceedings*, 364-374.
3. Yihdego, Y. and Webb, J. A., 2010. Characterising groundwater dynamics using Transfer Function-Noise and autoregressive modelling in western Victoria, Australia. *Proceedings of the 5th International Conference on Water Resources, Hydraulics and Hydrology, University of Cambridge, UK, February 23-25, 2010*, 97-101.
4. Arne, D., Nelson, A. and Webb, J., 2009. Sources of Arsenic Contamination and Remediation of Mine Water at the Historical Glen Wills Mining Area in Northeast Victoria, Australia. *Proceedings 24th International Applied Geochemistry Symposium, 1-4 June, 2009, Fredericton, Canada.*
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6. Yihdego, Y. and Webb, J. A., 2008. Modelling of Seasonal and Longterm Trends in Lake Salinity in Southwestern Victoria, Australia. *Proceedings of Water Down Under April 2008*, 994-1000.
7. Hagerty, S. and Webb, J.A., 2008. Aquifer Interactions and Groundwater Discharge into Streams Identified Using 87Sr/86Sr Isotope Ratios in the Upper Loddon Catchment, Central Victoria. *Proceedings of Water Down Under April 2008*, 1272-1278.
8. Raiber, M., Webb, J.A., Jacobsen, G.E., Chisari R. and Williams, A.A., 2008. Geological controls on the spatial variability of groundwater recharge and salinity in a regional-scale basalt aquifer in western Victoria. *Proceedings of Water Down Under April 2008*, 1279-1283.0406
9. Webb, J.A., Williams, B.G., Bailue, K., Walker, J. and Anderson, J.W., 2008. Short-term groundwater dynamics at a paddock scale. *Proceedings of Water Down Under April 2008*, 1493-1500.
10. Liu, L., Chen, X. and Webb, J., 2008. Production of stone spades and emergence of the first state in the Yiluo Region, China *Proceedings Stone Tools Conference, York, September 2007*
11. Raiber, M., Webb, J.A., Jacobsen, G., Chisari, R. and Neklapilova, B., 2007. Aquifer interactions and their impact on groundwater resources in the basalt plains of Western Victoria. *Twelfth International Symposium on Water-Rock Interaction, Kunming, China, August 2007; Conference Proceedings*, 985-988.

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14. Bennetts, D.A. and Webb, J.A., 2004. Processes affecting groundwater quality in a basalt aquifer system in southern Australia. In: R.B. Wanty and R.R. Seal (Editors), *Proceedings International Symposium on Water-Rock Interaction 11, Saratoga Springs, USA*, 347-351. Balkema, Rotterdam.
15. Santomartino S. and Webb, J. 2003. An experimental study of the chemistry of iron precipitation within Anoxic Limestone Drains. *6th ICARD Conference, July 2003, Cairns*, 1117-1121.
16. Webb, J.A. and Lithco, S., 2001. Use of water chemistry to identify flow conduits in the porous Gambier Limestone, southeast Australia. *In* Mudry, J. and Zwahlen, F. (eds), *Proceedings of 7th Conference on Limestone Hydrology, Besancon, September 2001*, 333-336.

Book chapters

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Consulting projects and reports since 2005

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2. Webb, J.A., 2013. Expert witness report on groundwater impact of proposed landfill at Arthurs Seat, Mornington Peninsula, for residents' group.
3. Webb, J.A., 2013. Expert witness report and testimony in the Land Court on modelling of groundwater impact from the proposed Alpha Coal Mine, central Qld, for Environmental Defenders Office, Qld.
4. Webb, J.A., 2013. Review of Kerang Lakes diversion proposal. Report for Goulburn Murray Water.
5. Webb, J.A., 2012. Comments on potential groundwater impacts of Moonee Valley Racecourse redevelopment, for residents' group.
6. Webb, J.A., 2012. Review of draft report on structural control of Cenozoic aquifers in Victoria. Report for GHD Pty Ltd.
7. Webb, J.A., 2012. Review of geomorphological development and sediment age at Werribee rail crossing site. Report for Andrew Long & Assoc.

8. Webb, J.A., 2011. Extent of Pleistocene sand sheet around Dowds Lane Quarry, Gippsland. Report for Keith Heywood.
9. Webb, J.A., 2011. Hydrogeological assessment of Renmark Group aquifer, central western Campaspe catchment, prepared for Morrison and Sawers Lawyers. Expert witness statement and testimony at VCAT.
10. Webb, J.A., 2011. Wonthaggi geomorphology report. Report for Ochre Imprints.
11. Webb, J.A., 2011. Assessment of acid sulphate soils risk at Cataby Mine, Western Australia. Report for Iluka Pty Ltd.
12. Webb, J.A. and Glover, F., 2011. XRD analysis of tailings samples; prepared for Lane Piper Pty Ltd.
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15. Webb, J.A., 2009-2011 – invited member, review panel of Lake Tutchewop Sustainability Project (consultant for Goulburn Murray Water).
16. Webb, J.A., 2009. Expert witness statement and testimony at VCAT; Application for groundwater extraction licence by Alanvale Pty Ltd.
17. Webb, J.A., 2009. Literature survey of Cr VI in cement for rehabilitation of Fyansford Cement Works; prepared for Lane Piper Pty Ltd.
18. Webb, J.A. and Glover, F., 2009. Salinity risk assessment for Pyrenees Shire. Maps and report prepared for Pyrenees Shire Council.
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20. Webb, J.A., 2008. Consultant for Earth Systems, providing independent review of new subsurface barrier technology.
21. Webb, J.A., 2008. Consultant for SKM groundwater mapping project across southern Victoria.
22. Webb, J.A., 2008. Invited member, panel for development of Index of Groundwater Condition in Victoria (consultant for Hyder Consulting).
23. Webb, J.A., 2008-2009. Invited member, review panel of Lake Tutchewop Sustainability Project (consultant for Goulburn Murray Water).
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29. Webb, J.A., 2006. Preliminary hydrogeological assessment of Warrnambool Cheese and Butter Factory. Report prepared for Rock Solid Pty Ltd, 2 pp.
30. Webb, J.A., 2005. Geological opinion for King Valley Vignerons, 5 pp. Followed by expert witness testimony at VCAT.

31. Webb, J.A., 2005. Application for an abattoir and saleyards near Learmonth – hydrological and hydrogeological assessment. 3 pp. Followed by expert witness testimony at VCAT.

Attachment B – Letter of instructions

EDO Qld.
Environmental Defenders Office
Using the law to protect our environment.
30 Hardgrave Rd WEST END, QLD 4101
tel +61 7 3211 4466 *fax* +61 7 3211 4655
edoqld@edo.org.au www.edo.org.au/edoqld

9 January 2014

Assoc Prof John Webb
Environmental Geoscience
Department of Agricultural Sciences
La Trobe University
Victoria 3086

Sent by email: John.Webb@latrobe.edu.au

Dear Dr Webb

Coast and Country Association of Queensland Inc. & Ors ats Hancock Galilee Pty Ltd, Land Court of Queensland Proceeding MRA713-13 & EPA714-13

Objection to Mining lease and Environmental Authority for Kevin's Corner Coal Mine

We refer to your telephone conversation with Michael Berkman on 17 December 2013. We confirm that we act for Coast and Country Association of Queensland Inc. (**CCAQ**) as an objector in the Queensland Land Court proceedings MRA713-13 & EPA714-13 (**Proceedings**).

1. **Engagement**

1.1 On behalf of CCAQ, we wish to engage you to act as an independent expert witness in relation to the groundwater issues in the Proceedings.

1.2 As yet our client has no budget for expert fees so, as discussed, any preliminary work by yourself will be on pro-bono or speculative basis.

1.3 Please provide us your preliminary oral opinion and a fee estimate for the remainder of the work as soon as possible.

2. **Instructions**

2.1 You are instructed to review this letter and accompanying documents.

2.2 Your attention is drawn to the advice of the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development to the Department of Sustainability, Environment, Water, Population and Communities (**IESC Advice**), which is enclosed as **Annexure C**.

2.3 You are further instructed to prepare a report setting out your opinion as to:

(1) whether there is sufficient information to form an adequate scientific basis for approval of the mine having regard in particular to potential groundwater impacts and the reasons for your view;

(2) whether, having reviewed all of the EIS documents, you agree with the conclusion of Coordinator-General's assessment in relation to groundwater and the reasons for your view;

(3) whether, having regard to all of the available material, there are issues that should be examined in more detail or additional lines of inquiry in relation to groundwater that should be explored before approval is granted and the reasons for your view.

3. **Background information**

3.1 The Kevin's Corner Project (**the Project**) is a proposed open-cut and underground coal mine north west of the township of Alpha, approximately 340km south west of Mackay in the Galilee Basin, Queensland. The mining lease application is for 40 years with an annual extraction rate of around 45 million tonnes per annum Run of Mine (**ROM**) coal.

3.2 The Project is situated in the Galilee Basin in the catchment of the Burdekin River which flows into wetlands and the Great Barrier Reef, and the area of the Project and its surroundings is predominantly used for agriculture, particularly grazing.

3.3 The thermal coal deposits for the Project are estimated to be 4.269 billion tonnes, within Mining Lease Application 70425 (**MLA**), which comprises approximately 37,380 hectares.

3.4 Hancock Galilee Pty Ltd (**Applicant**) applied for an environmental authority (mining lease) (**EA**) under the *Environmental Protection Act 1994* (Qld) (**EP Act**) and a mining lease (**ML**) under the *Mineral Resources Act 1989* (Qld) (**MR Act**) for the Project on or about 18 December 2009.

3.5 The Coordinator-General declared the Project a significant project for which an environmental impact state (**EIS**) was required under the *State Development and Public Works Organisation Act 1971* (Qld) (**SDPWO Act**) on 11 September 2009.

3.6 The Applicant undertook public consultation on an EIS in October 2011, a supplementary EIS (**SEIS**) in November 2012, an addendum to the supplementary EIS in November 2011 and provided additional supplementary documentation to the Coordinator-General's report in early 2013, for approval under the SDPWO Act (together, the **EIS documents**).

