North Wambo Underground Mine Longwall 10A Modification

Groundwater Assessment -

Responses to NSW Office of Water Concerns

FOR

Wambo Coal Pty Ltd

BY

Dr N.P. Merrick

Heritage Computing Pty Ltd

trading as

HydroSimulations

Project number: WAM009

Report: HC2015/010

Date: 4 March 2015

INTRODUCTION

Peabody Energy is awaiting determination of the North Wambo Underground Mine - Longwall 10A Modification. The Modification went on public exhibition in October 2014.

This report has been prepared in response to issues raised by the NSW Office of Water (NOW) in a number of meetings and in a series of documents, the latest of which is dated 11 February 2015, marked as Attachment A to a letter from Mitchell Isaacs (Manager Strategic Stakeholder Liaison) to Matthew Sprott (Senior Planning Officer - Mining Projects, NSW Department of Planning and Environment).

In essence, the opinion of the NOW is:

1. "There remains a significant risk the proposed modification could substantially increase the impact of the project on surface and groundwater resources."
2. "The Office of Water does not support the outcomes of the proponent's groundwater modelling."

The purpose of this report is to further demonstrate that the objections of the NOW have no foundation.

The documentation on the groundwater assessment is contained within the following reports:

1. HydroSimulations, 2014, North Wambo Underground Mine Longwall 10A Modification: Groundwater Assessment. HydroSimulations report HC2014/020 for Wambo Coal Pty Ltd, 5 September 2014.
2. HydroSimulations, 2014, North Wambo Underground Mine Longwall 10A Modification: Groundwater Assessment - Response to Draft Submission from the NSW Office of Water. HydroSimulations report HC2014/035 for Wambo Coal Pty Ltd, 9 November 2014.
3. HydroSimulations, 2015, North Wambo Underground Mine Longwall 10A Modification: Groundwater Assessment - Response to NSW Office of Water. HydroSimulations report HC2015/002 for Wambo Coal Pty Ltd, 21 January 2015.

The main features of Document #2 were:

1. An assurance that cumulative assessment of approved Arrowfield and Bowfield Seam mining had been undertaken and reported in Document #1.
2. An assurance that Wambo Seam extraction had been considered as a multi-seam operation, and the requested correction was not required.
3. Illustration of the extent of assumed fracturing in the groundwater model along five transects.
4. Confirmation that the fracturing represented in the model is definitely conservative, as all intervening interburden zones between mined coal seam pairs are fully fractured.

The main features of Document #3 were:

1. An explanation of the mathematics for the ramp function for vertical hydraulic conductivity across a fractured zone.
2. Provision of the ramp function end points.
3. Illustration of recovery hydrographs at a representative location above Longwall 10A. At this location, upflow from Permian strata to alluvium is expected to commence about 70 years after the cessation of mining, when the Upper Permian head first exceeds the Alluvium head. At 200 years, the water table in the alluvium is predicted to remain about 8.5 m below current ground level and to remain below maximum subsided ground level.
4. Additional modelling for pre-mining conditions. This shows significantly less upward head difference (3m) 200 years after completion of mining than would have occurred naturally (9m) before any mining commenced in the district.
5. An assertion that the risk of change in beneficial use of groundwater in the alluvium near Longwall 10A, compared to pre-mining conditions, is expected to be low.

In this report, the following additional work is presented:

1. Additional modelling of the recovery phase for an extreme fractured zone scenario, using hydraulic conductivity favoured by the NOW.
2. Quantification of the likely change in alluvial groundwater salinity.
3. Quantification of the degree of impact on the salinity of surface water in Wollombi Brook.

Items #2 and #3 aim to address the specific water quality minimal harm considerations of highly productive alluvial water sources in the Aquifer Interference Policy:

a. "Any change in the groundwater quality should not lower the beneficial use category of the groundwater source[1] beyond 40m from the activity."
b. "No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source[2] at the nearest point to the activity. "

