AN APPRAISAL OF GROUNDWATER CONDITIONS IN THE VICINITY OF THIRLMERE LAKES, NSW

FOR

TAHMOOR COAL PTY LTD
LEVEL 5, 17 CASTLEREAGH STREET
SYDNEY NSW 2000

By

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Report Number: HC2012/3
Date: March 2012
# DOCUMENT REGISTER

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EXECUTIVE SUMMARY

This report provides an independent appraisal of groundwater conditions in the vicinity of Thirlmere Lakes, which are located about 10 km south-west of Picton, New South Wales. Separate prior appraisals have been completed and issued by the NSW Office of Water (December 2010) and Pells Consulting (October 2011).

The motivation for another appraisal was provided by the NSW Government's announcement on 25 October 2011 of an Independent Inquiry into the "recent reduction of water levels in the Thirlmere Lakes".

This appraisal concludes that the major cause for the observed decline in lake levels is attributable to climate, with mining possibly having a marginal effect.

Analysis of the climate record since 1889 has corroborated the observation that the district has been experiencing drought conditions dating from 1992. Elsewhere in New South Wales, the drought dates from 2000. Also, unlike other areas in the State, the severity of the drought appears similar to the 1935-1949 depression/war drought, the worst on record. Temperature trend analysis has shown an unprecedented change in behaviour since 2000 with coincident steady rises in both maximum and minimum residual masses.

The lakes, on average, act as a naturally losing system under both dry and wet conditions. This is contrary to earlier conceptualisations that the lakes are primarily receiving groundwater, rather than leaking water continuously into the aquifer system.

Careful construction of a 3D geological model has shown that there is a substantial buffer, in the order of 100 m, between the floor of Lake Nerrigorang and the roof of the Bald Hill Claystone. Consequently, it is highly improbable that the observed drying out of Lake Nerrigorang is due to erosion of the Bald Hill Claystone as postulated in the Pells Report. The geological model also shows that the Bald Hill Claystone has a thickness of about 20 metres beneath the lakes. It is not a thin impermeable layer, but a thick aquitard that impedes the transmission of water.

There are clear transitory mining effects on groundwater levels in Hawkesbury Sandstone at sites close to mining, but there are no observed mining effects on groundwater levels in Hawkesbury Sandstone at monitoring network sites distant from mining. The piezometer (P8) closest to the Bargo River has been unaffected by mining 400 m away (Longwall 25), and the Bargo River has exhibited no ill effects in this area.

There is no available potentiometric data to enable the determination of the vertical hydrological regime at depth below the Thirlmere Lakes. It is conceivable that there would be depressurisation of the underlying Bulli Coal seam as a result of underground mining but without potentiometric and permeability data for the intervening strata, no accurate assessment of the potential for increased leakage from the lakes can be undertaken.

The available hydrological and hydrogeological data are insufficient to enable an accurate assessment of the cause of the recent drying of the Thirlmere lakes. However, it is clear that the recent drought conditions have been a significant factor if not entirely responsible for the current lake levels. The significant insufficiency of surface water monitoring data precludes the definitive inclusion of any influence other than the drought conditions and possible illegal pumping impacting on the lake water levels. The installation of a surface water and
groundwater monitoring (multi-level piezometer) network in near proximity to the lakes would be required to definitively assess the Thirlmere Lakes hydrological regime.

While it is possible that mining could have had a marginal effect on groundwater levels beneath the lakes, there is no definitive evidence that this has occurred. On the other hand, there is clear evidence for the drying of the lakes being coincident with a severe drought.
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1.0 INTRODUCTION

This report provides an independent appraisal of groundwater conditions in the vicinity of Thirlmere Lakes, which are located about 10 km south-west of Picton, New South Wales. Separate prior appraisals have been completed and issued by the NSW Office of Water (December 2010) and Pells Consulting (October 2011). Respectively, these appraisals will be referenced here as the NOW Report and the Pells Report.

The motivation for another appraisal was provided by the NSW Government's announcement on 25 October 2011 of an Independent Inquiry into the "recent reduction of water levels in the Thirlmere Lakes".

This report acknowledges the substantial effort underpinning the NOW Report and the Pells Report. Given the limited timeframe in which to prepare material for consideration by the Independent Inquiry members, no attempt is made to duplicate previous work. Instead, the focus will be on clarification of previous work where necessary, introduction of some new insights and discussion on points of difference.