3.7 The Coordinator-General's report on the Project under the SDPWO Act was delivered on 30 May 2013. The Coordinator-General recommended that the mine be approved subject to conditions.

3.8 We submitted on behalf of CCAQ an objection to the applications for a mining lease and an environmental authority on 6 December 2013.

4. **Enclosed Material**

4.1 We enclose the following documents, which are of general relevance to the Project:

(1) Initial Advice Statement to the Coordinator General (Application) (07/2009)

(2) Final Terms of Reference for EIS (09/02/2010)

(3) EIS Volume 1 (31/10/2011)

- Section 00 Executive Summary
- Section 01 Introduction
- Section 02 Description of the Project

(4) EIS Volume 2 (31/10/2011)

- Appendix W Environmental Management Plan

(5) Coordinator General's Assessment Report (30/05/2013).

4.2 Additionally, we enclose the following documents, which are relevant to surface water and groundwater:

(1) EIS Volume 1 (31/10/2011)

- Section 4 Geology
- Section 10 Aquatic Ecology and Stygofauna
- Section 11 Surface Water
- Section 12 Groundwater
- Section 16 Waste
- Section 24 Hazard and Risk
- Section 26 Decommissioning and Rehabilitation

(2) EIS Volume 2

- Appendix J Subsidence Report
- Appendix K Land Contamination (22/02/2011)
- Appendix L2 Aquatic Ecology Assessment (09/2011)
- Appendix L3 Stygofauna Assessment (09/2011)
- Appendix M1 Fluvial Geomorphology Report (15/04/2011)
- Appendix M2 Hydrology and Hydraulic Technical Reports (19/04/2011)
- Appendix M3 Site Water Management System and Water Balance Technical Report (15/04/2011)
- Appendix M4 Surface Water Quality Technical Report (Note that we do not yet have a copy of this document as it is not presently available online, but we are seeking disclosure of this document from Hancock and will include a copy in your brief as soon as possible)

- Appendix N1 Groundwater Technical Report (22/09/2011)
- Appendix N2 Groundwater Bore Survey Report (07/2011)
- Appendix Q1 Geochemical Characterisation (07/09/2011)
- Appendix X Cumulative Impacts (31/10/2011)

(3) Supplementary EIS Volume 2

- Appendix E Geochemical Assessment Coal and Mining Waste Materials (23/05/2012)
- Appendix F Aquatic Ecology Assessment (05/2012)
- Appendix K Revised Surface Water Hydraulics Report (12/06/2012)
- Appendix L Groundwater Report (18/05/2012)
- Appendix M Site Water Management (Basis of Design) Report (03/10/2012)
- Appendix N Interim Subsidence Management Plan (03/10/2012)
- Appendix O Interim Cumulative Impacts Assessment (03/11/2012)
- Appendix S Cumulative Surface Water Impacts Assessment (03/11/2012)

4.3 These documents are indexed and included in an electronic expert brief in Dropbox, however we can provide hard copies if necessary.

4.4 We have included all EIS Documents relevant to surface water and groundwater, as we are uncertain of the extent to which surface water may be relevant to groundwater issues. We do not assume that all documents included in the index will be relevant to your report, but have included them for the sake of completeness, and we would appreciate it if you could consider the documentation enclosed with a view to identifying any additional documentation or other expert opinions you may require.

5. **Timing**

5.1 At this stage the Land Court has deferred the making of an Order setting out complete directions through to trial, and under the current Court Order the process will not be determined until early March 2014.

5.2 Under the current Order we expect to receive a request for particulars by 20 January 2014, to which we will be required to respond by 21 February 2014.

5.3 At this stage, can you please review the enclosed materials and provide us your preliminary oral opinion by **Friday 7 February 2014** to assist us in the preparation of CCAQ's response to any request for particulars.

6. **Your duty to the Land Court**

6.1 We enclose as **Annexure A** rule 23 of the *Land Court Rules 2000* and rules 426, 428 and 429B of the *Uniform Civil Procedure Rules 1999* which govern experts in the Land Court.

6.2 In particular we note that rule 426 of the *Uniform Civil Procedure Rules 1999* provides that you have a duty to assist the Land Court which overrides any obligations you may have to CCAQ as your client.

6.3 We also emphasise that we and our client don't seek to influence your views in any way and we ask for your independent opinion to assist the Land Court. Consequently, please note that any statements of fact or opinion in this letter of instructions, the above documents, or anything given or said to you by us relevant to the issues in your report do not constrain you in any way and are not intended to influence your views. We ask you to form your own opinion about the relevant facts and circumstances for the purposes of your report.

6.4 We recommend that any joint report or separate expert report you prepare should contain:

(1) an acknowledgement of having been instructed on an expert's duty in accordance with rule 426 of the *Uniform Civil Procedure Rules 1999* and having understood and discharged that duty; and

(2) a statement verifying that no instructions were given or accepted to adopt, or reject, any particular opinion in preparing the report.

7. **Format of your report**

7.1 Suggestions for the format of your report are set out in **Annexure B**, "Format of your report".

7.2 Your report must include:

(1) your qualifications;

(2) all material facts, whether written or oral, on which your report is based;

(3) references to any literature or other material you relied on to prepare the report;

(4) for any inspection, examination or experiment you conducted, initiated, or relied on to prepare your report—

i. a description of what was done; and

ii. whether the inspection, examination or experiment was done by the expert or under the expert's supervision; and

iii. the name and qualifications of any other person involved; and

iv. the result;

(5) if there is a range of opinion on matters dealt with in your report, a summary of the range of opinion, and the reasons why you adopted a particular opinion;

(6) a summary of the conclusions you reached; and

(7) a statement about whether access to any readily ascertainable additional facts would assist you in reaching a more reliable conclusion.

7.3 You should attach to the report:

(1) a copy of your Curriculum Vitae; and

(2) a copy of this letter.

7.4 Please number all pages and paragraphs of your report. You may wish to include an index.

7.5 If your report includes any photographs, measurements, graphs or illustrations these should be firmly attached to the report, and clearly identified and numbered.

7.6 You are required to include a summary of your opinion.

7.7 Your report should contain:

(1) an acknowledgement of having been instructed on an expert's duty in accordance with rule 426 of the *Uniform Civil Procedure Rules 1999* and having understood and discharged that duty; and

(2) a statement verifying that no instructions were given or accepted to adopt, or reject, any particular opinion in preparing the report.

8. **Change of opinion**

8.1 If for some reason, you change your opinion after delivering your report, please advise us as soon as possible. If that change is material, a supplementary report will need to be prepared, which explains the reasons for the change in your opinion.

9. **Confidentiality and privilege**

9.1 In accepting this engagement, you agree that:

(1) this letter and all future communications (whether electronically maintained or not) between us are confidential. These communications may be subject to client legal privilege;

(2) you must take **all** steps necessary to preserve the confidentiality of our communications and of any material or documents created or obtained by you in the course of preparing your report;

(3) you must not disclose the information contained in our communications or obtained or prepared by you in the course of preparing your report without obtaining consent from us;

(4) you must not provide any other person with documents which come into your possession during the course of preparing this report, whether created by you or provided to you by us or our clients, without obtaining consent from us.

9.2 The duty of confidentiality continues beyond the conclusion of your instructions.

9.3 If you are ever obliged by law to produce documents containing any of this confidential information (whether by subpoena, notice of non-party discovery or otherwise) please contact us immediately so that we may take steps to claim client legal privilege.

9.4 You should ensure that you retain copies of all drafts of your report together with all documents that you rely on in preparing your report. We will inform you when you are no longer required to retain them.

9.5 If requested, you must return to us all documents and other material (including copies) containing confidential information. Where any confidential information is in electronic form, we may require you to delete this information instead.

9.6 Any internal working documents and draft reports prepared by you may not be privileged from disclosure and may be required to be produced to the opposing parties in the litigation, and to the Court.

9.7 You may be cross-examined about any changes between your working documents and your report. The Court will be interested to understand the reason or reasons for any changes, and you should be prepared to, and able to, explain them.

10. **Document management**

10.1 Please ensure that all documents created pursuant to this retainer are marked "Privileged and Confidential: prepared for the purpose of the Queensland Land Court objection hearing to the Kevin's Corner Mine".

11. **Court appearance**

11.1 At the hearing of this objection, you may be required to attend Court and give evidence. You must be personally involved and knowledgeable in all aspects of the preparation of the report.

11.2 If you are required to attend Court to give evidence, we will contact you to discuss your availability and make the necessary arrangements.

If you have any questions regarding your engagement or require further information, please do not hesitate to call us on 3211 4466.

Yours faithfully

Environmental Defenders Office (Qld) Inc

Michael Berkman

Solicitor

To provide feedback on EDO services, write to us at the above address.

ANNEXURE A

***Land Court Rules 2000* (Qld)**

23 Expert evidence

(1) A party who intends to call a person to give evidence as an expert witness must file and serve on each other party a statement—

(a) giving the name and address of the witness; and

(b) describing the witness' qualifications to give evidence as an expert; and

(c) containing the witness' evidence for the hearing.

(2) A party must comply with subrule (1) at least 21 days before the date set for the hearing or, if the court directs a different time, within the time directed by the court.

(3) A party may not, except with the leave of the court or with the consent of each other party, call evidence from a witness as an expert unless the party has complied with subrules (1) and (2).

(4) An expert witness, in examination in chief, must not, except with the leave of the court, expand on matters contained in the witness' statement of evidence or introduce fresh material.

(5) The court may order expert witnesses to confer and prepare and file a document setting out areas of agreement and disagreement and the reasons for any disagreement.

(6) The court may make the order it considers appropriate about the cost of preparing the document.

Uniform Civil Procedure Rules 1999 **(Qld)**

Part 5 Division 2 Evidence given by an expert

426 Duty of expert

(1) A witness giving evidence in a proceeding as an expert has a duty to assist the court.

(2) The duty overrides any obligation the witness may have to any party to the proceeding or to any person who is liable for the expert's fee or expenses.

428 Requirements for report

(1) An expert's report must be addressed to the court and signed by the expert.