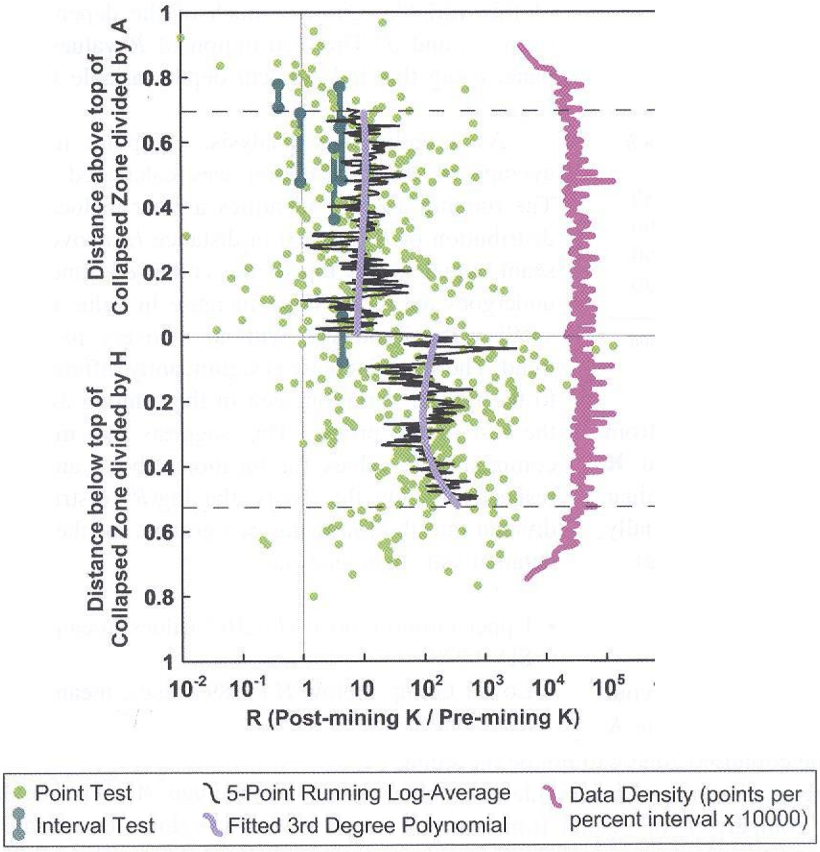
Note that Rule (a) applies only to a groundwater source, and Rule (b) applies only to a surface water source.

ADDITIONAL MODELLING

The NOW Attachment A (February 2015) stated: "The Kz max values applied in the model are constrained to very low values as not to be consistent with the textural description of the A fracture zone."

A very recent paper by Tammetta (2015)[3] shows that *in situ* permeability enhancement in a fractured zone is only a factor (R) of 100 or so (±1 order of magnitude); reproduced below.

[1] Emphasis added
[2] Emphasis added
[3] Tammetta, P., 2015, Estimation of the Change in Hydraulic Conductivity above Mined Longwall Panels. *Groundwater*, vol.53, no.1, Jan-Feb 2015, 122-129.



The NOW is of the view that fractured zone hydraulic conductivities in the order of 1 m/day are appropriate, and cited one instance of adoption of this value for the Russell Vale Colliery model. However, the same model has instances of maximum values of $1x10^{-6}$ to $3x10^{-4}$ m/d for different mined seams. The values adopted in the Wambo model are constrained by calibration to very low observed mine inflows. Such high values (about 1 m/day) are inadmissible.

Nevertheless, a model has been prepared with 1 m/day as the maximum value in each fractured zone. The ramp functions for the Calibrated Model and the Extreme Model are illustrated in **Figure 1**.

The Calibrated model has a maximum R-multiplier of 73, consistent with the Tammetta database, while the Extreme model has a maximum R-multiplier of 909,000.

The Extreme Model also accounted for the final cumulatively subsided ground surface along Longwall 10A.

LONG-TERM RECOVERY

To examine the timing of upflow from Permian strata to alluvium, which could create a water quality impact, a synthetic monitoring bore has been placed in the model at the location marked "LW10A" in **Figure 2**. The groundwater hydrographs in **Figure 3** show that upflow would be expected to commence about 70 years after the cessation of mining for the Calibrated model, and at about 110 years for the Extreme model.

It is noted that the three Permian hydrographs coalesce 15 years after mining finishes, due to the assumed very high vertical connectivity between the strata.

For the Calibrated model, all heads remain below the current ground level. For the Extreme model, the Permian heads are marginally artesian (above the subsided ground level), but the water table in the alluvium remains about 5 m below the subsided ground level at this location. This means that there would be no surface expression of the water table at this location.

