10

Submission IPC - KEPCO Bylong Coal Mine proposal
Mudgee 7 November 2018

This presentation is in addition to an earlier submission to the PAC on potential water impacts on behalf of the BVPA. I will be focusing on the **significant uncertainties** in the water **modelling** when **assessing RISK and long term impacts** of the proposed Bylong coal mine project and comparing this to the actual experience of other working mines in the Ulan area.

I have lived on upper Goulburn River for over 40 years and am researching surface and groundwater connectivity in the Goulburn River in the context of changing land use and climate as part of a PhD project at ANU. I have first-hand experience of the impacts on water systems caused by mining at Ulan in both the Ulan and Moolarben mines.

Numerical modelling is used extensively by the mining industry for predicting mining impacts. Modelling can provide a range of **possible** outcomes to assist water management in the short term and in this context is useful... but it is *only able to represent complex natural systems in a highly simplified manner.* The predicted or possible outcomes are controlled and limited by the model **assumptions** and parameters **that are set by the proponent's modeller**.

Mine groundwater modelling is based on a series of conceptual hydrogeological layers, each with estimated hydraulic conductivity or permeability – that is how water flows through the strata, vertically and horizontally. These layers are assigned hydraulic ratios that can vary considerably, by many orders of magnitude (dependent on modeller preference which influences the predicted outcome). For example the assumed permeability factor, of a similar hydrological unit in groundwater models used by Moolarben Coal and Ulan Coal varies from 2 to 5000[1].
Rainfall recharge rate also varies, DPI Water estimates annual recharge of 5% for Triassic Narrabeen Group aquifers[2] however the mines use 0-2% annual rainfall, considerably less than widely accepted.

With such a complex range of variables there is **significant uncertainty** in the predictions.
Even with extensive groundwater monitoring, interpreting the data is extraordinarily difficult. One of my lecturers likened it to extracting meaning from a dictionary with a paper punch by piecing together the confetti. And I am inclined to agree.

Examples of uncertainties KEPCOs project proposal

1. KEPCO Water Consultants in the RTS admit to numerous modelling uncertainties and having only "*medium confidence*" in their modelling predictions. This is justified on the basis it is a Greenfield mine and predictions can only be realistically verified ***after mining.***[3]
   This is a typical *'suck it and see'* approach used frequently by the mining industry.
   Model verification is only after approval and extensive mining.
   – this is **not good enough for the Bylong Valley**

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[1] See *Cumulative hydrological impacts of coal mining in the upper Goulburn River, Hunter Valley NSW-* tabled

[2] Pearse – Hawkins, N., O'Keefe, V. and Webb, L., 2015. *Coastal Porous Rock Rainfall Recharge Study,* prepared by EMM - EMGA Mitchell McLennan for DPI-Water NSW

[3] AGE consultants - Report on Bylong Coal Project Response to Planning Assessment Commission App K

2. KEPCO modelling assumes the licenced water allocations they hold in the Bylong River are sustainable. It is widely recognised that the total volume of alluvial water licences in the valley was historically over-allocated and has never been adequately tested or verified. KEPCO admits the mine will still need to acquire a further 1596 ML of licences entitlements from the fractured rock groundwater system to offset the estimated 4099 ML/year as modelled water take[4] , and this could be higher.
   However according to DPI water it is uncertain whether additional entitlements from the Sydney Basin – North Coast Groundwater Source will be available to offset this take[5]

3. The interception and drawdown of groundwater with mining creates a 'regional sink' - the reduction in water pressure due to mining basically draws in surrounding groundwater from many kilometres outside the mining footprint; including leakage from the alluvium, as the coal seam and alluvium are connected.
   KEPCO modelling indicates a sustained change in water levels for + 100 years, including dewatering of large sections of the alluvial sands entirely and no going back to pre-mining levels. The **long term impact** of this draw down of the alluvial water system[6], on the Tarwyn Park Natural Sequence Farming property, on groundwater dependent ecosystems such as River red gums, and on downstream water users is basically unknown, unproven and uncertain. One thing we do know is this level of disruption to the water system will reduce the resilience and increase the Bylong valleys vulnerability to drought for many decades into the future.

