THE WATER LEVELS OF THIRLMERE LAKES – WHERE DID THE WATER GO, AND WHEN WILL IT RETURN?

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ABSTRACT

This paper presents the methodology and findings of an independent study into the declining water levels of five unique natural freshwater bodies, known collectively as the 'Thirlmere Lakes', NSW Australia. This study included a wide range of conventional and unconventional approaches to understand the historical, current and future hydrology of the lakes and postulate on the future health and impacts of these unique water bodies.
Key Words: water balance, mining impacts, natural lakes, baseflow loss.

INTRODUCTION

Nestled within a world-heritage listed national park, near the town of Thirlmere in New South Wales, Australia, a chain of five natural freshwater lakes have formed by a unique series of geomorphological processes (Fanning, 1974). The lakes are formed at the headwaters of a river system, such that slow deposition of soils beneath the lakes provide a continuous record of plant life, climate impacts, and the more recent impacts of humans, dating back to many hundreds of thousands of years (Black et al, 2006).

In recent times, it became clear that water levels in the lakes had dropped substantially, over the past decade, to the extent that locals who had used the area for recreation were voicing concerns. The low water levels correlated with both a regional drought, and with the operation of underground (longwall) mining in close vicinity of the lakes. Without any historical water level readings, the true cause of low levels, and the forecast for the future, was unclear.

Privately funded and State Government funded enquiries (Russell et al, 2010; Riley et al, 2012) were instigated, and some are still ongoing. A definitive answer has not been forthcoming because of a mixture of politics and science, including the following:

- Baseline monitoring and historical levels have not been recorded at any of the lakes.
- Underground coal mining provides major income to Australia, and the consequences are substantial if it is shown that such mining can have significant impact of surface water bodies.
- Thirlmere lakes are World heritage and the reputational damage to Australia would not be trivial if it is shown that irreparable damage has been done because of poor management.
- Because the climate of the area, as with most of Australia, is dramatically variable, it is difficult to establish a baseline from which human impacts can be assessed
- If water has been lost to the longwall mine then the quantities are probably a relatively small amount compared with rainfall input and normal evapotranspiration, and it is always very difficult to prove changes to small components of a water balance.

This paper summarises one of the privately funded studies that have been undertaken, seeking to determine where the water has gone (Pells Consulting, 2011 and 2012).

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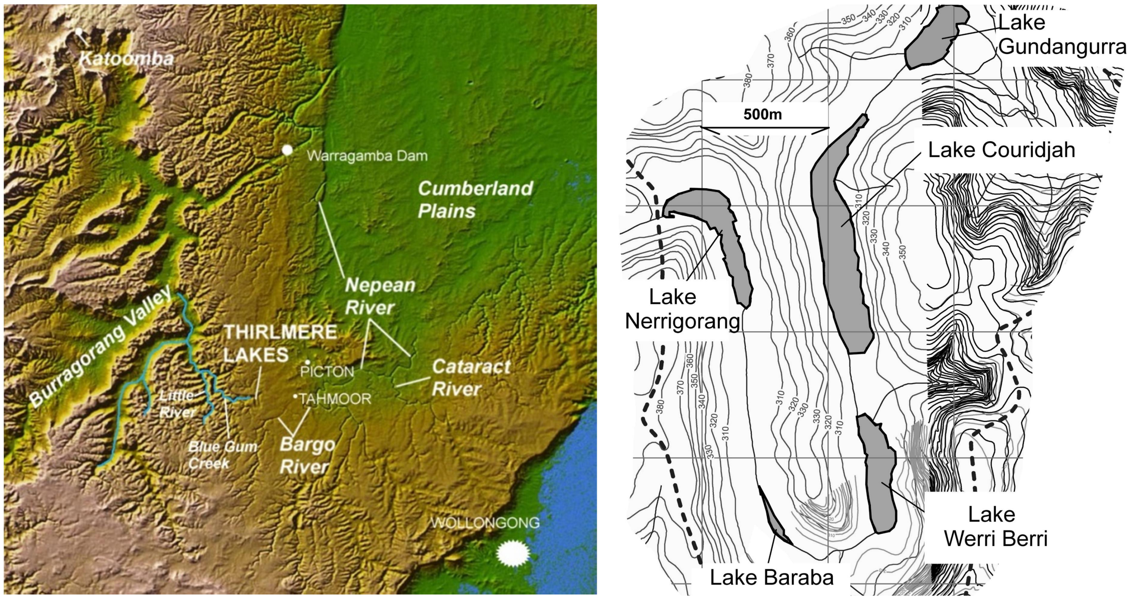