(2) The report must include the following information—

- (a) the expert's qualifications;
- (b) all material facts, whether written or oral, on which the report is based;
- (c) references to any literature or other material relied on by the expert to prepare the report;
- (d) for any inspection, examination or experiment conducted, initiated, or relied on by the expert to prepare the report—
  - (i) a description of what was done; and
  - (ii) whether the inspection, examination or experiment was done by the expert or under the expert's supervision; and
  - (iii) the name and qualifications of any other person involved; and
  - (iv) the result;
- (e) if there is a range of opinion on matters dealt with in the report, a summary of the range of opinion, and the reasons why the expert adopted a particular opinion;
- (f) a summary of the conclusions reached by the expert;
- (g) a statement about whether access to any readily ascertainable additional facts would assist the expert in reaching a more reliable conclusion.

(3) The expert must confirm, at the end of the report—

- (a) the factual matters stated in the report are, as far as the expert knows, true; and
- (b) the expert has made all enquiries considered appropriate; and
- (c) the opinions stated in the report are genuinely held by the expert; and
- (d) the report contains reference to all matters the expert considers significant; and
- (e) the expert understands the expert's duty to the court and has complied with the duty.

429B Court may direct experts to meet

(1) The court may, at any stage of a proceeding, direct experts to meet and—

- (a) identify the matters on which they agree; and
- (b) identify the matters on which they disagree and the reasons why; and

(c) attempt to resolve any disagreement.

(2) The court may, for the meeting—

(a) set the agenda; and

(b) specify the matters the experts must discuss; and

(c) direct whether or not legal representatives may be present; and

(d) give directions about the form of any report to be made to the court about the meeting; and

(e) give any other directions the court considers appropriate.

(3) Evidence of anything done or said, or an admission made, at the meeting is admissible at a trial of the proceeding only if all parties to the proceeding agree.

(4) However, subrule (3) does not apply to a report made to the court about the meeting identifying the matters mentioned in subrule (1)(a) or (1)(b).

ANNEXURE B

Court Rules

1 A copy of the relevant sections of the *Land Court Rules 2000* and the *Uniform Civil Procedure Rules 1999* is provided at Annexure A.

2 While the format of your report is discretionary, you should ensure that your report complies with the above requirements, and that compliance with these requirements is readily apparent.

Format

3 We make the following suggestions regarding the layout of your report.

4 Ensure that your report contains your full name and address.

5 Please number all pages and paragraphs of your report. You may wish to include an index. If your report includes any photographs, measurements, graphs or illustrations these should be firmly attached to the report, and clearly identified and numbered.

6 Your report may include the following sections and headings:

6.1 **"Introduction"**

This section should:

- refer to, and annex, the letter of instructions received from me;
- refer to, and disclose, the substance of any conversations that you have had **and** to which you have had regard in preparing the report;
- specifically identify and refer to any literature or other source materials (eg text books, industry guidelines and handbooks) used in support of your opinion. This will include the documents supplied by me, as well as any other documents to which you have referred. If lengthy, it may be practical to list this material in an annexure to the report. If for some reason, you do not refer to certain material when preparing your report, please specifically identify this material and outline the reasons it was not referred to; and
- refer to any methodology you have adopted in preparing the report, including a detailed description of any test or examinations, who carried them out, their qualifications and the results.

6.2 **"My qualifications"**

In this section of your report, you need to qualify yourself as an expert in the areas in which you have been asked to provide an opinion. You should describe how your specialist knowledge (whether obtained through training, study or experience), your experience and qualifications qualify you as an expert in these areas.

Your curriculum vitae should also be annexed to your report and referred to under this heading.

6.3 **"Summary of my opinion"**

You are required to include a summary of your opinion.

6.4 **"Background facts and assumptions"**

The Court Rules require you to list all "facts, matters and assumptions on which each opinion expressed in the report is based".

The facts and assumptions you rely on need to be linked to their sources and clearly stated and verifiable. These may be sufficiently set out in our letter of instructions.

If you are called as a witness, you may be required to give evidence in relation to your assumptions.

6.5 **"My opinion"**

This part of your report should contain your detailed reasons for your opinions on the questions put to you. This will be the most substantial part of your report.

When drafting your report, you should make it clear that the opinion is wholly or substantially based on your expert knowledge. Your opinions must be confined to areas within your expert knowledge.

You must set out the process of reasoning that you followed in coming to your opinion and identify the facts and assumptions upon which you rely for the opinion. Where there are alternative views available, you should explain why you have chosen a particular alternative.

6.6 **"Qualification of the opinion"**

If appropriate, you should set out any qualification of your opinion, without which the report would be incomplete or inaccurate. If applicable, you should state that a particular question or issue falls outside your relevant field of expertise.

You should also state if your opinion is not concluded because of insufficient research or data or for any other reason.

6.7 **"Confirmation"**

You must confirm, at the end of the report—

(a) the factual matters stated in the report are, as far as the expert knows, true; and

(b) the expert has made all enquiries considered appropriate; and

(c) the opinions stated in the report are genuinely held by the expert; and

(d) the report contains reference to all matters the expert considers significant; and

(e) the expert understands the expert's duty to the court and has complied with the duty.

Please ensure that you make all necessary inquiries in a timely fashion to enable you to confirm these matters.

6.8 **"Signature"**

The final page of your report must be signed by you.

ANNEXURE C

Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development: Advice to decision maker on coal mining project

Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development

Advice to decision maker on coal mining project

Proposed action: Kevin's Corner Coal Mine Project (2009/5033)

Requesting agencies	• Office of the Coordinator-General, Queensland Department of State Development, Infrastructure and Planning; and • Australian Government Department of Sustainability, Environment, Water, Population and Communities.
Date of request	20 December 2012
Date request accepted	20 December 2012
Advice Stage	Environmental Impact Assessment - Supplementary

Summary of request from the regulators

The Department of Sustainability, Environment, Water, Population and Communities (the Department) is currently assessing the Kevin's Corner project (2009/5033) in accordance with the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* and the Queensland Office of the Coordinator-General is currently assessing the proposed project under Part 4 of the *State Development and Public Works Organisation Act 1971*.

The Department and the Queensland Office of the Coordinator-General jointly notifies the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the Committee) of an opportunity to comment on a draft and supplementary Environmental Impact Statement. Specifically, advice of the Committee is requested to:

1. Review the Groundwater Report (SEIS Vol 2 Appendix L) and provide advice on whether the information is sufficiently robust enough to understand the potential for impacts to, and the proposed management of these impacts on:
    - the Great Artesian Basin (GAB);
    - flood management, and;
    - groundwater quality.
2. Review the Revised Surface Water Hydraulics Report (SEIS Vol 2 Appendix K) and the Site Water Management (Basis of Design) Report (SEIS Vol 2 App M). Has enough detail been provided to understand and assess the potential flood impacts at the mine site? Does the Site Water Management (Basis of Design) Report provide enough detail to understand the water balance of the site? Are impacts manageable and acceptable?
3. Review the Cumulative Surface Water Impact Assessment Report (SEIS Vol 2 Appendix S). Does this provide enough detail to understand and assess potential cumulative surface water impacts?
4. Review the Subsidence Management Plan (SEIS Vol 2 Appendix N). Does this provide

enough detail to understand and assess the impacts of subsidence? Are impacts manageable and acceptable?

5. Review section T.3.4 (Water Resources) of the Environmental Management Plan (SEIS Vol 2 Appendix T1). Will the proposed mitigation and control strategies mitigate potential impacts of the project to water resources?

Advice

The Committee was referred the Kevin’s Corner proposal, in the Queensland Burdekin catchment, for joint advice at the supplementary environmental impact statement stage to the Commonwealth and State regulators.

Regional Consideration

1. In terms of cumulative impacts within the Galilee Basin, the Committee notes that the Interim Independent Expert Scientific Committee considered the Alpha Coal Project in 2012 and that a suite of further projects is proposed for the region. It is anticipated that the developments in the Galilee Basin are going to be large in scale, with tributaries to the Burdekin Catchment dissected by mines along a coal strike of approximately 300 km. The Kevin’s Corner proposal may significantly contribute to cumulative impacts associated with mining proposals along this strike, noting that the project will be one of the largest coal mines in Australia, mining approximately 30 million tonnes of coal per year for over 30 years. Further, more than three billion tons of overburden and interburden will be generated from the open-cut pits. As such, the Committee considers that information relating to the potential impacts of this project should be commensurate with its scale.
2. Given the pending development scenarios for the region, the Committee has been advised by the Office of Water Science that the Galilee Basin has been identified as a priority sub-region for completion of a bioregional assessment. The Committee recommends that the bioregional assessment should include an assessment of groundwater impacts associated with the Galilee Basin (which may affect the Great Artesian Basin to the west), and surface water impacts associated with the Burdekin Catchment (which may be impacted to the east).

Kevin’s Corner

3. The Committee suggests that a regional and site water balance should be provided as baseline information and a risk-based approach should be developed to examine local and regional impacts. The cumulative impact assessment should also include an assessment of habitat loss and impacts to ecological systems.
4. In terms of the integrity of the Rewan Formation (the basal confining unit of the hydrological Great Artesian Basin), particularly in relation to its ability to restrict connectivity with the Great Artesian Basin, the Committee advises that the Formation is generally considered to have low porosity and permeability. However, there is evidence to suggest that localised faulting may exist. Thus, while the primary porosity and permeability of the rock matrix is considered to be low, it is plausible that site specific faulting presents a potential for connectivity and vertical groundwater flow. The extent of faulting in the Rewan Formation in the local setting should be determined in order to inform the connectivity assessment. The Committee further notes that there are a range of studies underway, such as the Great Artesian Basin Water Resource Assessment, which will provide for better understanding of the level of complexity and connectivity in such systems.
5. The Committee considers that groundwater quality may be impacted by increased aquifer connectivity associated with subsidence and from uncertainty regarding tailings management. The Committee notes that toxicants (associated with overburden placed into out-of-pit emplacement areas for the first two years of mining) are predicted to remain on site, migrating towards the Kevin’s Corner and Alpha final voids. However, a detailed tailings assessment is required to determine potential impacts from the

overburden that will be placed in-pit behind the active mining strip.