1.1 SCOPE OF WORK

The key tasks for this appraisal are:

- Review and analysis of the NOW and Pells reports;
- Assessment of the impact or potential impact of operations at Tahmoor Colliery on Thirlmere Lakes; and
- Consideration of other relevant issues.

1.2 DOCUMENTS AND DATA SOURCES

The appraisal in this report has considered the following primary documentation:


4. Tahmoor Colliery End of Panel Monitoring Reports for Longwalls 22 to 25. By Mine Subsidence Engineering Consultants (MSEC) and GeoTerra Pty Ltd.

For this appraisal, Tahmoor Coal Pty Ltd (TCPL) has made available substantial datasets on general mining operations and monitoring data.

### 2.0 HYDROGEOLOGY

A semi-regional extent has been adopted for this appraisal, as indicated in Figure 1 which extends 16 km east-west and 23 km north-south. The land surface topography in Figure 1 shows elevated land along the western edge in excess of 400 mAHDD grading down to less than 100 mAHDD in the central-east. The valley that hosts the Thirlmere Lakes is generally 300-310 mAHDD.

#### 2.1 GEOLOGY

The Thirlmere Lakes are hosted by a narrow alluvial channel that leads into Blue Gum Creek. The alluvial deposit overlies Hawkesbury Sandstone of Triassic age (<225 million years ago) which in turn overlies sandstones and claystones of the Narrabeen Group, also of Triassic age. In places throughout the study area there is, as shown in Figure 2, a capping of younger shale-dominated Wianamatta Group exposures over Hawkesbury Sandstone, the dominant outcropping lithology.

The study area lies within the Southern Coalfield in the southern part of the Sydney Basin (Moffitt, 2000), which is infilled with sedimentary rocks of Permian age (<270 million years ago) beneath those of Triassic age. The majority of mining in the Southern Coalfield extracts coal from the Bulli or Wongawilli Seams within the Illawarra Coal Measures. At the Tahmoor Colliery, only the Bulli Seam is mined. The Narrabeen Group immediately overlies the uppermost Bulli Coal unit.

Regional and local surface geology maps are included in the NOW Report and the Pells Report.

There are several known major and minor structures (e.g. faults or fault systems) in the vicinity, including the following (Figure 2):

- Nepean Fault Zone;
- Bargo Fault;
- T2 Fault Zone (as named in the Pells Report);
- T1 Fault (as named in the Pells Report);
- Central Fault;
- Western Fault; and
- Eastern Fault.

The Nepean Fault Zone is the only hydraulically charged geological structure encountered during mining to date.
2.2 STRATIGRAPHY

The general stratigraphy and facies changes across the Narrabeen Group from the Southern Coalfield to the Western Coalfield are illustrated in Figure 3. An adequate lithological description of the major formations is provided in the NOW Report.

This appraisal has examined 127 exploration bore records in the study area and has generated structural contours for the floor of each formation. In particular, median thicknesses have been determined for each formation, as listed in Table 1. The locations of the exploration bores are marked on Figure 4. The exploration bores include the following to the west of the lakes:

- CPN5, CPN6, CPN8 and CPN11 drilled by J.H. Houben Pty Ltd for Central Pacific Minerals N.L. in 1969; and
- PMX1, PMX2, PMX3 and PMX4 drilled by Pacminex Pty Ltd (Mollan, 1973).

Table 1. Typical Formation Elevations and Thicknesses

<table>
<thead>
<tr>
<th>FORMATION</th>
<th>MEDIAN FLOOR ELEVATION [mAHD]</th>
<th>MEDIAN THICKNESS [m]</th>
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<tr>
<td>Ground Surface</td>
<td>298</td>
<td>-</td>
</tr>
<tr>
<td>Wianamatta Group</td>
<td>248</td>
<td>50</td>
</tr>
<tr>
<td>Hawkesbury Sandstone</td>
<td>111</td>
<td>187</td>
</tr>
<tr>
<td>Bald Hill Claystone</td>
<td>88</td>
<td>16</td>
</tr>
<tr>
<td>Bulgo Sandstone</td>
<td>-92</td>
<td>180</td>
</tr>
<tr>
<td>Stanwell Park Claystone</td>
<td>-97</td>
<td>5</td>
</tr>
<tr>
<td>Scarborough Sandstone</td>
<td>-113</td>
<td>16</td>
</tr>
<tr>
<td>Wombarra Claystone</td>
<td>-120</td>
<td>7</td>
</tr>
<tr>
<td>Bulli Seam</td>
<td>-122</td>
<td>2</td>
</tr>
<tr>
<td>Eckersley Formation</td>
<td>-141</td>
<td>19</td>
</tr>
<tr>
<td>Wongawilli Seam</td>
<td>-153</td>
<td>11</td>
</tr>
</tbody>
</table>