Fig 1. Location (left) and layout (right) of the Thirlmere lakes

DECLINING LEVELS

For at least 50 years, up to about 2008, the lakes were used for recreation by the community; including swimming, water skiing and canoeing. Then the water levels started to drop rapidly, and most of the lakes have been effectively dry since about 2011. Many members of the public wanted to know why; and whether the nearby longwall coal mining had contributed to the low water levels. At the outset of the study, the evidence for declining water levels was anecdotal only (see Figures 2 to 4), and no historical records of water levels were available.

Fig 2. Lake Werri Berri, near-full in 2008

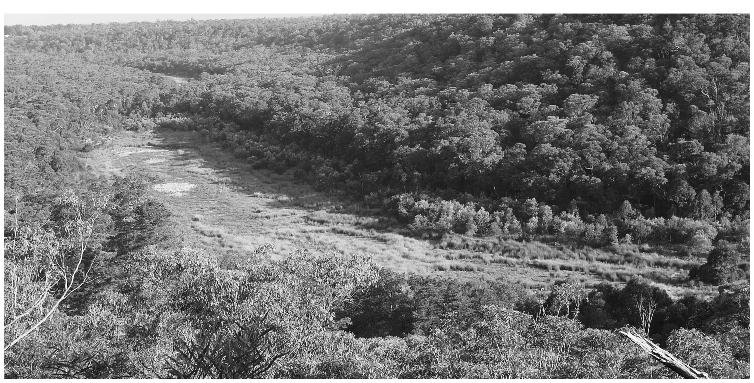

Fig 3. Lake Nerrigorang, empty in 2012

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DATA GATHERING

Topographic data were available for the region, as shown in Figure 1 (right), but were inadequate to define lake bathymetry. Additional ground survey data were collated from various sources, including surveys of Lakes Nerrigorang and Werri Berri by Schädler (2015). A digital elevation model incorporating the lakes was constructed using this data, from which the long section through the lakes shown in Figure 4, and stage-storage relationships were compiled.

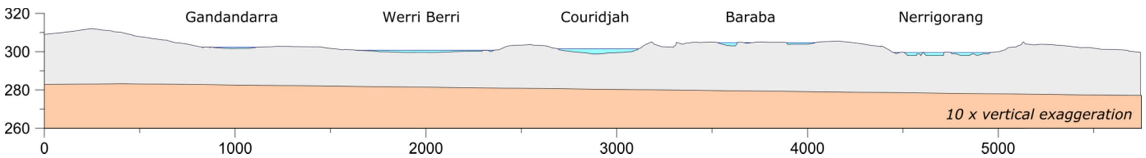

Fig 4. Long section through the lakes

Since 2014, in response to low levels, monitoring of water levels in each of the lakes has been undertaken. Additional water level monitoring was also undertaken by the present authors at Lake Couridjah for the period Jan 2012 to April 2013. These data are shown in Figure 5. Also shown are the monthly rainfall totals, and rainfall mass curve, taken a station at Picton (Figure 8). As expected, rainfall has a clear influence on the water level dynamics.