Figure 4 shows the topographic profiles along Longwall 10A for current conditions (after Whybrow Seam workings), after Wambo Seam mining, and after Arrowfield-Bowfield Seams mining. The simulated water table along this transect (200 years after mining) is illustrated for both models. Only along the north-eastern half of the panel would the water table reach final ground surface. In this location, about 100 years after cessation of mining, Permian groundwater would reach the cumulatively subsided land surface. The broader water quality impacts for both models are quantified below.

ALLUVIAL GROUNDWATER SALINITY

This section examines the water quality impact of salt gains by the alluvial aquifer from Permian upflow and salt losses to the Permian strata from the alluvial aquifer.

Representative salinities of alluvial and Permian groundwaters are required for this analysis. The results of a statistical analysis of local data, summarised in **Table 1**, show that the median alluvial water salinity is about 500 mg/L and the median Permian water salinity is about 3,000 mg/L.

Table 1. Statistical Analysis of Electrical Conductivity (EC) Measurements at Wambo

STATISTIC	ALLUVIUM EC (µS/cm)	PERMIAN EC (µS/cm)
Number of Records	893	297
MIN	0	0
MEAN	2477	5178
STDEV	3479	2665
MAX	22300	16200
PERCENTILE_10	484	2347
PERCENTILE_25	574	2595
MEDIAN	745	4600
PERCENTILE_75	2943	7530
PERCENTILE_90	8158	9040
MEDIAN TDS (mg/L)[4]	500	3000

[4] Assuming EC to TDS factor 0.67

The wide range in alluvial EC values indicates a range in beneficial uses that includes potable (0 - 781 µS/cm), marginal potable (to 2,344 µS/cm), irrigation (to 7,813 µS/cm), and saline(to 21,875 µS/cm)[5]. The only beneficial use categories for Permian groundwater are irrigation and saline. The median alluvial water salinity lies close to the potable / marginal potable boundary, but the mean value lies beyond marginal potable in the irrigation category. For Permian groundwater, the median and mean both reside in the irrigation category.

The upwards and downwards salt loads have been calculated for pre-mining conditions and for recovered conditions (for both models) as:

$$SL = Q * C$$

where *SL* is salt load; *Q* is upflow or downflow; and *C* is concentration (salinity).

To convert salt load into changes in average salinity throughout the alluvial extent shown in **Figure 2**, the following facts and assumptions are used:

- Alluvium baseline salinity = 500 mg/L.
- Permian baseline salinity = 3,000 mg/L.
- Alluvium area = 1.09 x 10^7 m^2.
- Alluvium thickness = 10 m.
- Saturated alluvium thickness = 4 m.
- Porosity = 0.2
- Volume of saturated alluvium = 4.36 x 10^7 m^3.
- Volume of groundwater in alluvium = 8.72 x 10^6 m^3.
- Saturated alluvium salt content = 4,360 tonnes.

Figure 5 shows that, due to a net loss in salt from the alluvial aquifer for about 100 years after cessation of mining (assuming the saturated alluvium volume is maintained by recharge with fresher water), the salinity in the alluvium would reduce a little. After 200 years, due to eventual net upflow from Permian strata, the average salinity would rise to about 3 percent above what would occur naturally without mining. The baseline value of 500 mg/L would be expected to rise to about 515 mg/L, and stabilise near that level.

There is no significant difference in response for the alternative models (Calibration and Extreme). As the marginal potable beneficial use category is defined as 500-1,500 mg/L (MDBC, 2005), no lowering of the beneficial use category would occur.

Accordingly, the first of the water quality minimal harm considerations for highly productive alluvial water sources is satisfied:

> *"Any change in the groundwater quality should not lower the beneficial use category of the <u>groundwater source</u> beyond 40m from the activity."*

[5] Murray Darling Basin Commission (MDBC), 2005, *National Land and Water Resources Audit*.

WOLLOMBI BROOK SALINITY

This section examines the water quality impact of salt gains by Wollombi Brook from lateral alluvial groundwater discharge, and salt losses to the alluvial aquifer from Wollombi Brook.