The Bald Hill Claystone plays a prominent role as an aquitard separating the Hawkesbury Sandstone from the Narrabeen Group. As the latter is depressurised by underground mining, the integrity of the Bald Hill Claystone is important in protecting the Hawkesbury Sandstone from significant depressurisation and subsequent potential impacts on lakes and watercourses.
hosted in the Hawkesbury Sandstone. The effectiveness of the Bald Hill Claystone as a barrier, or seal, will reduce if:

- The formation is thin;
- The formation has sandy inclusions; or
- The depth of cover is small (from the bottom of the lakes to the top of the claystone).

While Table 1 shows the typical thickness of the Bald Hill Claystone to be about 16 m regionally, it will vary spatially. The Pells Report states that its "thickness beneath the Thirlmere Lakes is interpreted as about 20m to 25m". To allow an appreciation of spatial variability, the individual thickness at each exploration bore is marked on Figure 5 and interpolated thickness contours are shown in Figure 6. In the vicinity of the lakes, the claystone thickness is inferred to be about 20 m (± 5 m). There is a distinct thinning of the claystone to about 10 m to the immediate east of Lake Couridjah over the Tahmoor mine workings, but the claystone appears to thicken to about 25 m to the east of Lake Gandangarra and to the west of the lake system.

The minimum recorded Bald Hill Claystone thickness is 4.5 m. It exceeds 8 m in 90 percent of records and is more than 25 m thick in 10 percent of records. Other statistics are listed in Table 2.

Table 2. Bald Hill Claystone Thickness Statistics [based on 114 samples]

<table>
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<th>STATISTIC</th>
<th>BALD HILL CLAYSTONE THICKNESS (m)</th>
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<tr>
<td>Minimum</td>
<td>4.5</td>
</tr>
<tr>
<td>90% Exceedance</td>
<td>8.1</td>
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<tr>
<td>75% Exceedance</td>
<td>11.9</td>
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<td>Median</td>
<td>15.5</td>
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<tr>
<td>25% Exceedance</td>
<td>21.0</td>
</tr>
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<td>10% Exceedance</td>
<td>25.4</td>
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<tr>
<td>Maximum</td>
<td>34.0</td>
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The depth of cover, from ground surface to the roof of the Bald Hill Claystone, is more than 75 m at the western lakes and about 100 m at the eastern lakes (Figure 7). Where mining has occurred to the immediate east of the lakes, the depth of cover is generally 150 m.

Mining of the Bulli Seam to the east of the lakes has occurred at a depth of more than 350 m in general (Figure 8). At the lakes, the depth of cover for the Bulli Seam ranges from 300 m to 350 m.
Stratigraphic picks from the 127 exploration bores, supplemented by Base of Narrabeen contours on the 1:100000 Southern Coalfield Regional Geology Map, have allowed construction of a three-dimensional (3D) geological model. Two west-east cross-sections through the lakes at northings 6210500 and 6209500 are illustrated in Figure 9. They show a consistent dip of all formations from west to east, with Bald Hill Claystone about 100 m below the lakes.

The Pells Report suggests a cover of only about 50 m beneath Lake Nerrigorang and about 75 m at Lake Werri Berri. The postulated thin cover at Lake Nerrigorang provides a basis for his assumed breaching of the Bald Hill Claystone by ancient erosion prior to deposition of lake sediments. This is put forward as a possible explanation for the observed dewatering of this lake earlier than the eastern lakes, as the breach could open up a path for transmission of depressurisation effects from deep mining. However, the analysis presented here shows a much greater depth of cover beneath Lake Nerrigorang.

In Figure 9, the cross-section on the left matches the northing of the section in Figure 3.3 of the Pells Report. Figure 10 compares the geological model section with the Pells section, approximately to the same scale. They agree quite well, except that the Pells section has about 50 m less depth of cover.