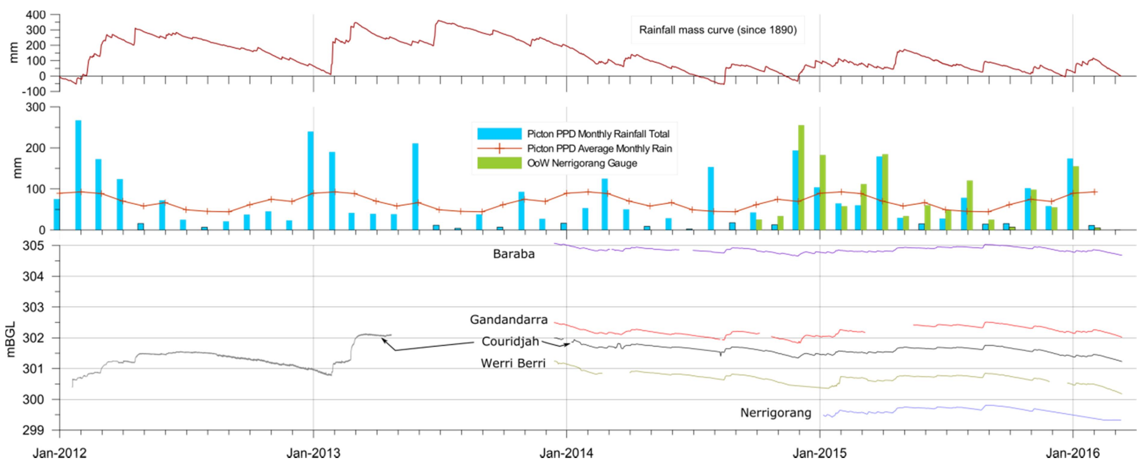

Fig 5. Monitored water levels, since 2012, with daily rainfall

In order to establish a reasonable historical record of lake levels, substantial research was undertaken using available aerial photographs dating back to the 1940s, terrestrial photographs sourced from long term residents in the area, old journals of bushwalkers, old magazines and newspapers, and anecdotal evidence. This work was undertaken independently by 3 different groups. Space does not permit detailing the sources and the individual interpretations of each proxy source. The result of the work was that it was possible to reconstruct a reasonable record of lake levels back to 1900 (i.e. 112 years). There is some proxy information as far back as 1860, but insufficient points between 1860 and 1900 to provide useful data. The reconstructed levels for lakes Werri Berri, Couridjah and Nerrigorang since 1925 are presented in Figure 6. Levels are considered typically accurate to about +/- 0.75m. The data indicates that lakes Couridjah and Werri Berri and Nerrigorang were empty in the early 1940s (WW2); and Werri Berri was also empty in about 1906.