6. In terms of impacts to surface water, the Committee considers that the proposed discharge scenarios are inadequate, as scenarios are not discussed for all of the proposed release points. Further, water quantity and quality parameters of proposed medium and high flow discharge scenarios appear to be significantly above, site specific, reference data and have the potential to adversely impact ecological communities.
7. The Committee considers that the proponent's existing discharge strategy is inadequate. The strategy should be revised so that median levels for water quality parameters for stressors should not exceed the relevant 80^{th} percentile values of reference data for the appropriate discharge. The median release water quality for toxicants should be sufficient to protect 95 per cent of species, consistent with ANZECC 2000 guidelines. If water quality parameters are unable to be met water should be retained on site, such as in proposed dams or temporarily stored in open-cut pits, and treated to levels that allow discharge with no or minimal environmental risks. Baseline monitoring should also be undertaken daily after an event, for a minimum of the first seven days, to help determine water quality parameters of first flush events.
8. The Committee notes that the Kevin's Corner and Alpha projects involve a number of creek diversions and levees which have the potential to impact water quality and local hydrology. Specifically:
    a. the Alpha Project will divert creeks towards the Kevin's Corner tenement. Due to the close proximity of the creeks to the Kevin's Corner mine, the Committee considers that there may be ingress of surface water to completed longwall panels; and
    b. in sections where stream power is increasing, the Kevin's Corner creek diversion has the potential to increase erosion in some areas (especially in areas affected by subsidence), which may reduce channel capacity and increase floodplain inundation and frequency. Changes to hydrology have the potential to alter community composition towards species which can tolerate more frequent inundation.
9. The Committee considers that subsidence also has the potential to alter surface-groundwater connectivity. It is highly probable that fracturing will have surface expression over a significant portion of the proposed mine resulting in increased surface water loss to the groundwater. It is stated by the proponent that clays present in the overburden will swell to stop this leakage; however no supporting evidence has been provided to support this claim. Subsidence and associated mitigation measures are also likely to alter water quantity and quality and vegetation communities towards species which can tolerate more frequent inundation. Further, the Committee notes that there is insufficient evidence to substantiate the effectiveness of proposed mitigation measures at the site.
10. The Committee also considers that changes to hydrology may impact vegetation community composition at the site. For example, inundation regimes may adversely impact Matters of National Environment Significance (e.g. Black Throated Finch and Red Goshawk) in the area. Due to the reduction in catchment area from the Alpha and Kevin's Corner proposals, the proponent's assessment concludes that areas inundated for more than 96 hours will be reduced. The Committee considers that further information is required to determine potential impacts from the proposal, such as site species tolerances to inundation regimes and implications for Matters of National Environmental Significance.
11. The Committee notes that the proponent proposes a number of conditions as part of the Environmental Management Plan, italicised below, and suggests the following points:
    a. <u>*Proposed condition W15*</u>*: The environmental authority holder must notify the administering authority as soon as practicable, and no later than 24 hours, after commencing to release mine affected water to the receiving environment. Notification must include the submission of written advice to the administering authority of the following information:*
        i. release commencement date/time;

ii. *expected release cessation date/time;*

iii. *release point/s;*

iv. *release volume (estimated);*

v. *receiving water/s including the natural flow rate; and*

vi. *details (including available data) regarding likely impacts on the receiving water/s.*

To assist in determining potential impacts, the Committee suggests the addition of information relating to: expected release timings and durations; released water quality; water quality upstream and downstream of release sites; and the total estimated salt loads and heavy metal concentrations of the discharge event.

b. <u>Proposed condition W22</u>*: If quality characteristics of the receiving water at the downstream monitoring points exceed any of the specified trigger levels during a release event, the Environmental Authority holder must compare the downstream results to the upstream results in the receiving waters and:*

i. *where the downstream result is the same or a lower value than the upstream value for the quality characteristic then no action is to be taken; or*

ii. *where the downstream results exceed the upstream results, complete an investigation in accordance with the ANZECC and ARMCANZ 2000 methodology, into the potential for environmental harm and provide a written report to the administering authority in the next annual return outlining:*

1. *details of the investigation carried out; and*
2. *actions to prevent environmental harm.*

The Committee suggests for Condition W22 (and where relevant for W15) that disposal of pit water should be underpinned by best environmental practice and take into consideration the frequency of extreme weather conditions/events.

c. <u>Proposed condition W60</u>*: The holder of the environmental authority must monitor and record water levels within the Rewan Formation as the basal aquitard unit of the Great Artesian Basin ... Where groundwater drawdown fluctuations of five metres or more below the minimum levels recorded within the Rewan Formation during background monitoring ... are recorded, not resulting from pumping of licensed bores, the holder of this environmental authority must undertake an assessment of the potential for induced flow from the Great Artesian Basin aquifers. The holder must notify the administrating authority of the outcomes of this assessment within 14 days following completion of this assessment.*

The Committee notes that the proposed five metre drawdown trigger conforms with the Queensland Baseline Assessment Guideline (2011) definition of long term affected areas. However, as information on observed water levels and fluctuations does not appear to have been provided, the Committee is unable to determine whether a five metre drawdown trigger in the Rewan Formation is adequate for early detection of induced flow from Great Artesian Basin aquifers. The Committee suggests that consideration be given to an independent assessment to determine an appropriate drawdown trigger level for the Rewan Formation. The assessment should be in addition to proposed monitoring of the Clematis Sandstone and the development of a cumulative impacts model for the Galilee Basin.

Date of advice	1 February 2013

Revel Pointon

From:	Juanita Williams
Sent:	Tuesday, 9 December 2014 3:52 PM
To:	John Webb
Cc:	Revel Pointon; Sean Ryan
Subject:	CCAQ ats Hancock - Kevin's Corner - Land Court Rules
Attachments:	2014-12-09 Land Court Rules (ss 22-24I).pdf

Dear John,

We note that your letter of engagement dated 9 January 2014 makes reference in Annexure A to section 23 of the *Land Court Rules 2000* (Qld).

For completeness, we would like to further draw your attention to the rules of evidence relating to experts in sections 22-24I of the *Land Court Rules 2000* (Qld). A copy of the Rules can be found here.

For ease of reference, please also find **attached** a PDF copy of the relevant Rules.

If you have any queries about these Rules please do not hesitate to contact us.

Kind regards

Juanita Williams
Solicitor

EDO Qld.
Environmental Defenders Office
Using the law to protect our environment.

30 Hardgrave Rd WEST END, QLD 4101
tel +61 7 3211 4466 *fax* +61 7 3211 4655
edoqld@edo.org.au www.edo.org.au/edoqld

Revel Pointon

From: Juanita Williams
Sent: Tuesday, 9 December 2014 4:26 PM
To: Roderick Campbell; John Webb
Cc: Sean Ryan; Revel Pointon
Subject: CCAQ ats Hancock - Kevin's Corner - Land Court Rules
Attachments: 2014-12-09 Land Court Rules (ss 22-24I) V2.pdf

Dear Experts,

Please ignore the last PDF sent in the previous email as it mistakenly had "Annexure B" at the top. Please use the **attached** PDF V2 for ease of reference to the Land Court Rules.

Kind regards

Juanita Williams
Solicitor

EDO Qld.
Environmental Defenders Office
Using the law to protect our environment.

30 Hardgrave Rd WEST END, QLD 4101
tel +61 7 3211 4466 *fax* +61 7 3211 4655
edoqld@edo.org.au www.edo.org.au/edoqld

Part 5 Evidence

Division 1 Preliminary

22 Definitions for pt 5

In this part—

expert means a person who would, if called as a witness in a proceeding, be qualified to give opinion evidence as an expert witness in relation to an issue in dispute in the proceeding.

joint report, for a proceeding, means a report—

(a) stating the joint opinion of experts in relation to an issue in dispute in the proceeding; and

(b) identifying the matters about which the experts agree or disagree and the reasons for any disagreement.

meeting of experts—

1 A meeting of experts is a meeting at which experts in each area of expertise relevant to a proceeding meet, in the absence of the parties—

(a) to discuss and attempt to reach agreement about the experts' evidence in relation to an issue in dispute in the proceeding as it relates to the experts' area of expertise; and

(b) to prepare a joint report.

2 The term includes —

(a) a resumed meeting of experts or further meeting of experts; and

(b) a meeting attended by the experts in either, or a combination, of the following ways—

(i) personally;

(ii) a way that allows contemporaneous communication between the experts, including by telephone, video link or email.

party, for a proceeding, means a party to the proceeding or the party's lawyer or agent.

statement of evidence, of an expert, see rule 24E.

Division 2 Meetings of experts

23 Application of div 2

Unless the court otherwise orders, this division applies in relation to a meeting of experts ordered or directed by the court at any time in a proceeding.

24 Party must ensure expert ready to take part in meeting of experts

Before a meeting of experts, a party to a proceeding must do all things reasonably necessary or expedient to ensure an expert chosen by the party is ready to take part fully, properly and promptly in the meeting, including by giving the expert—

(a) reasonable prior notice that the court has ordered or directed a meeting of experts; and

(b) notice of the contents of any order or direction about the meeting, including the time by which the meeting must be held; and

(c) reasonable notice of the issue in dispute in the proceeding to the extent it is relevant to the expert's expertise; and

(d) enough information and opportunity for the expert to adequately investigate the facts in relation to the issue in dispute in the proceeding; and

(e) written notice that the expert has a duty to assist the court and the duty overrides any obligation the expert may have to the party or any person who is liable for the expert's fee or expenses.

24A Experts attending meeting must prepare joint report

(1) The experts attending a meeting of experts must, without further reference to or instruction from the parties, prepare a joint report in relation to the meeting.

(2) However, the experts attending the meeting may, at any time before the joint report is completed, ask all parties to respond to an inquiry the experts make jointly of all parties.

(3) Despite subrule (1), any of the experts may participate in a mediation involving the parties.

(4) The joint report must—

(a) confirm that each expert understands the expert's duty to the court and has complied with the duty; and

(b) be given to the parties.

(5) The applicant or appellant must deliver to the registry, personally or by facsimile or email, a copy of the joint report received under subrule (4) at least 21 days before the date set for the hearing.