4. The KEPCO project suggests the maximum captured catchment represents only 1.3% of the general Bylong Valley catchment however you must remember these water impacts are concentrated in the valley floor affecting key areas of water recharge and discharge.

5. There is also significant uncertainty in KEPCOs modelling of climatic extremes. This is when systems are under most stress and the most environmental damage will occur, made even more likely with climate change. An example would be an extreme rainfall event that floods the OC pit.
   Over a three day period rainfall totals >100mm has a probability of occurring once every 3 years (0.999 percentile or I in 1000 probability) (based on local daily rainfall data).
   A similar rainfall event occurred at Ulan in December 2010 on a wet catchment resulting in the EPA having to suspend mine EPLs to allow the discharge of untreated mine water for over 3 months. This discharge contained > 2000 tonnes of salt exported to the already stressed Goulburn/Hunter system[7].

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[4] KEPCO holds 2535 entitlements for the Bylong River (alluvial), and was granted a further 2093 ML of groundwater entitlements to cover groundwater take from the North Coast Fractured Rock Water Source

[5] Whilst water was made available in the North Coast Fractured and Porous Rock Groundwater Source in the 2017 Controlled Allocation Order, this did not include the Sydney Basin – North Coast Groundwater Source. Controlled Allocations for this water source may not be available in the future to account for the Permian water required for the project (DoI Advice 2018 App A)

[6] See App G- RTS 3.2.2 Water Take – likelihood of + 100 years before GW re-equilibrates and the net water take from the alluvium ceases.

[7] See *Cumulative hydrological impacts of coal mining in the upper Goulburn River, Hunter Valley NSW-* tabled

6. **Nil Discharge** - KEPCO Surface water RTS (App M) claims they have sufficient storage space for excess mine water up to Project Year 20 - allowing them to achieve Nil discharge in all but extreme rainfall scenarios. This relies on storage in the mined underground goaf from year 5-8. This is a substantial claim that requires substantial proof.
   The proposed storing of excess water in underground goafs and open cut pits is extremely problematic considering the dip of the coal seam and connectivity between the working coal seam and previously mined voids.
   Most of the excess mine water-make originates from the underground.
   Injection of waste water into mined underground areas at Ulan Coal Mine was rejected on numerous occasions due to the significant risk it posed to miners if the water barrier fails. These mines lie in the same coal field, hydrogeology and variable rainfall climate as the Bylong valley. They, like KEPCO, initially claimed they could achieve NIL discharge
   As such all the mines in the Ulan area have failed to achieve NIL discharge due to a combination of underestimating peak groundwater inflows combined with extreme rainfall runoff events. Now they all have pollution licenses that permit 10-30 ML/day mine water discharge along with a total 27 tonnes of additional salt/day into the Goulburn River[8]

7. **KEPCOs predictions require rigorous testing against the reality and experience at** Ulan Mine modelling for both Ulan Coal and Moolarben Coal underground mines have *repeatedly underestimated* the water make coming from the fractured porous rock groundwater system. Moolarben water modelling predicted in 2017 less than 1ML/day in their new underground mine; the reality is over 6 ML/day. While Ulan Coal Mine underground produced over 22 ML per day in 2016 and is predicted to exceed 28 ML/day[9].

8. KEPCOs groundwater modelling fails to adequately represent the Triassic / upper Permian fractured porous rock geology and significance of this to baseflow in the Bylong River. The fractured rock groundwater source seeps as a natural slow-release towards the valley floor, sustaining streams during dry periods and improving water quality.
   However, once mine subsidence cracks and dewaters these aquifers they arepermanently lost to the natural system.
   This geological feature (vertical jointing or cracking) is clearly visible in the characteristic cliff lines that form the dramatic escarpments around the Bylong valley.