### 2.3 CLIMATE TRENDS

The Picton Council Depot (Station 68052) has daily climate records since January 1889. The long-term averages for key climate parameters, given in Table 3, show that the average annual evaporation (1471 mm) has been 45 percent higher than the average annual rainfall (806 mm).

Table 3. Picton climate averages (*January 1889 to December 2011*)

<table>
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<tr>
<th>MONTH</th>
<th>RAIN [mm]</th>
<th>EVAPORATION [mm]</th>
<th>MINIMUM TEMPERATURE [°C]</th>
<th>MAXIMUM TEMPERATURE [°C]</th>
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<tr>
<td>January</td>
<td>88</td>
<td>189</td>
<td>16</td>
<td>28</td>
</tr>
<tr>
<td>February</td>
<td>92</td>
<td>151</td>
<td>16</td>
<td>28</td>
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<tr>
<td>March</td>
<td>88</td>
<td>135</td>
<td>14</td>
<td>26</td>
</tr>
<tr>
<td>April</td>
<td>69</td>
<td>98</td>
<td>11</td>
<td>23</td>
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<tr>
<td>May</td>
<td>59</td>
<td>69</td>
<td>7</td>
<td>20</td>
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<td>June</td>
<td>66</td>
<td>53</td>
<td>5</td>
<td>17</td>
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<tr>
<td>July</td>
<td>49</td>
<td>62</td>
<td>3</td>
<td>16</td>
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<tr>
<td>August</td>
<td>45</td>
<td>87</td>
<td>4</td>
<td>18</td>
</tr>
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<td>September</td>
<td>45</td>
<td>116</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>October</td>
<td>62</td>
<td>147</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td>November</td>
<td>74</td>
<td>166</td>
<td>12</td>
<td>25</td>
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<tr>
<td>December</td>
<td>69</td>
<td>200</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>TOTAL</td>
<td>806</td>
<td>1471</td>
<td></td>
<td></td>
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<tr>
<td>AVERAGE</td>
<td>67</td>
<td>123</td>
<td>10</td>
<td>23</td>
</tr>
</tbody>
</table>
Long-term climate trends can be inferred from the datasets through a residual mass filtering process. The actual monthly value of a climate parameter is compared with its monthly average to give a residual for each month. Then the residuals are accumulated to give what is called the residual mass (RM) or the cumulative deviation from the mean (CDM). This process filters out short-term fluctuations and leaves behind only long-term trends.

The RM plots for rain and temperature are shown in Figure 11. A rising limb on a plot indicates a period when the climate indicator is above average (wetter, for rain; hotter, for temperature). Conversely, a falling limb indicates a period when the climate indicator is below average (drier, for rain; cooler, for temperature).

The rainfall RM plot shows clearly the major droughts from 1901 to 1911, 1935 to 1948 and 1992 to 2011. The recent drought appears to have set in a decade earlier than elsewhere in NSW, although there is a more severe deficit starting around 2002 in keeping with other areas. Pronounced wet periods commenced in 1949, 1973 and 1987.

The rainfall RM plots for Picton and other weather stations have been analysed in detail in the NOW Report. It is noted in that report that the volume of surface water runoff to the lakes will be reduced until the soil moisture store is replenished after a long period in rainfall deficit. Comparison is also made in the NOW Report between the Moss Vale RM plot and long-term groundwater hydrographs in the Southern Highlands. This shows sympathetic relationships that suggest groundwater declines to be the result of rainfall deficit. There are no long-term monitors close to the lakes that can be used for more localised comparison. However, comparative plots at Tahmoor Mine bores are presented in Section 2.5.

The temperature RM plots show generally mirror-image behaviour for minimum and maximum temperatures, except from 1976 onwards when the minimum temperature residual has been rising inexorably while the maximum temperature residual has been more stable. From 2000 both temperature residuals have been rising at about the same rate, coinciding in time with the duration of the most severe portion of the recent drought. While the current rate of rise in maximum temperature residual mass has been experienced before, in the 1900s for example, the rate of change in minimum temperature residual mass has no precedent in the historical climate record since 1889. For the past decade, the day-night range in temperature has been stable but the overall temperatures have increased.

For the half-century up to 1957, the day-night temperature range increased each year until a sudden reversal caused a substantial reduction in temperature range. This situation lasted until about 1964 when a pronounced night-time cooling period commenced just as suddenly.