Representative salinities of alluvial groundwater and brook water are required for this analysis. **Table 1** demonstrates that the median alluvial groundwater salinity is about 500 mg/L. **Table 2** records a range of mean salinities from 346 mg/L at SW04 (near Longwall 10A) to 1,035 mg/L at SW02.

Table 2. Reported EC and TDS Measurements at Wollombi Brook

SAMPLING SITE	LOCATION	BROOK MEAN EC (µS/cm)	BROOK MEAN TDS (mg/L)
SW01	Upstream	816	463
SW02	Downstream	1,860	1,035
SW03	Pump Out	1,790	975
SW04	Upstream of SWC; nearest LW10A	621	346

Source: Wambo Coal Pty Limited, 2010, *Wambo Coal Environmental Management System*: *Surface Water Monitoring Program*. Revision 4, January 2010.

The salt load in the brook gained through baseflow and the salt load lost from the brook through leakage have been calculated for pre-mining conditions and for recovered conditions (for both models) as:

$$SL = Q * C$$

where *SL* is salt load; *Q* is baseflow or leakage; and *C* is concentration (salinity), assuming:

- Alluvium baseline salinity = 500 mg/L.
- Wollombi Brook baseline salinity = 346 mg/L[6].

Pre-mining, Wollombi Brook is naturally a losing system overall. The pre-mining model estimates a baseflow (in gaining reaches) of about 0.6 ML/day and a leakage (in losing reaches) of about 1.0 ML/day. The net natural salt loss is estimated to be about 34 kg/day, or about 12 t/year.

At 200 years after cessation of mining, the Calibration model estimates a baseflow (in gaining reaches) of about 0.35 ML/day and a leakage (in losing reaches) of about 1.3 ML/day. The net salt loss is estimated to be about 308 kg/day, or about 113 t/year[7]. Similarly, the Extreme model estimates a baseflow of about 0.37 ML/day and a leakage of about 1.3 ML/day. The net salt loss is estimated to be about 317 kg/day, or about 116 t/year[8].

Figure 6 shows the net salt loss with time during recovery after mining, over and above what would be expected to occur naturally without mining.

---

[6] A sensitivity analysis for 1,000 mg/L was conducted.
[7] Sensitivity result: 173 t/year.
[8] Sensitivity result: 178 t/year.

There is no significant difference in response for the alternative models (Calibration and Extreme). As Wollombi Brook remains a net exporter of salt, it is not possible for the salinity in the surface water to increase due to mining.

Accordingly, the second of the water quality minimal harm considerations for highly productive alluvial water sources is satisfied:

> *" No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity."*

SUMMARY

Peabody Energy is awaiting determination of the North Wambo Underground Mine - Longwall 10A Modification. The Modification went on public exhibition in October 2014.

This report has been prepared in response to issues raised by the NSW Office of Water, the latest ones being:

1. "There remains a significant risk the proposed modification could substantially increase the impact of the project on surface and groundwater resources."
2. "The Office of Water does not support the outcomes of the proponent's groundwater modelling."

The issues have been addressed in this report and in previous reports by:

- Confirming that the modelling has always accounted for the effects of cumulative subsidence resulting from multi-seam mining.
- Demonstrating that the adopted fractured zone heights in the groundwater model are conservative.
- Testing the Office of Water hypothesis of extremely permeable fractured zone material by setting up a model variant called the "Extreme model" in which the maximum vertical hydraulic conductivity has been increased by a factor of nearly 1 million (as distinct from the "Calibrated model" in which the maximum enhancement factor is about 70).
- Allowing for the cumulatively subsided ground surface above Longwall 10A in the Extreme model.
- Quantifying the likely change in alluvial groundwater salinity.
- Quantifying the degree of impact on the salinity of surface water in Wollombi Brook.

As the likely change in the alluvial groundwater salinity is expected to be in the order of 3 percent[9], no alteration in the beneficial use category can be expected.

With respect to the surface water in Wollombi Brook, the groundwater models demonstrate that the brook is naturally a net losing system and would remain a net losing system. It is naturally a net exporter of salt and would remain a net exporter of salt. Consequently, it is not possible for mining to induce any increased salinity in the surface water of the brook.

[9] Note: this should not be confused with the 1 percent rule for surface water impact.