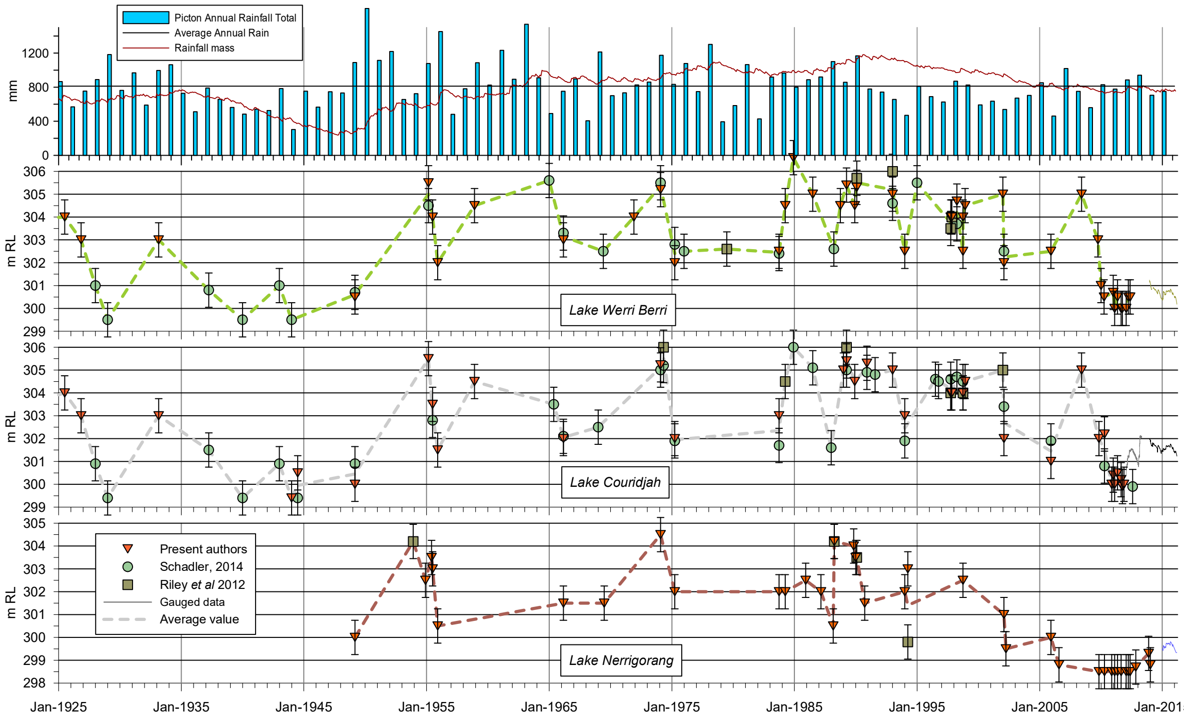

Fig 6. Interpreted historical lake levels

No historical flow gauging data is available for the Thirlmere Lakes catchment. Two local gauged catchments are shown in Figure 7. It is clear that these catchments are significantly larger than the catchment for Thirlmere Lakes. The closer catchment (68052) has only recorded flows since 1990, while the farther catchment (213200) has recorded flows since 1978 and was selected as a basis for calibration in previous studies on the Thirlmere Lakes (Gilbert, 2012). However, the further catchment has significantly higher rainfall (~1050 mm/a) with runoff assessed at 350 mm/annum, whereas the closer catchment records approximately 812 mm/annum rainfall, with assessed 70 mm/annum of runoff.