### 2.4 Mine Inflow

The mine water make at Tahmoor Colliery is addressed in the NOW Report (their Figure 41). Since publication of the NOW Report, Tahmoor Coal has refined the assessment of mine inflow and the revised plot for recent years (since 2009) is shown in Figure 12. The net mine inflow (groundwater flowing into the mine workings which is pumped to the surface) is calculated as the sum of the pumping rates from the main drift, the mid-drift, No.2 shaft and No.3 shaft, less the potable water supply sent underground. Where measurements of the latter were unavailable, the observed average (about 40%) of total mine potable supply has been assumed. While meters have provided accurate measurements since January 2009, earlier rates are estimates based usually on pump hours and nominal pump rates. The chronology for the varying methods of estimation is covered in the NOW report.
Since 2009, the average net mine inflow has been 2.8 ML/day. Figure 12 shows a clear decline in mine inflow in recent years.

2.5 GROUNDWATER FLOW

A water table contour map has been prepared in Figure 13 based on the following sources of data:

- Three Office of Water monitoring bores installed adjacent to Lakes Gandangarra, Couridjah and Nerrigorang;
- Four shallow bores (P1, P3, P4, P5) in the Tahmoor Colliery monitoring network;
- Seven vibrating wire piezometers in the Tahmoor Colliery monitoring network installed in Hawkesbury Sandstone;
- Digitised contours from the Sydney Catchment Authority Leonay-Wallacia groundwater investigation (Coffey, 2008); and
- Groundwater elevation estimates along Blue Gum Creek (5 m below topography).

The groundwater flow direction is generally to the east and to the north-east across the Tahmoor mine lease. However, as there is a groundwater divide between the mine and the lakes, groundwater in the vicinity of the lakes flows to the west beneath Blue Gum Creek. In dry times, the groundwater beneath Lake Couridjah appears to move north towards Lake Werri Berri and then rotates westward beneath Lake Nerrigorang.

As the Office of Water bores have not been survey-levelled, the water elevations remain as estimates. In addition, until data logger downloads are released, only a few dip measurements are available. The average depths to water have been:

- 12.9 m at GW075411 [near Lake Gandangarra];
- 8.6 m at GW075409-1 [near Lake Couridjah]; and
- 9.9 m at GW075410 [near Lake Nerrigorang].

2.6 GROUNDWATER HYDROGRAPHS

The Tahmoor Mine and Office of Water groundwater monitoring networks are displayed in Figure 14. The networks consist of the following bores:

- GW075409-11: all Hawkesbury Sandstone, screened 3-27 m and one at 84 m depth;
- P1 to P8: all Hawkesbury Sandstone, screened from 48 m to 150 m depth; and
- TNC28, 29, 36, 40 and TNC43: vibrating wire piezometers, settings at 27 m to 502 m depth.

In Figure 15, Bores P7 and P8 are shown in more detail as they are positioned between mined longwall panels and Bargo River. They provide the best indication of the effects of longwall extraction on groundwater levels close to a body of open water. Bore P7 is about 400 m from
the river, while P8 is about 250 m away. Longwall 24A at its closest point is 350 m from the river. For comparison, the closest approach of longwall mining to the lakes is about 700 m (between Longwall 18 and Lake Couridjah).

Approximate groundwater elevations for the Office of Water bores are displayed in Figure 16 as hydrographs since June 2011, compared with rainfall residual mass. The water levels have remained fairly stable but the data sampling is too coarse for meaningful interpretation of trends or variations. However, data logger records (when available) might show more dynamic behaviour. Recent shallow elevations are in the range 293-301 mAHD.

At the Lake Couridjah site [GW075409], there is a drop in head of about 8.5 m from shallow groundwater (screened at 3-13 m depth) to deeper groundwater (screened at 72-84 m depth). This indicates that groundwater moves vertically downwards beneath Lake Couridjah.

Groundwater hydrographs at the Hawkesbury Sandstone Tahmoor Mine standpipe bores are shown in Figure 17 to Figure 19. The graphs are compared with rainfall residual mass (to discern climate signatures) and are related to longwall durations (to discern mining effects). The NOW Report provides a thorough analysis of the groundwater responses to mining at bores P1 to P8, with which we agree. The difference here is that the graphs have been converted from water depth to approximate elevations, and the latest data have been included. This mode of presentation suggests that P3 is faulty and that P8 has a low head due to its proximity to the Nepean Fault.