In terms of the water quality minimal harm considerations of the Aquifer Interference Policy, which are understood to be the main remaining issues for the Office of Water, it has been demonstrated that the North Wambo Underground Mine Longwall 10A Modification complies with Level 1 for both rules:

a. "Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity."
b. "No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. "

There is no material change to the environmental consequences when the Office of Water's preferred extreme hydraulic conductivity values are applied to the groundwater model.

It is concluded, therefore, that the Longwall 10A Modification could not be considered to have a significant impact on water quality in the alluvial water source or the salinity in Wollombi Creek.

Any quantitative water losses ("takes") due to mining can be accounted for through groundwater licensing in accordance with the Aquifer Interference Policy.

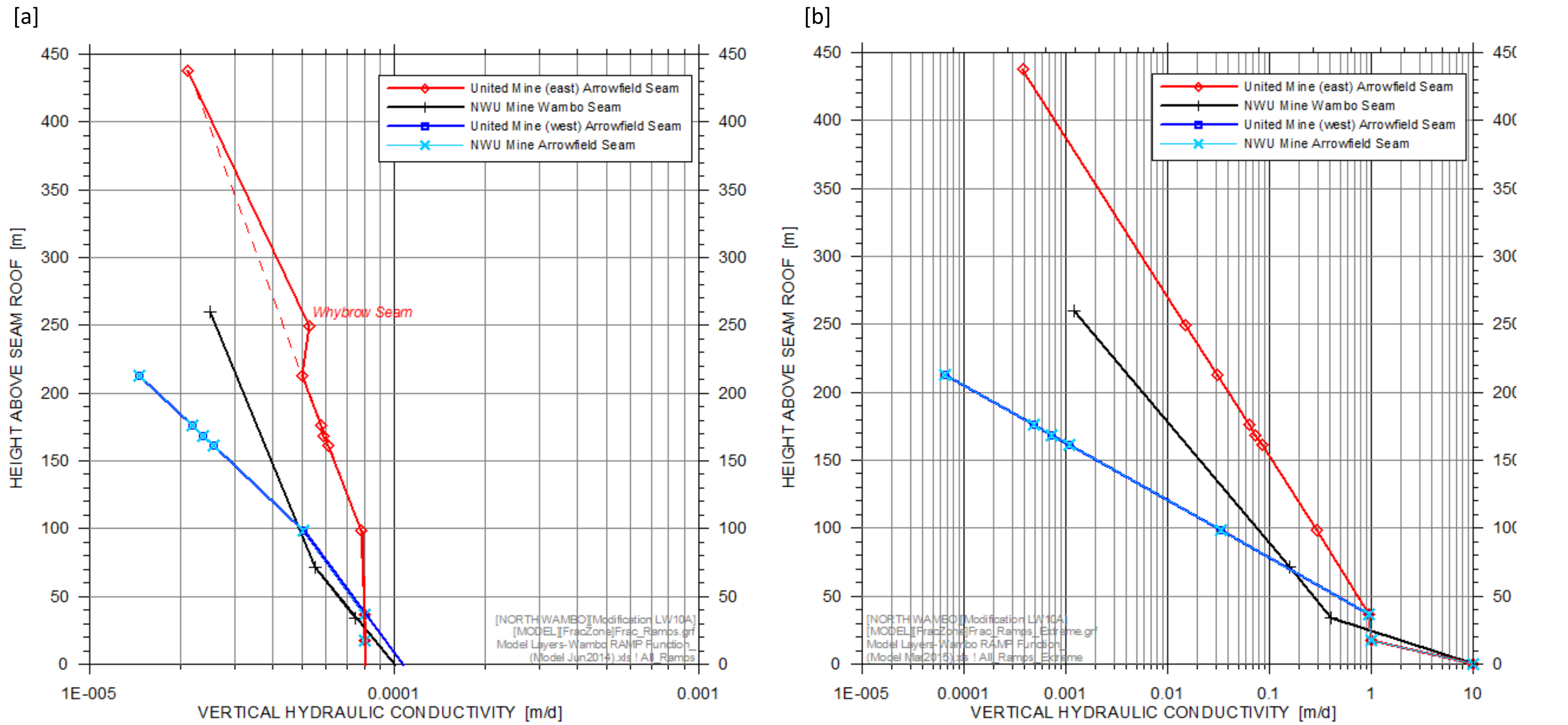


Figure 1. Ramp functions applied in the Wambo regional groundwater model [a] Calibration model; [b] Extreme model