24B Admissions made at meeting of experts

(1) Subrule (2) does not apply to a joint report prepared in relation to a meeting of experts.

(2) Evidence of anything done or said, or an admission made, at a meeting of experts is admissible at the hearing of the proceeding or at the hearing of another proceeding in the court or in another civil proceeding only if all parties to the proceeding agree.

(3) In this rule—

civil proceeding does not include a civil proceeding founded on fraud alleged to be connected with, or to have happened during, the meeting.

Division 3 Evidence given by experts

24C Duty of Expert

(1) A witness giving evidence in a proceeding as an expert has a duty to assist the court.

(2) The duty overrides any obligation the witness may have to any party to the proceeding or to any person who is liable for the expert's fee or expenses.

24D Giving or accepting instructions to adopt or reject a particular opinion prohibited

A person must not give, and an expert must not accept, instructions to adopt or reject a particular opinion in relation to an issue in dispute in a proceeding.

24E Expert must prepare statement of evidence

(1) An expert must prepare a written statement of the expert's evidence (a statement of evidence) for the hearing of a proceeding.

(2) If the expert has taken part in a meeting of experts—

(a) a joint report prepared in relation to the meeting is taken to be the expert's statement of evidence in the proceeding; and

(b) a further statement of evidence in relation to any issue of disagreement recorded in the joint report is to be prepared by the expert.

(3) However, the further statement of evidence must not, without the court's leave—

(a) contradict, depart from or qualify an opinion in relation to an issue the subject of agreement in the joint report; or

(b) raise a new matter not already mentioned in the joint report.

24F Requirements for statement of evidence other than joint report

(1) An expert's statement of evidence, other than a joint report, must be addressed to the court and signed by the expert.

(2) The statement of evidence must include the following information, to the extent the information is not already contained in a joint report prepared for the proceeding—

(a) the expert's qualifications;

(b) all material facts, whether written or oral, on which the statement is based;

(c) references to any literature or other material relied on by the expert to prepare the statement;

(d) for any inspection, examination or experiment conducted, initiated or relied on by the expert to prepare the statement—

(i) a description of what was done; and

(ii) whether the inspection, examination or experiment was done by the expert or under the expert's supervision; and

(iii) the name and qualifications of any other person involved; and

(iv) the result;

(e) if there is a range of opinion on matters dealt with in the statement, a summary of the range of opinion and the reasons why the expert adopted a particular opinion;

(f) a summary of the conclusions reached by the expert;

(g) a statement about whether access to any readily ascertainable additional facts would assist the expert in reaching a more reliable conclusion.

(3) The expert must confirm, at the end of the statement of evidence—

(a) the factual matters included in the statement are, as far as the expert knows, true; and

(b) the expert has made all enquiries considered appropriate; and

(c) the opinions included in the statement are genuinely held by the expert; and

(d) the statement contains reference to all matters the expert considers significant; and

(e) the expert understands the expert's duty to the court and has complied with the duty; and

(f) the expert has read and understood the rules contained in this part, as far as they apply to the expert; and

(g) the expert has not received or accepted instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.

24G Serving statement of evidence other than joint report

(1) This rule applies to a statement of evidence other than a joint report.

(2) A party to a proceeding intending to call evidence by an expert in the proceeding must deliver to the registry, personally or by facsimile or email, and serve on each other party to the proceeding, a copy of the expert's statement of evidence.

(3) A party must comply with subrule (2) at least 21 days before the date set for the hearing or, if the court directs a different time, within the time directed by the court.

24H Matters contained in statement of evidence not to be repeated

During examination in chief, an expert must not, without the court's leave, repeat or expand on matters contained in the expert's statement of evidence or introduce new material.

24I Evidence from only 1 expert may be called

Other than with the court's leave, a party to a proceeding, at any hearing of the proceeding, may call evidence from only 1 expert for each area of expertise dealt with in the hearing.

Attachment C – Glossary of terms

Glossary of terms and core hydrogeological concepts

alluvial:

- Deposited by a stream or other running water.[1]

alluvium:

- A general term for the unconsolidated materials deposited by a stream or other running water.[2]

- Sediments deposited by flowing rivers. Depending on the location in the floodplain of the river, different-size sediments are deposited.[3]

anticline: (contrast *syncline*)

- In structural geology, an **anticline** is a fold that is convex up and has its oldest beds at its core. The term is not to be confused with *antiform*, which is a purely descriptive term for any fold that is convex up. Therefore if age relationships between various strata are unknown, the term antiform should be used.[4]

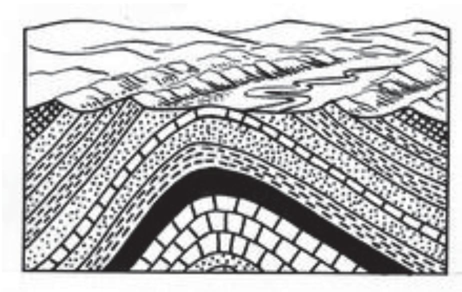

Figure 1(a): Diagram of anticline

Figure --1(b): Photograph of anticline (left) and syncline (right) in exposed rock strata. Note person in centre for scale.

aquiclude: (a type of *confining layer*; contrast *aquiclude* and *aquitard*)

- A geologic formation which limits the movement of *groundwater* (e.g. clay, silt or shale).[5]

- A low-permeability unit that forms either the upper or lower boundary of a ground-water flow system.[6]

- A hydrogeologic unit which, although *porous* and capable of storing water, does not transmit it at rates sufficient to furnish an appreciable supply for a bore/well or spring.[7]

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[1] Schwalbaum WJ (1997) *Understanding Groundwater*, Nova Science Publishing, USA, "glossary", p 169.
[2] Schwalbaum, n 1, p 169.
[3] Fetter CW (2001) *Applied Hydrogeology*, 4th ed, Prentice Hall, USA, "glossary", p 552.
[4] Source (including images in Figure 1(a) and (b)): Wikepedia, http://en.wikipedia.org/wiki/Anticline
[5] Schwalbaum, n 1, p 169.
[6] Fetter, n 3, p 552.

- A geological material through which zero flow occurs.[8]

aquifer:

- A body of saturated rock that both stores and transmits important quantities of *groundwater*.[9]

- Rock or sediment in a formation, group or formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to bores/wells or springs.[10]

- A water-bearing geologic formation, or part of a formation, capable of yielding significant quantities of water to bores/wells, springs or rivers.[11]

- A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to bores/wells and springs.[12]

- (Figures 2-4 provide illustrations of different types of aquifers)

aquitard: (a type of *confining layer*; contrast *aquiclude* and *aquitard*)

- A saturated body of rock that impedes the movement of groundwater.[13]

- Compacted layers of clay, silt or rock that retard water flow underground [but through which] significant quantities of water can seep ... in some conditions. [In contrast] At the very end of the spectrum, an *aquiclude* is a geological material through which zero flow occurs.[14]

- A confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; a leaky confining bed. It does not readily yield water to bores/wells or springs, but may serve as a storage unit for ground water.[15]

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[7] Oregon Water Science Centre, "Glossary of hydrologic terms" at http://or.water.usgs.gov/projs_dir/willgw/glossary.html (reference omitted)
[8] National Centre for Groundwater Research and Training, "Understanding Aquitards and Aquicludes", at www.groundwater.com.au/media/W1siZiIsIjIwMTMvMDEvMTcvMjFfMDNfMjlfNzg0X1VuZGVyc3RhbmRpbmdfYXF1aXRhcmRzX2FuZF9hcXVpY2x1ZGVzX0ZJTkFMLnBkZiJdXQ/Understanding+aquitards+and+aquicludes_FINAL.pdf
[9] Younger PL (2007) *Groundwater in the Environment: an introduction*, Blackwell Publishing, UK, "glossary", p 277.
[10] Fetter, n 3, p 552.
[11] Schwalbaum, n 1, p 169.
[12] Moore JE (2002) *Field Hydrogeology: a guide for site investigations and report preparation*, Lewis Publishers, USA, "glossary", p 126.
[13] Younger, n 9, p 277.
[14] National Centre for Groundwater Research and Training, n 8.
[15] Oregon Water Science Centre, n 7 (reference omitted).