There are clear mining effects at bores located over or adjacent to mined panels. For bores positioned over active longwall panels, drawdowns up to 10 m have been observed, with partial to complete recovery after the passage of mining. Off-site bore P5 in mid Hawkesbury Sandstone (91 m depth), about 4 km to the north-east of Lake Gandangarra, has been fairly stable in water level with a maximum temporary drop of about 0.5 m. This is believed to be a natural variation rather than mine-induced.

Of particular interest are Bores P7 and P8, as they lie between the eastern end of Longwalls 25-26 and the Bargo Gorge. Bore P7 shows clear mining effects from Longwall 24A, 25 and 26. The water level at P7 starts to recover about midway through the excavation of Longwall 25, a little earlier than the residual mass curve would suggest if the recovery were due to rainfall recharge. This indicates that recovery is occurring as mining moves away through lateral groundwater recharge. Although the amplitude of variation is about 15 m, the water levels at the start and end of Longwall 25 mining are the same. Bore P8 shows no definitive response to either mining or rainfall.

Figure 20 presents the shallowest Hawkesbury Sandstone records at five vibrating wire installations. Bore TNC28 is the nearest to active mining, being about 750 m away from Longwall 26. There is no definitive mining effect at any bore, and most bores are consistent with the residual mass trend. A residual mass high at the temporal boundary between Longwalls 25 and 26 complicates the interpretation of cause and effect. The low head at TNC43 is probably due to its proximity to the Nepean Fault.

### 3.0 OPINION

#### 3.1 PREVIOUS MODELLING

There is no regional 3D groundwater model for the Tahmoor mine and surroundings. Although there was an intention to develop a local area model for this study, completion of a
robust model could not be achieved in the limited time available. Initial experimentation with the model led to the conclusion that the Office of Water data available for model calibration in the vicinity of the lakes was insufficient in quantity and unreliable as to accuracy. The three Office of Water bores have not been survey-levelled and only irregular dip measurements of water depth were made available.

A nearby regional 3D MODFLOW finite-difference groundwater model has been developed for the Bulli Seam Operations to the east and north-east of Tahmoor (Merrick, 2009). This model includes the Tahmoor Mine in the south-western corner of the model, but the model was not specifically calibrated in that area and a coarse model cell size was applied there. Hence, it is not of direct use in this appraisal.

The Pells Report includes a 2D finite element cross-section model along northing 6210500 between eastings 271700 and 276700. The model appears to have seven model layers. Above the Bulli coal seam, a fractured zone of height 60 m has been applied. This would place the top of the fractured zone about the middle of the Bulgo Sandstone. Sensitivity analysis was performed on rainfall recharge rate and Bald Hill Claystone vertical permeability (from about $4 \times 10^{-4}$ m/day to $4 \times 10^{-6}$ m/day).

The Pells Report also points out the difficulties and the expense in developing a full 3D groundwater model.

Nevertheless, the preliminary local area model has provided insights into how the groundwater system is likely to respond in wet and dry times. This experience has contributed to the conceptualisation of the groundwater system in the vicinity of the lakes.

### 3.2 Conceptual Model

Figure 21 reproduces the groundwater system conceptual model from the NOW Report, with coloured arrows and text added in this appraisal.

A conceptual model diagram is a simplified 2D or 3D summary picture (without stratigraphic detail) that conveys the essential features of the hydrological system, denoting all recharge/discharge processes that are likely to be significant.

Evapotranspiration (ET) and natural lake leakage have been added to Figure 21 to show they are significant processes occurring in the vicinity of the lakes. The original figure posed groundwater discharge to the lakes in the form of baseflow, without any indication of leakage to the underlying aquifer. While some baseflow will occur, at least intermittently, the net behaviour of the lakes is as a losing system, not a gaining system. ET is believed to be a strong process, particularly in the inter-lake reaches and downstream along Blue Gum Creek.

An important observation is the presence of a groundwater divide separating the regional groundwater system in the vicinity of the mine from a separate localised groundwater system in the vicinity of the lakes, extending westwards along Blue Gum Creek.