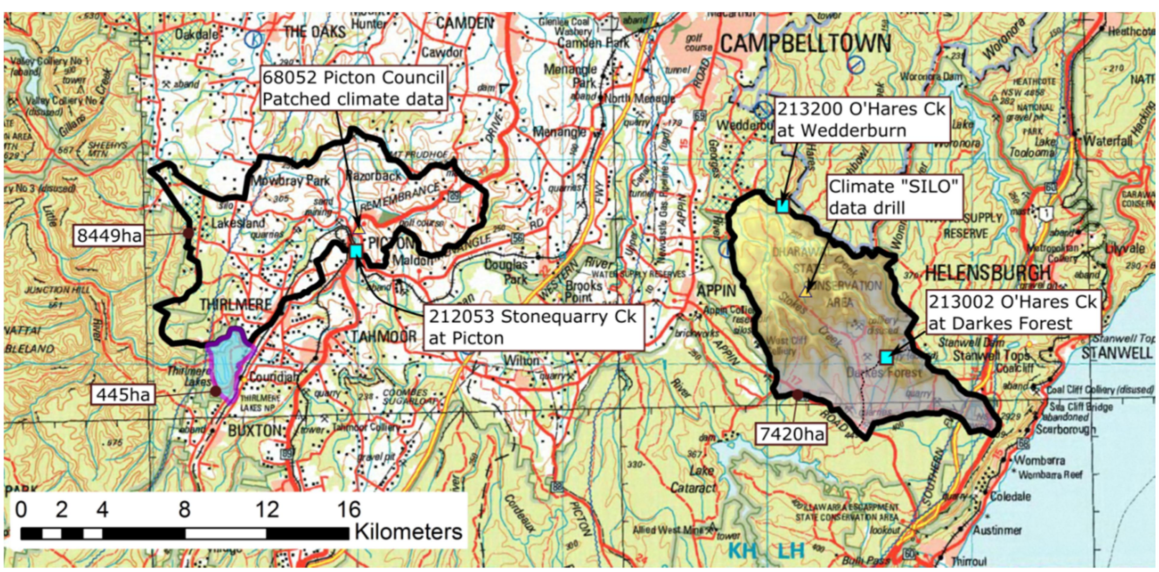

Fig 7. Local gauged catchments

Tahmoor Colliery is located a short distance east of the lakes. The longwall panels, at a depth of about 300m, do not extend into the National Park, but at their closest point are about 700m east of the nearest lake (see Figure 4). Mining commenced in 1980, and the longwalls closest to the lakes were mined between 1996 and 2004. Discharge from the mine, which is almost entirely groundwater inflow, increased from 800ML/year in 1995 to between 1200 and 2000ML/year from 2002 onwards (Xstrata, 2008).

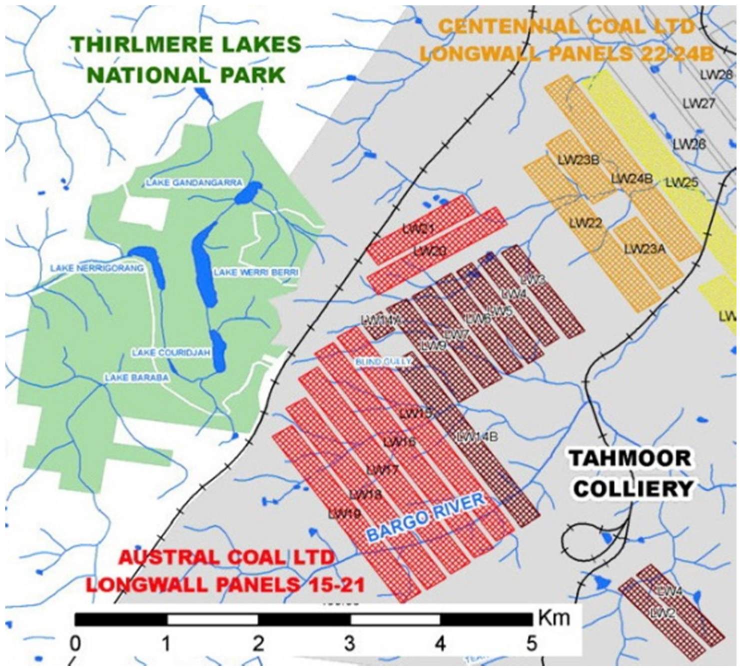

Fig 8. Thirlmere Lakes; the World Heritage National Park; and proximity to Tahmoor Colliery longwalls.

HYDROLOGIC MODELLING

A coupled hydrologic/hydraulic model was established using SWMM (US EPA). While this is traditionally a model for urban catchments, rural properties were simulated by invoking the aquifer and groundwater routines, following the methodology presented in Pells and Pells (2016). The modelling did not represent impacts from mining, but was established to test if the observed levels could be explained based on climate alone.

The hydrological aspects of the SWMM model was calibrated to gauged catchment 213200 (see Figure 7). The measured and modelled flow frequency diagram is shown in Figure 9.