[Bowfield would have lines from (1,39) to (10,21) to (1,10) to (10,0) for the Extreme model]

[Bowfield would have lines from (8E-5,39) to (10,21) to (1E-4,10) to (10,0) for the Calibrated model]

Figure 2. Location of the synthetic monitoring bore LW10A within the alluvial extent represented in the Wambo regional groundwater model

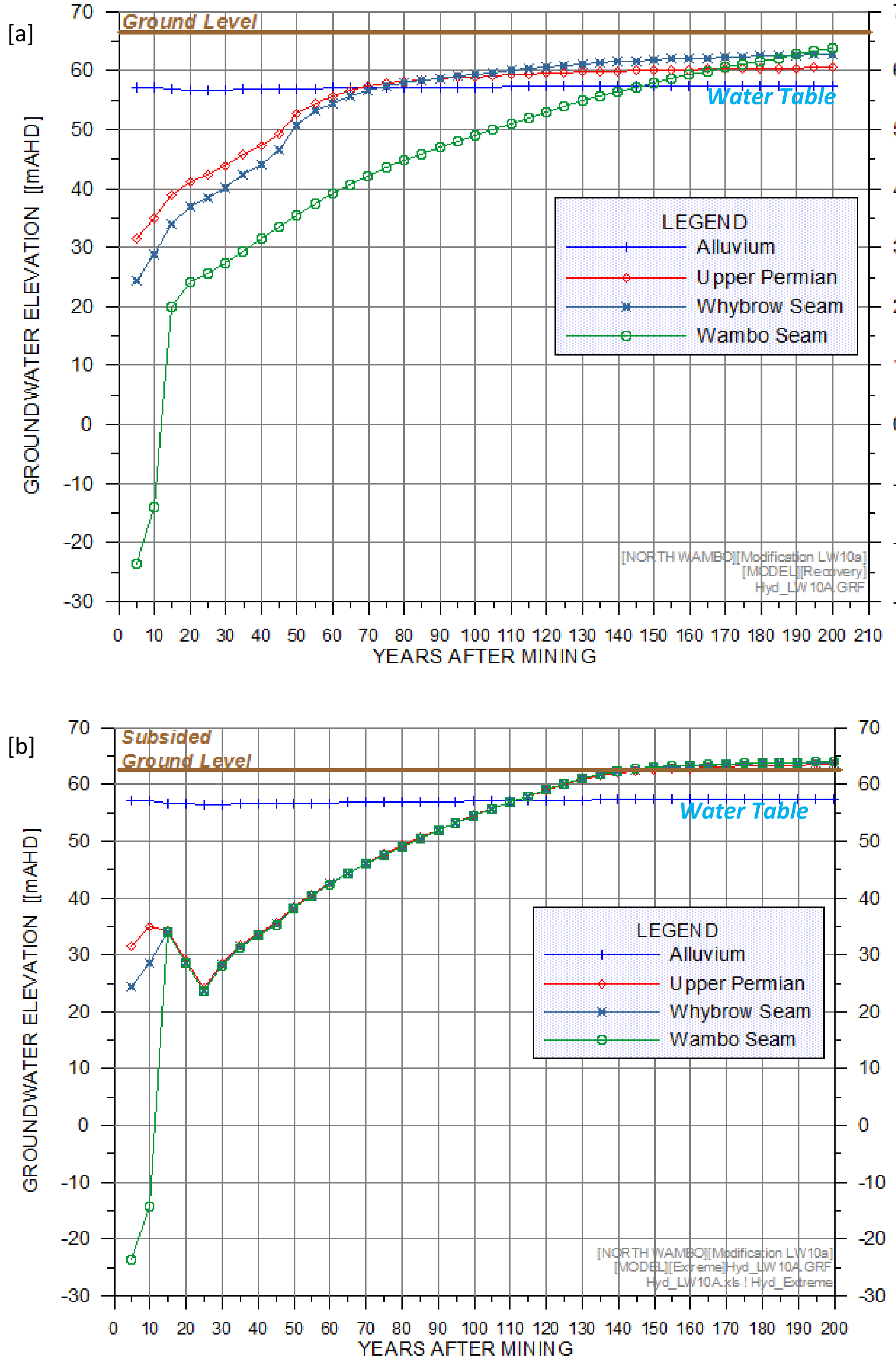


Figure 3. Recovery hydrographs at synthetic monitoring bore LW10A [a] Calibration model; [b] Extreme model