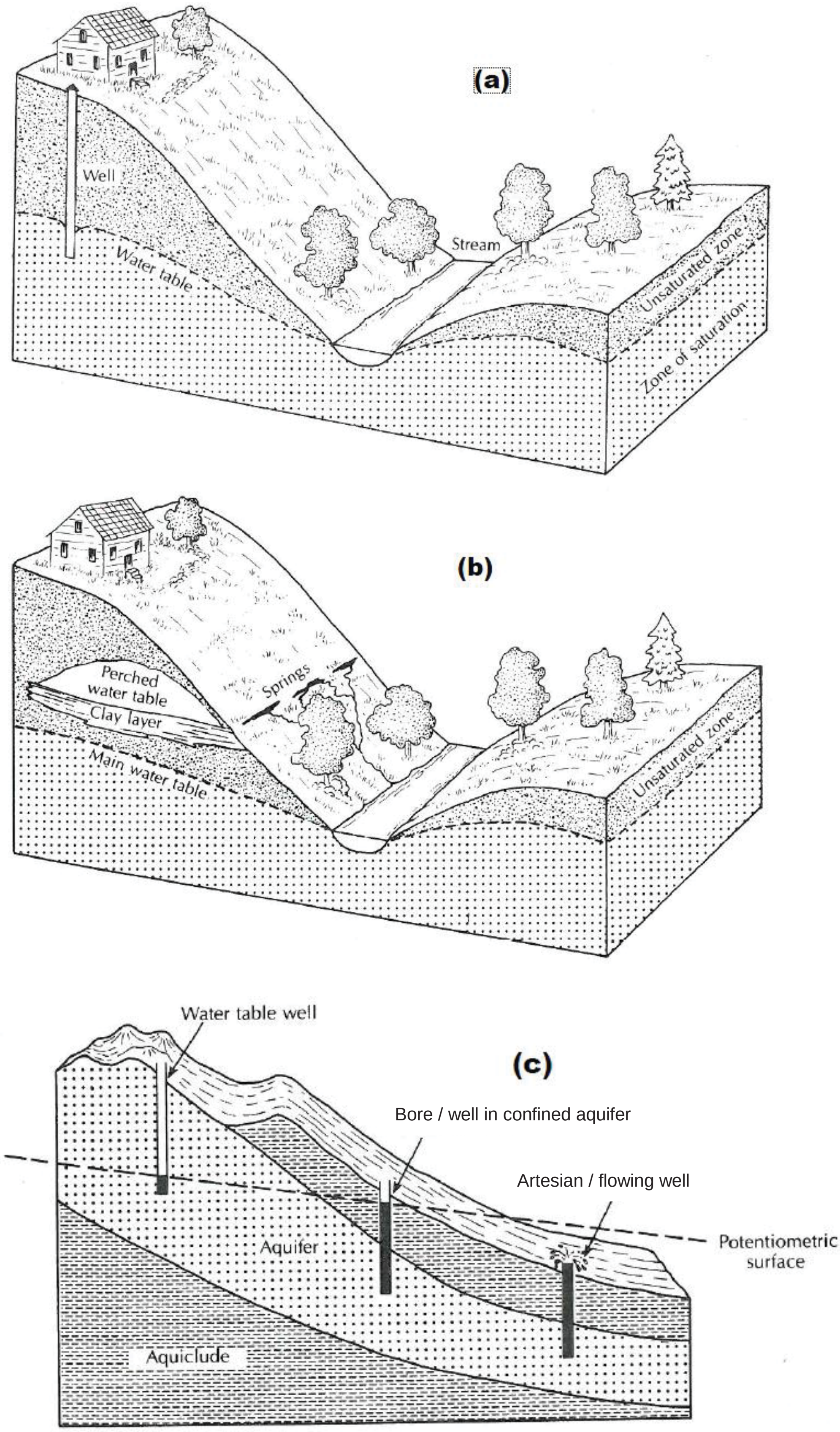

Figure 2: Different types of aquifers. (a) Unconfined, or water-table, aquifer. (b) Perched aquifer formed above the main water table on a low-permeability layer in the unsaturated zone.
(c) Artesian and non-artesian bores/wells in confined aquifer.[16]

[16] Adapted from Fetter, n 3, pp 96 and 98.

artesian:

- Involving, relating to, or supplied by the upward movement of water under hydrostatic pressure in rocks or unconsolidated material beneath the earth's surface.[17]

- The word “artesian” is derived from the name of Artois (Belgium) where artesian conditions were first recognized long ago.[18]

- In North American hydrogeological literature, generally regarded as synonymous with confined,[19] but in Australian hydrogeological usage, applied only to conditions where groundwater flows from a bore/well without pumping.

artesian aquifer: (see also *confined aquifer*)

- A confined aquifer in which water from a bore/well would naturally flow.[20]

artesian bore/well:

- A bore/well deriving its water from an *artesian confined aquifer*.[21]

- A bore/well in an artesian aquifer from which water flows without pumping[22]

boundary:

- In hydrogeology, *confining units* act as boundaries to *groundwater* flow. In groundwater computer modeling, the boundaries of the modeling domain can be defined in various ways, e.g. constant head, no flow[23]

cone of depression:

- A conical depression in the *water table* (or *piezometric surface*) which develops around a pumping bore/well, as a consequence of the fact that drawdown increases with proximity to the bore/well.[24]

confined aquifer:

- An *aquifer* that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the *aquifer*.[25]

- An *aquifer* lying below an *aquitard/aquiclude*, such that there is no unsaturated zone between the base of the *aquitard/aquiclude* and the groundwater within the *aquifer*.

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[17] Merriam-Webster online dictionary at http://www.merriam-webster.com/dictionary/artesian
[18] Younger, n 9, pp 24-25.
[19] Oregon Water Science Centre, n 7.
[20] Schwalbaum, n 1, p 169.
[21] Oregon Water Science Centre, n 7 (reference omitted).
[22] Schwalbaum, n 1, p 170.
[23] Schwalbaum, n 1, p 170.
[24] Younger, n 9, p 279.
[25] Fetter, n 3, p 552; Moore, n 12, p 129.

- An *aquifer* bounded above and below by *confining units*.[26]

confining layer: (see also related term, *confining unit*)

- A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more *aquifers*. It may lie above or below the *aquifer*.[27]

confining unit (or bed): (see also related term, *confining layer*)

- (1) A hydrogeologic unit of impermeable or distinctly less permeable material bounding one or more *aquifers* and is a general term for *aquitard*, *aquiclude*. (2) Means a body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more *aquifers*.[28]

- (1) A layer (bed) of "impermeable" material stratigraphically adjacent to one or more aquifers. In nature, its hydraulic conductivity may range from nearly zero to some value distinctly lower than that of the aquifer. (2) A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. It may be above or below the aquifer.[29]

- A geologic formation which limits the movement of groundwater (e.g., clay, silt or shale).[30]

consolidation:

- In geology, any process by which loose earth material become compacted, including cementation, diagenesis, recrystallization, dehydration, and metamorphism.[31]

constant head boundary:

- In hydrogeological modelling, a constant head boundary is defined as having a constant hydraulic head; for groundwater flow across the boundary, horizontal inflow and outflow across the boundary are equal. It is a simple boundary condition to solve within a model.

- A natural feature such as a lake or river that effectively fully penetrates the *aquifer* can form a constant head boundary at that location.[32]

contours:

- Lines on a map connecting points of equal value; topographic contours connect points of equal elevation. *Potentiometric* contours connect points of equal

[26] Schwalbaum, n 1, p 171.
[27] Fetter, n 3, p 553.
[28] Oregon Water Science Centre, n 7 (references omitted).
[29] Moore, n 12, p 129 (references omitted).
[30] Schwalbaum, n 1, p 171.
[31] Allaby M (2008), *Oxford Dictionary of Earth Sciences*, 3rd ed, Oxford University Press, Oxford, p 127.
[32] Moore, n 12, p 130 (reference omitted).

hydraulic head and can be used to define *groundwater* gradients and flow directions.[33]

Darcy's Law:

- An empirical law which states that the velocity of flow through *porous* medium is directly proportional to the *hydraulic gradient* assuming that the flow is laminar and inertia can be neglected (after Darcy, 1856).[34]

- An equation that can be used to compute the quantity of water flowing through an *aquifer*.[35]

- The basic law of laminar groundwater flow, which states that flow rate (Q) is equal to the product of the *hydraulic conductivity* (K), the *hydraulic gradient* (i) and the area (A) of aquifer material (perpendicular to the direction of flow) through which flow is taking place. Darcy's Law is most commonly written: $Q = K \cdot i \cdot A$ [36]

discharge:

- The transfer of water out of an aquifer usually to a surface water body, a bore/well or a spring.[37]

divide (groundwater):

- An imaginary line which separates the areas within an aquifer in which groundwater flows to different points of *discharge*. It is defined by the *potentiometric* or *water table* contours.[38]

downgradient:

- In the direction of decreasing groundwater head, in the direction of groundwater flow.[39]

fault:

- A *fracture*, or zone of fractures in a rock along which there was movement in the past.[40]

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[33] Schwalbaum, n 1, p 171.
[34] Oregon Water Science Centre, n 7. Material identical definition in Moore, n 12, p 132.
[35] Fetter, n 3, p 553.
[36] Younger, n 9, p 279.
[37] Schwalbaum, n 1, p 171.
[38] Schwalbaum, n 1, p 171.
[39] Schwalbaum, n 1, p 172.
[40] Schwalbaum, n 1, p 172.

fold:

- A bend or buckle in any pre-existing structure in a rock as a result of deformation.[41]

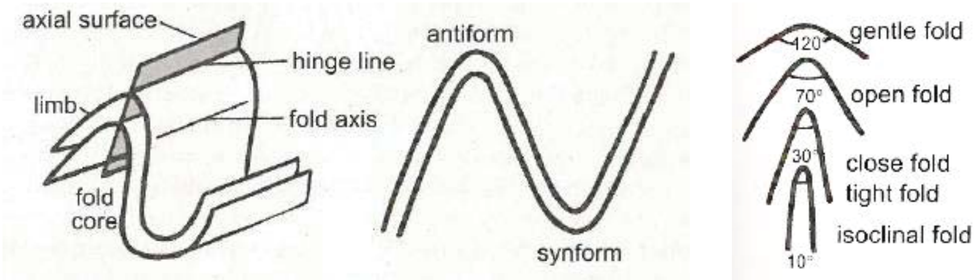

Figure 3: Some terms used to describe folds[42]

fracture:

- A linear opening in a rock.[43]
- Joint, or fault in rock or rock material.[44]

geologic time scale [with era and periods relevant to Kevin's Corner mine]**:**

- A scale that subdivides all geological time into named units and all rocks formed during geological time into a sequence from the oldest to the youngest (Table 1).
- (geological era and periods relevant to Kevin's Corner Mine are shown in Table 2).[45]

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41 Lapidus DF (revised and updated by MacDonald J and Burton C) (2006) *Collins Dictionary of Geology*, Revised ed, Glasgow (UK), p 187.
42 Adapted from Lapidus DF, n 41, p 187.
43 Schwalbaum, n 1, p 172.
44 Moore, n 12, p 135.
45 Note: The Tertiary Period (66 – 2.58 million years before present) is no longer recognized as a formal unit by the International Commission on Stratigraphy, but the word is still widely used and is used here. The Tertiary Period has now been divided between the Paleogene and Neogene Periods.