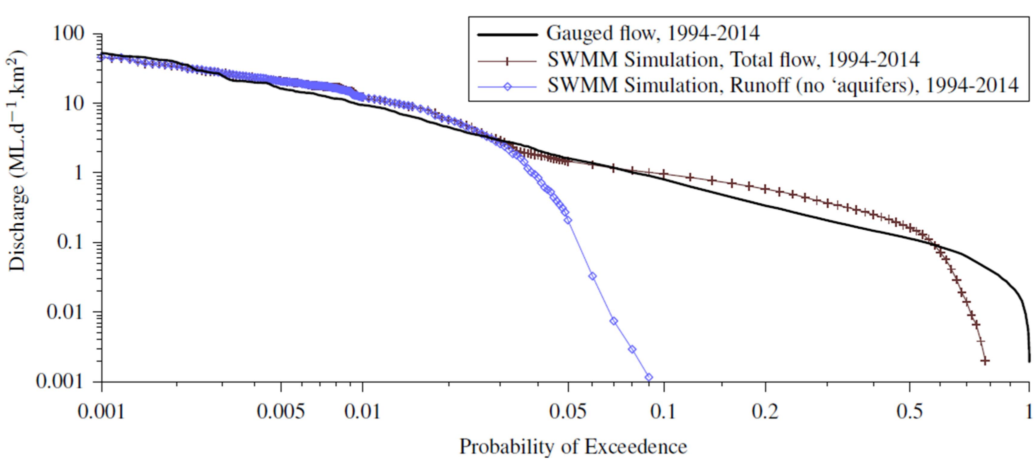

Fig 9. Calibration of SWMM model to O'Hares Ck at Wedderburn Gauge

The water levels in Thirlmere lakes were then simulated using parameters from the calibration process, as shown in Figure 10. It can be seen that these parameters significantly over-predict water levels. In contrast to previous studies (Gilbert, 2012) it is found that this gauged catchment is not suitable for simulation of Thirlmere Lakes.

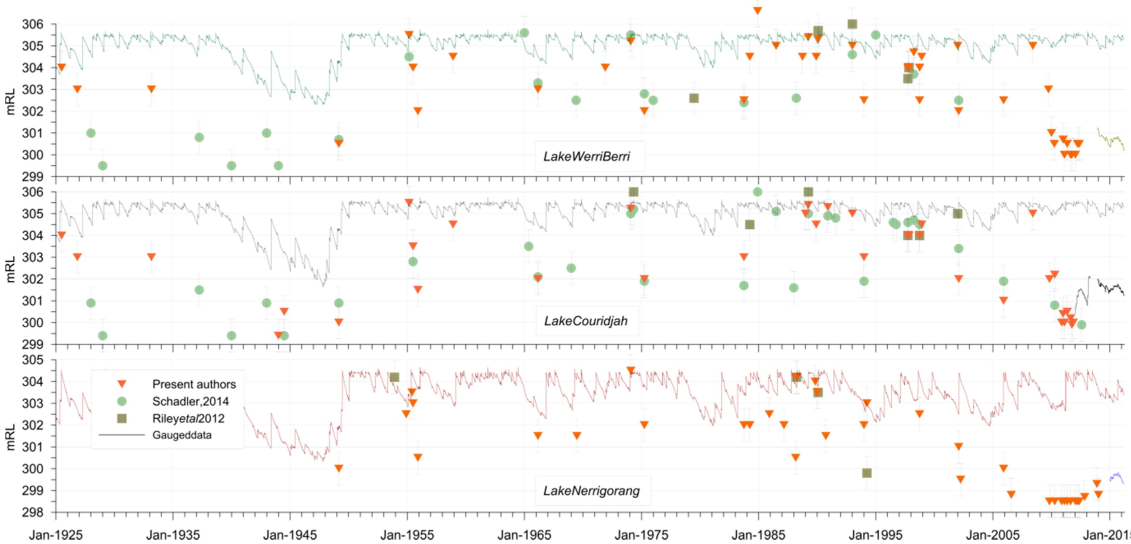

Fig 10. Simulated levels for Thirlmere Lakes, using parameters calibrated to O'Hares

The hydrologic model parameters were adjusted to replicate the monitored water levels since 2012, as shown in Figure 11. In so doing it was found that higher-than expected allowance had to be made for leakage from the lakes and/or for depression storage.