The fact that Lake Nerrigorang, the lake farthest from the mine, has dried out before the eastern lakes is inconsistent with a mining cause. However, higher groundwater use along Blue Gum Creek (by evapotranspiration for example) would have the effect of drying out Lake Nerrigorang before the other lakes.
3.3 COMMENTS ON THE PELLS REPORT

Although most of the work in the Pells Report is commendable, there are a few points of difference:

- Section 3.2: The stratigraphic section in Figure 3.3 is said to be based on Clutha bores drilled from 1975 to 1983; however, the minimum bore easting in Table 3.1 (E274165) lies about 600 m to the east of the lakes;

- Page 75: It is postulated that the paleovalley beneath Lake Nerrigrorang is eroded through the Bald Hill Claystone; the geological model presented here makes that an unlikely explanation for the water level decline in Lake Nerrigrorang, as our best estimate is a thickness of about 100 m between the floor of the lake and the roof of the Bald Hill Claystone;

- Page 78: Exception is taken to the use of the term "aquiclude" or its lay equivalent "thick sheet of plastic"; this presumably is in reference to the Bald Hill Claystone. There is no reference to whoever uses this term in this area, and I know of no-one who would describe the Bald Hill Claystone as anything other than an "aquitard". The Bulli Seam Operations model (Merrick, 2009), for example, clearly allows water to pass through the Bald Hill Claystone - it is not assumed to be impermeable;

- Page 91: The Bald Hill Claystone vertical permeabilities applied in the 2D model are about $4 \times 10^{-4}$ m/d "best guess" with sensitivity tests on $4 \times 10^{-5}$ m/d and $4 \times 10^{-6}$ m/d; the Bulli Seam Operations model (Merrick, 2009) found a value of about $7 \times 10^{-7}$ m/d by calibrating against a number of vertical head profiles in vibrating wire installations. This means that the 2D model permeabilities are 6 to 600 times more permeable than the nearest calibrated value. Consequently, the 2D model will overestimate losses from the lakes which pass through the Bald Hill Claystone. The sensitivity analysis has not been extended sufficiently far to take in reasonable values for the claystone;

- Page 95: The computed flows are said to be fifty times the pre-mining flows; however, the quoted magnitudes are so low that they would not produce a perceptible drop in water level in the lakes.

4.0 CONCLUSION

The findings of this appraisal are:

- The Thirlmere Lakes appear to act as a naturally losing system under both dry and wet conditions;

- Rainfall trend analysis shows that the district has been experiencing drought conditions dating from 1992 of a severity similar to the 1935-1949 depression/war drought;
Temperature trend analysis shows an unprecedented change in behaviour since 2000 with coincident steady rises in both maximum and minimum residual masses;

The drying out of Lake Nerrigorang is not due to erosion of the Bald Hill Claystone as postulated in the Pells Report;

There are clear transitory mining effects on groundwater levels in Hawkesbury Sandstone at sites close to mining;

There are no definitive mining effects on groundwater levels in Hawkesbury Sandstone at monitoring network sites distant from mining; and

The piezometer (P8) closest to the Bargo River has been unaffected by mining 400 m away (Longwall 25), and the Bargo River has exhibited no ill effects in this area.

There is no available potentiometric data to enable the determination of the vertical hydrological regime at depth below the Thirlmere Lakes. It is conceivable that there would be depressurisation of the underlying Bulli Coal seam as a result of underground mining but without potentiometric and permeability data for the intervening strata, no accurate assessment of the potential for increased leakage from the lakes can be undertaken.

The available hydrological and hydrogeological data are insufficient to enable an accurate assessment of the cause of the recent drying of the Thirlmere lakes. However, it is clear that the recent drought conditions have been a significant factor if not entirely responsible for the current lake levels. The installation of a multi-level piezometer groundwater monitoring network in near proximity to the lakes, in association with routine measurement of lake water levels, would be required to definitively assess the Thirlmere Lakes hydrological regime.

While it is possible that mining could have had a marginal effect on groundwater levels beneath the lakes, there is no definitive evidence that this has occurred. On the other hand, there is clear evidence for the drying of the lakes being coincident with a severe drought.
5.0 REFERENCES


APPENDIX

Figures 1 to 21
Figure 1. Ground Topography [mAHD]
Figure 2. Wianamatta Group Distribution, Mapped Faults and Monoclines [Sources: 1:100000 Southern Coalfield Regional Geology Map; Tahmoor Coal]. [Black lines are from the geology map; red and green traces are mapped by Tahmoor Coal]
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Figure 20. Shallow Hawkesbury Sandstone Groundwater Hydrographs at Vibrating Wire Piezometer Installations
Figure 21. Conceptual Model for Groundwater Flow near Thirlmere Lakes [after Russell et al., 2010] [Coloured elements are added in this appraisal]