Table 1: Geological time scale[46]

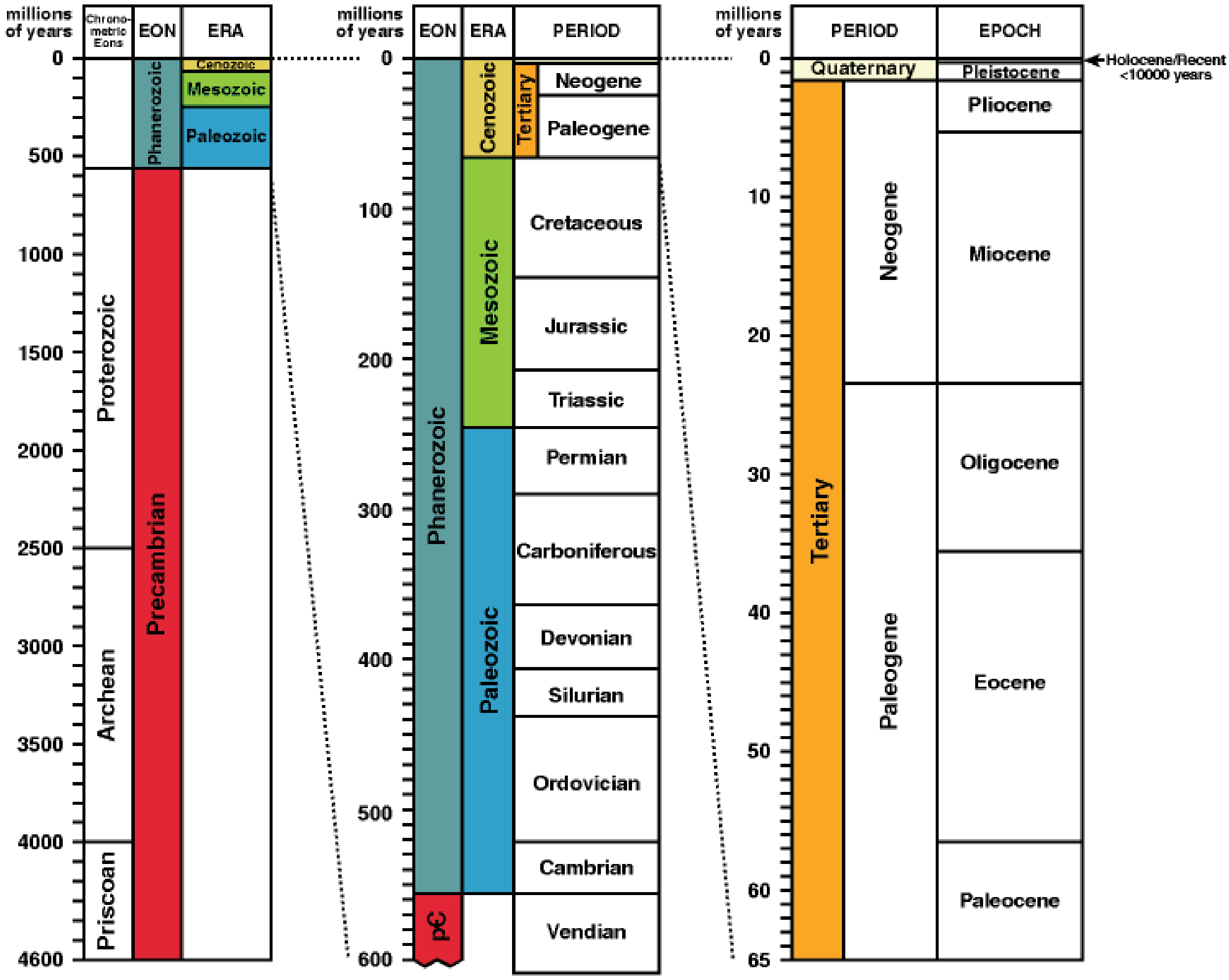

Table 2: Geological era and periods relevant to Kevin's Corner Mine[47]

Era	Period	Basin	Unit	Rock types
Cainozoic	Quaternary (present to 2.6 Million years)			Alluvium
	Tertiary (65 to 2.6 Million years)			Argillaceous sandstone, laterite and clay, where laterite is extremely weathered, leached residue
Mesozoic	Triassic (201 to 252 Million years)	Eromanga / Galilee	Rewan Formation	Green-grey mudstone, siltstone and labile sandstone
Palaeozoic	Permian (252 to 299 Million years)	Galilee	Bandanna Formation	Coal seams A and B, labile sandstone, siltstone, and mudstone
			Colinlea Sandstone	Coal seams C, D, E, and F, labile and quartz sandstone
	Late Carboniferous to Early Permian (299 to 359 Million years)	Drummond	Joe Joe Formation	Mudstone, labile sandstone, siltstone, shale and thin carbonaceous beds

[46] Source: MacRae A (1996) 'Geological time scale', http://www.talkorigins.org/faqs/timescale.html
[47] Steward M, "Expert Report to the Land Court [for Kevin's Corner Mine]", 17 October 2014, Table 5-1, p 19.

gradient (groundwater or water table):

- The change in elevation of the *water table* or *piezometric/potentiometric surface* between two points divided by the distance between them. The slope of the *water table* or *piezometric/potentiometric surface*.[48]

groundwater:

- Underground water, usually the water in an *aquifer* below the *water table*.[49]

groundwater basin:

- The area of an *aquifer* which contributes *groundwater* to a common point or area of discharge (such as a river or lake).[50]

groundwater divide:

- An imaginery line which separates the areas within an *aquifer* in which groundwaters flow to different points of discharge. It is defined by the *potentiometric* or water table contours.[51]

head (or hydraulic head):

- The elevation of the water level in a bore/well. Technically it is the potential energy of the groundwater at the screened interval in the bore produced by water pressure at that point, and due to the elevation of the recharge area of the aquifer.[52]

hydraulic conductivity:

- A measure of the *permeability* of *aquifer* material. Defined as the rate of flow of water through a unit cross section of *aquifer* under a unit *hydraulic head*.[53]

hydraulic gradient:

- The slope of a *water table* or *potentiometric surface*. The change in *groundwater* head over a given distance in a given direction.[54]

hydrogeology:

- The study of the interrelationships of geologic materials and processes with water, especially ground water.[55]

- The science of the occurrence and movement of *groundwater* in geologic formations.[56]

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[48] Schwalbaum, n 1, p 172.
[49] Schwalbaum, n 1, p 173.
[50] Schwalbaum, n 1, p 173.
[51] Schwalbaum, n 1, p 173.
[52] Schwalbaum, n 1, p 173.
[53] Schwalbaum, n 1, p 173.
[54] Schwalbaum, n 1, p 173.
[55] Fetter, n 3, p 556. Material identical definition in Moore, n 12, p 141.
[56] Schwalbaum, n 1, p 173.

infiltrate:

- To seep into or through; recharge to aquifers mainly occurs as rainfall infiltration through soils.[57]

laterite:

- Weathering product of rock, composed mainly of hydrated iron oxides and hydroxides; may also contain aluminium oxides/hydroxides clay minerals and silica. It is typically formed in humid, tropical settings.[58]

permeability:

- The capacity of a *porous* medium to transmit water. Same as *hydraulic conductivity*.[59]

- The property of soil or rock that allows passage of water through it when subjected to a difference in head. It depends not only on the volume of the openings and pores but also on how those openings are connected to each other. The property or capacity of a *porous* rock, sediment, or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under unequal pressure[60]

piezometer:

- A non-pumping bore/well, usually of small diameter, which is used to measure the elevation of the *water table* or *piezometric surface*.[61]

- A device used to measure groundwater pressure head at a point in the subsurface.[62]

- The word "piezo" in Greek means "pressure" and "meter" means to measure. Thus "piezometer" means a device to measure pressure. In the field of study of aquifers, we use piezometers to measure the **pressure** of the groundwater at various locations and depths.[63]

- (see Figure 4 and 5 for images of a piezometer)

piezometer nest:

- A set of two or more *piezometers set close to each other but screened to different depths.*[64]

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57 Schwalbaum, n 1, p 174.
58 Allaby, n 31, p 328.
59 Schwalbaum, n 1, p 175.
60 Moore, n 12, pp 153-154 (references omitted).
61 Schwalbaum, n 1, p 175. A short (3 minute) minute video describing the hydraulic principles for a piezometer is available at https://www.youtube.com/watch?v=_VDVi_zq3nk
62 Oregon Water Science Centre, n 7.
63 Ami Adini (2011) at http://www.amiadini.com/NewsletterArchive/110330-NL172/envEnl-172.html
64 Moore, n 12, p 154 (reference omitted).

Figure 4: Above ground casing of a piezometer[65]

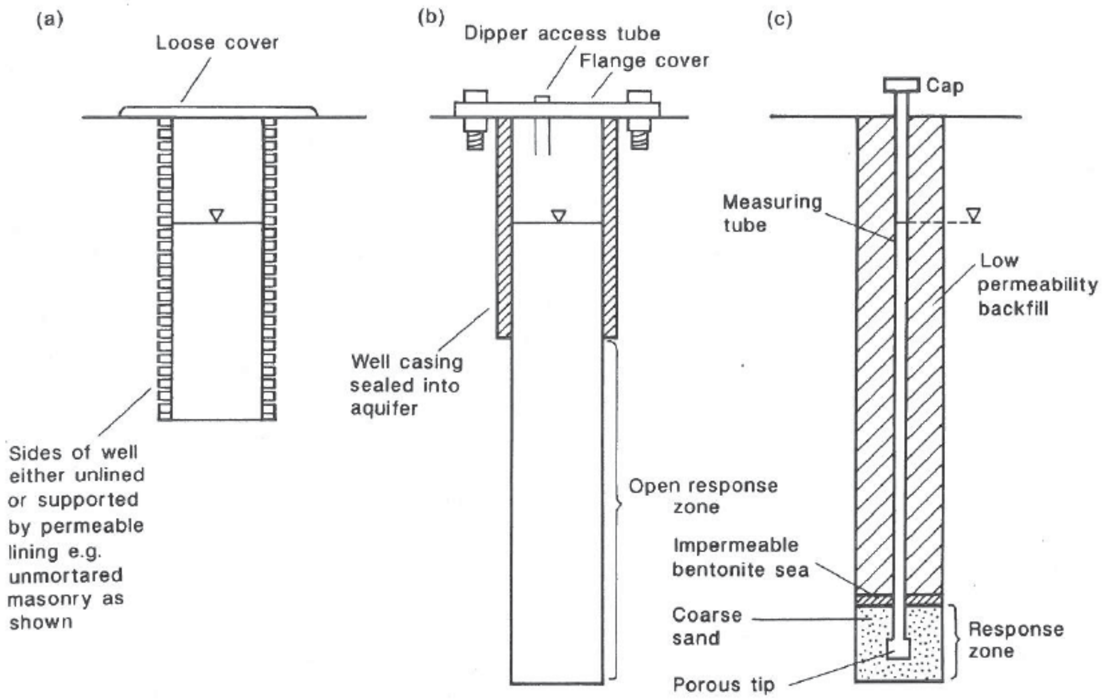

Figure 5: General designs of (a) well, (b) observation borehole and (c) piezometer for the measurement of groundwater level.[66]

porosity:

- Property of containing interstices or voids; may be expressed quantitatively as the ratio of the volume of interstices to the total volume of material, either as a decimal fraction or percentage.[67]

[65] Source: Wikipedia at http://en.wikipedia.org/wiki/Piezometer
[66] Source: Hiscock K (2005), *Hydrogeology Principles and Practice*, Blackwell Publishing, Oxford (UK), p 143.
[67] Moore, n 12, pp 155-6.