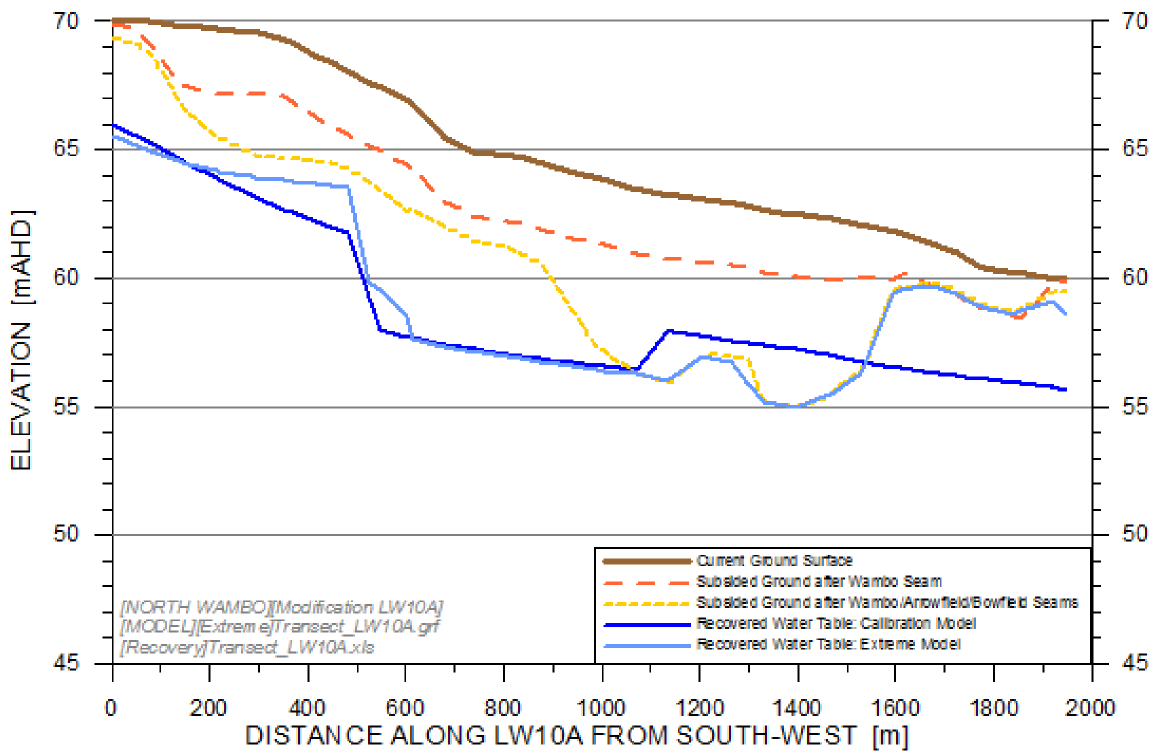


Figure 4. Ground surface and water table elevations from west to east along Longwall 10A for the Calibration model and the Extreme model (at 200 years after mining)