The resulting model was then used to "back-cast" historical water levels (Figure 12). It was found that this under-predicted historical water levels. The inference, then, is that the water balance in the current catchment is not representative of previous conditions, suggesting a change to the catchment water balance has occurred.

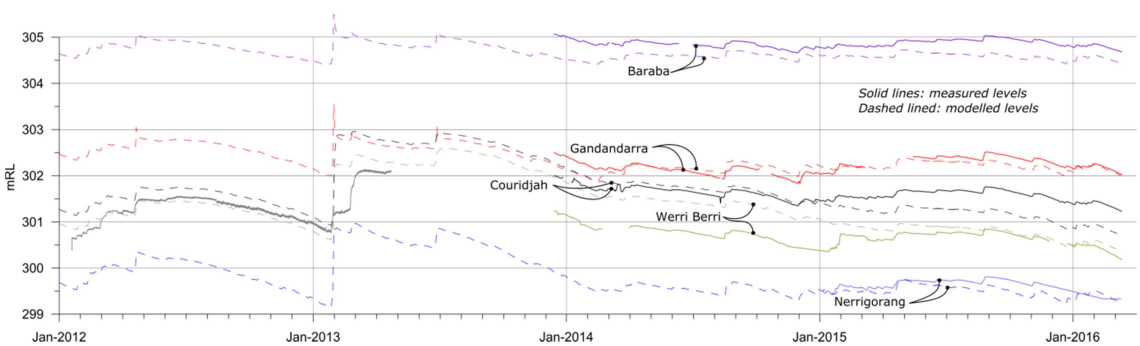

Fig 11. Calibration of model to lake monitoring data

Parameters in the hydrologic model were adjusted to achieve the best possible replication of interpreted historical levels (Figure 13). It was found that adequate replication of historical levels was incompatible with replication of levels since about 2007. Again the inference is a change in water balance over the catchment.

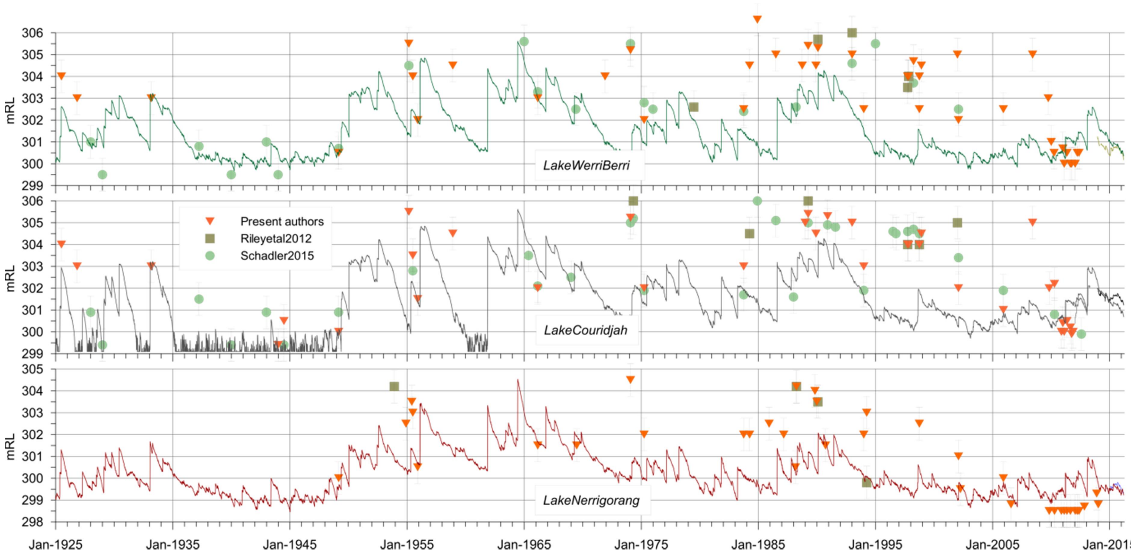

Fig 12. Simulated levels for Thirlmere Lakes, using parameters calibrated to monitored levels since 2012