- Porosity is either primary or secondary and it defines the storage capacity of an aquifer. Primary porosity, such as pores between sand grains, is created when rocks are formed. The shape, sorting, and packing of grains control primary porosity. Sediment is poorly sorted when grains are not of the same size, and thus the spaces between the larger grains are filled with smaller grains. When pores are not connected and dead-end pores exist, there is no groundwater flow. This condition is analogous to water in a sponge. On the other hand, effective porosity refers to pores that are interconnected. Cementation of sand may isolate pores and thereby reduce the sand's effective porosity. Clays have many pores but do not yield water readily. Secondary porosity, such as joints, fractures, solution openings, and openings created by plants and animals, develops after rocks are formed. The number and arrangement of fracture openings and the degree to which they are filled by finer grained material control secondary porosity.[68]

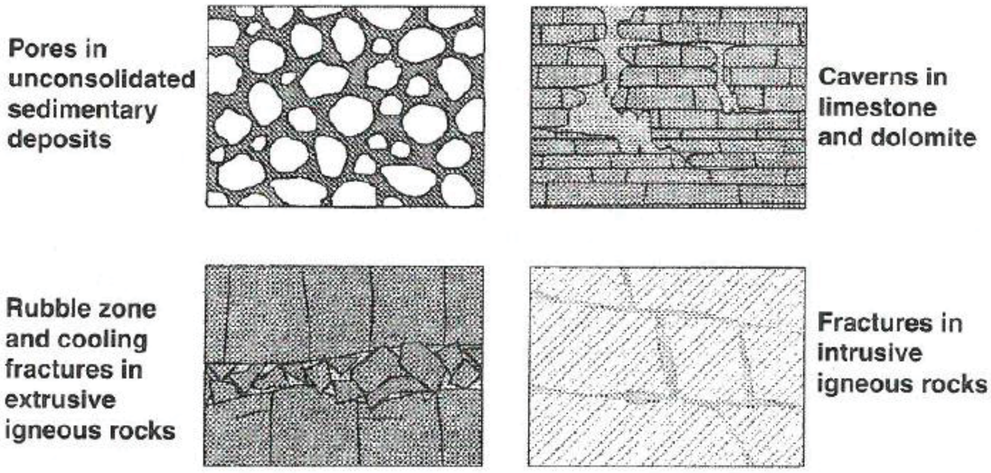

Figure 6: Aquifer pore spaces.[69]

porous:

- Having numerous interstices, whether connected or isolated.[70]

potentiometric level / piezometric level:

- The elevation of the water surface in a bore/well or *piezometer* screened within an aquifer. Same as *hydraulic head*.[71]

potentiometric surface / piezometric surface:

- An imaginary surface representing the static head of *groundwater* and defined by the level to which water will rise in a tightly cased bore/well.[72]

- An imaginary surface connecting the *potentiomentric levels* of an *aquifer*. It is a general term which applies to both *water table* and *confined aquifers*. A water table is the potentiometric surface of an *unconfined aquifer*,[73]

[68] Moore, n 12, pp 3-4.
[69] Moore, n 12, p 3.
[70] Moore, n 12, pp 156.
[71] Schwalbaum, n 1, p 175.
[72] Oregon Water Science Centre, n 7.

- The surface that represents the level to which water will rise in tightly cased bores/wells.[74]

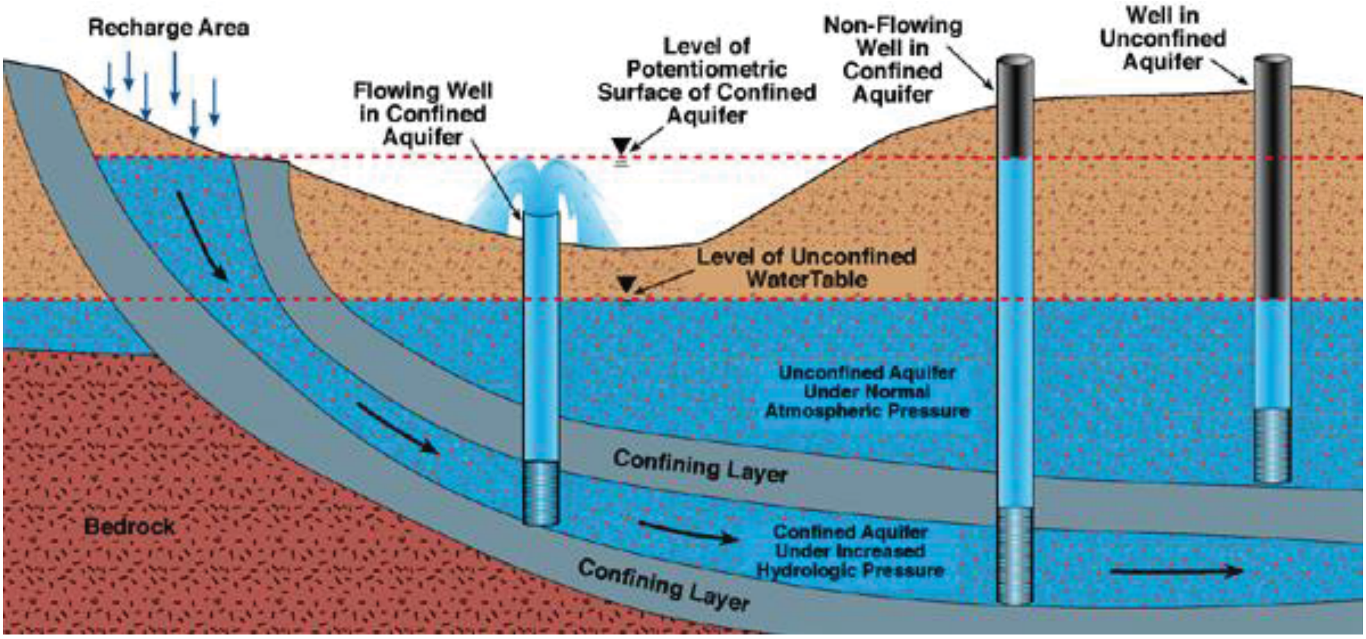

Figure 7: Potentiometric surface and flowing bores/wells[75]

pumping test:

- A test made by pumping a bore/well for a period of time and observing the change in *hydraulic head* in the *aquifer*. A pumping test may be used to determine the capacity of the bore/well and the hydraulic properties of the *aquifer*.[76]

recharge:

- 1) The transfer of water to an aquifer (usually through rainfall). 2) The water which is added to an aquifer.[77]

recharge area:

- That portion of land which allows infiltration into an aquifer.[78]

saturated zone:

- The portion of an *unconfined aquifer* below the *water table*.[79]

[73] Schwalbaum, n 1, p 176.
[74] Moore, n 12, p 156 (references omitted).
[75] Source: Ohio Department of Natural Resources.
[76] Moore, n 12, p 157.
[77] Schwalbaum, n 1, p 176.
[78] Schwalbaum, n 1, p 176.
[79] Schwalbaum, n 1, p 176.

semi-confining unit:

- In reality, all confining units are semi-confining in the sense that a small quantity of water can always leak through. The term semi-confining unit is sometimes used to describe a relatively leaky confining unit.[80]

syncline: (contrast *anticline*)

- In structural geology, a **syncline** is a fold with younger layers closer to the center of the structure. Synclines are typically a downward fold, termed a synformal syncline (i.e. a trough); but synclines that point upwards, or perched, can be found when strata have been overturned and folded (an antiformal syncline).[81]

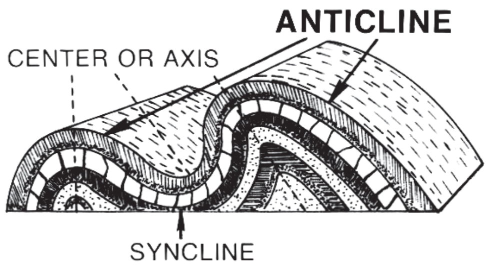

Figure 10: Diagram of syncline and anticline (see also photograph in Figure 1(b)).

unconfined:

- A condition in which the upper surface of the zone of saturation forms a water table under atmospheric pressure.[82]

unconfined aquifer:

- An *aquifer* which has a *water table*.[83]

- An *aquifer* in which the *groundwater* is exposed to atmospheric pressure through openings (pore spaces) in the overlying material. Same as *water table aquifer*.[84]

unconsolidated:

- Applied to particles that are loose and not cemented together.[85]

unsaturated zone:

- The portion of an unconfined aquifer above the water table.[86]

water table:

- The upper surface of a zone of saturation except where that surface is formed by a confining unit.[87]

- The surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.[88]

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[80] Schwalbaum, n 1, p 177.
[81] Source (including image in Figure 10): Wikepedia, http://en.wikipedia.org/wiki/Syncline
[82] Oregon Water Science Centre, n 7.
[83] Oregon Water Science Centre, n 7.
[84] Schwalbaum, n 1, p 178.
[85] Allaby, n 31, p 601.
[86] Schwalbaum, n 1, p 178.
[87] Oregon Water Science Centre, n 7 (references omitted).
[88] Schwalbaum, n 1, p 179.