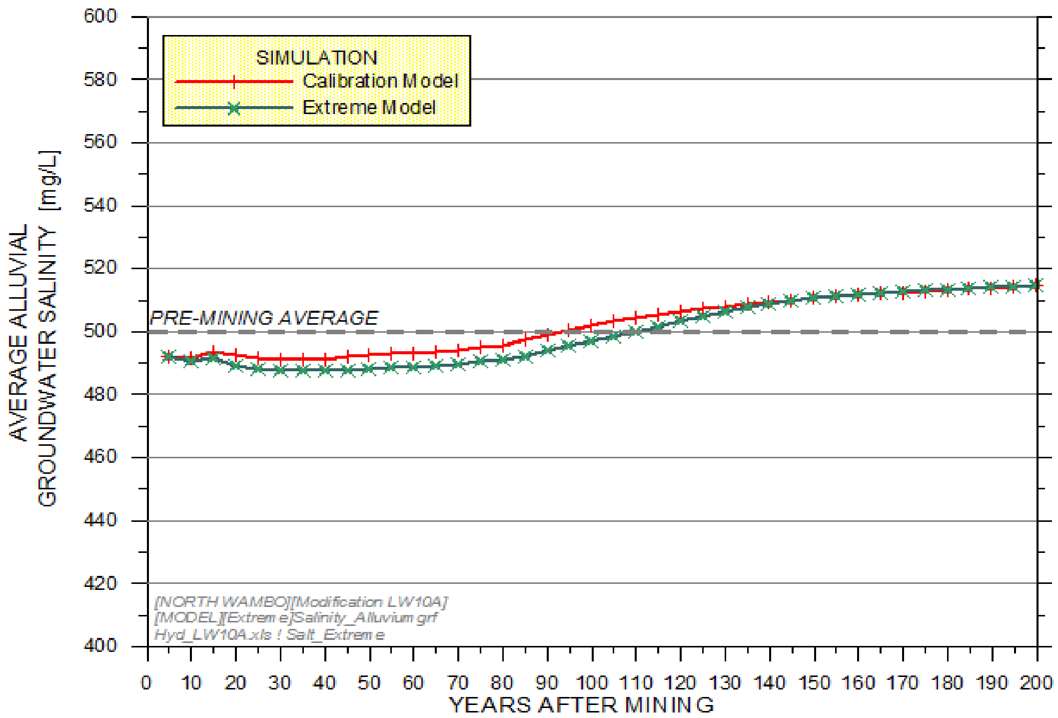


Figure 5. Recovery hydrographs for average alluvial groundwater salinity for the Calibration model and the Extreme model

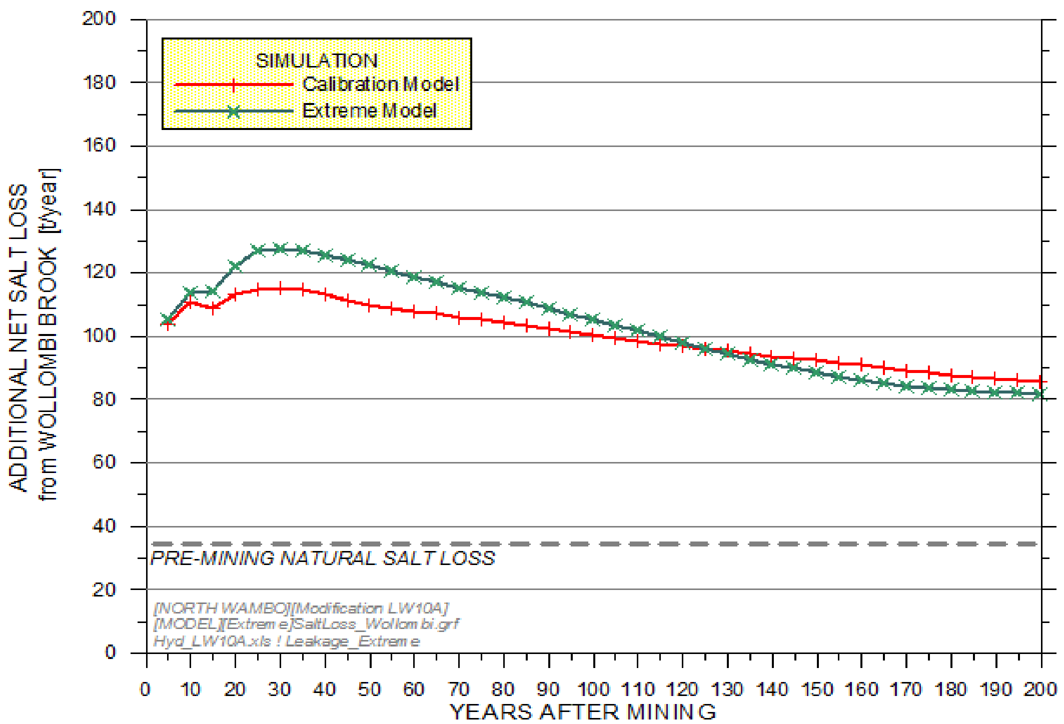


Figure 6. Wollombi Brook salt exchange for the Calibration model and the Extreme model