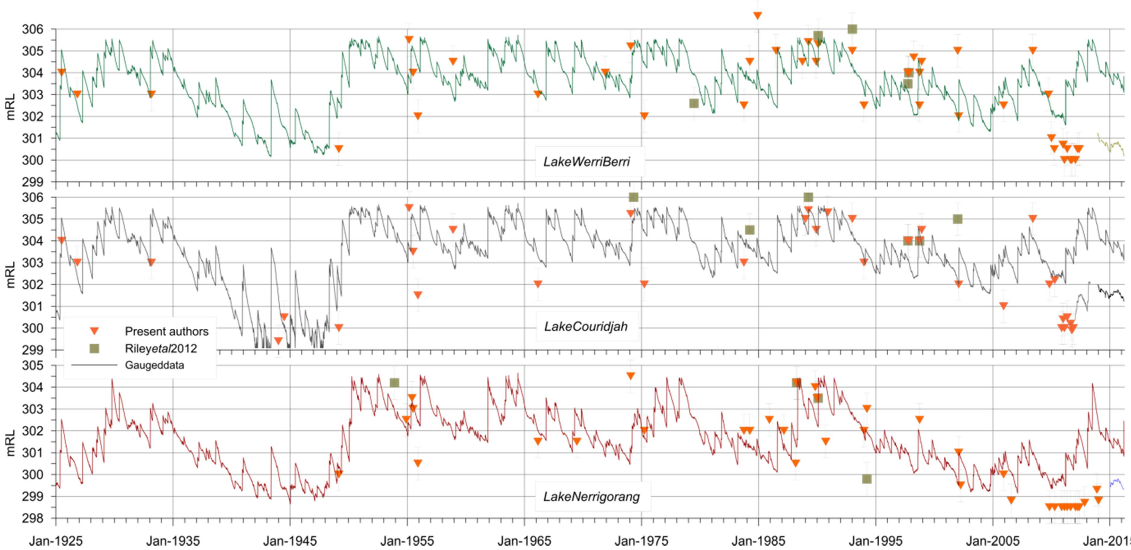

Fig 13. Simulated levels for Thirlmere Lakes, to match interpreted historical levels

FINDINGS

It is acknowledged that there are many parameters in hydrological modelling of the kind presented above. It is also acknowledged that with so many variables it is possible to match most field records of water levels or flows. However, in the analyses conducted for this study the opposite was the case. It was not possible to select a set of consistent parameters that allowed a match to lake level behavior before existence of the nearby underground coal mine, and lake level behavior after some years of mine operations. The only reasonable scientific conclusion is that extraction of an average of 1200ML/year of groundwater by the mine since about 1995 has impacted on the water levels in the lakes. This conclusion is consistent with that of Schädler (2014), reached using a completely different methodology.

The mechanism whereby the lake level impact would occur is a change to the boundary conditions in the groundwater system, creating a free flow boundary at atmospheric pressure some 300m below lake level and over an area of more than $100km^2$, effectively reducing baseflows from the lakes. Groundwater modelling indicates that it would be reasonable to expect that the impact of such a

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boundary condition change on near surface flows would be measured in decades (Pells and Pells, 2012) ; hence the delay between commencement of mining and lake water level impacts.

Such mining impacts do not mean that the lakes will not refill. It is maintained that the primary driver for water levels is rainfall, and hence water levels will rise with above-average rainfall, and extreme rainfall events could still fill the lakes completely. Such mining impacts would subtly compromise the natural hydraulics of the system, causing it to be statistically drier than it would be from climate effects alone. It is unclear if permanent damage has occurred, but it is expected that it would take decades after completion of mining, for groundwater conditions to recover towards pre-mining conditions.

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