If there is one clear lesson that can be learnt from the actions of other mines is once approval has been granted, KEPCO will also want to modify and expand their mining footprint. This cannot be allowed in the Bylong Valley

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[8] EPL 394 (UCML) = 30 ML/day EC800-900 μS/cm; EPL12932 (MCO) 10-20 ML/day @ EC800-900 μS/cm ; EPL212424 (WCM) = 10ML/day @EC500 μS/cm - Empirical relationship to estimate daily salt load S (tonnes/day) from EC (Electrical Conductivity) and TDS using best fit power law over a wide range of representative data. TDS = a. EC x 0.68 x Q(ML) x 10^{-3}.

[9] See Cumulative hydrological impacts of coal mining in the upper Goulburn River, Hunter Valley NSW- tabled

Conclusion

KEPCO justifies the many uncertainties by saying as mining proceeds they will monitor to verify the modelling *and then* make adjustments to mining water management; **this is too big a risk. Once the damage to the groundwater system is done it cannot be undone.** It is too late for mitigation remediation or compensation – unproven words used by the industry to justify approval despite all the uncertainties and long term risk. The potential scale of these impacts cannot be effectively managed post mining for the many decades and centuries into an unknown climate future

Assessing risk inevitably involves a certain amount of subjectivity –and what the coal industry may believe is acceptable is not the same as the community would regard as acceptable and what might be essential in a warming and increasingly unpredictable climate. In the face of climate change it lacks a social license and ignores the inevitable transition to renewable energy.

It makes far better economic sense to support farming for the future than risk permanently damaging the irreplaceable water systems that supports the Bylong valley

The future of the magnificent, heritage listed Bylong Valley; with its abundant water resources set within a stunning landscape must be agricultural and recreational it should not be compromised or sterilized by a short-term, ill-conceived and high risk coal mining venture.

Thank you

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Cumulative hydrological impacts of coal mining in the upper Goulburn River, Hunter Valley NSW

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The cumulative impacts from the expansion of mining operations in the upper Goulburn River has long term implications for the groundwater and river system and the resilience of riverine and groundwater dependent ecosystems (IESC, 2012). Impacts include the interception and extraction of surface and groundwater flows, dewatering and depressurisation of the groundwater system, and declining water quality due to the direct and passive discharge of salts and other pollutants. These are all recognized as significant water management issues for the mining industry in the Hunter Valley (Mackie, 2009) (Krogh *et al.*, 2013) and are of great concern to the community (Hydrocology Consulting, 2014; Walters, 2016). However there has been no in-depth review of the cumulative impacts of mining developments on regional groundwater sources and surface flows for the Goulburn River catchment.[1] Analysis of catchment yield in the upper Goulburn between 1920 and 2016 using spatially interpolated monthly rainfall and stream discharge data indicate a decreasing trend in catchment yield in relation to rainfall (Somerville *et al.*, 2018; Imrie-Mullins, 2018). The apparent decoupling of catchment yield from rainfall generates significant uncertainties and an identifiable environmental risk for water planners allocating sustainable water limits. Understanding the full cumulative impacts on water resources from the large scale expansion of mining is an imperative for catchment planning and management when faced with an uncertain climate future.

Background

There are currently three approved mines operating in the Ulan Wollar area that target the Permian Illawarra Coal Measures (see Table 1, Figure 1).

- Ulan Coal Mine Ltd (UCML - Glencore): a major underground and open cut mining operation was first approved in 1985. This was followed by a series of expansions (most recently Ulan West) and modifications (Mod 4 under assessment). The current life of mine is approved to 2036.
- Wilpinjong Coal Mine (WCM - Peabody's): an open cut mine first approved in 2006, followed by a number of Modifications (Mod 7) and expansions. The most recent approved expansion was the Wilpinjong Extension Project in 2017. The current life of mine is to 2033.
- Moolarben Coal Complex (MCC- Yancoal) Stage 1: one underground and three open cut areas were approved in 2007. Stage 2: an additional open cut and two underground mines

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[1] Hunter subregion Bioregional Assessment Coal and CSG released June 2018 involves regional scale modelling. Areas at risk of large hydrological changes require further investigation using local scale information.

were approved in 2015. Approval for Modification 14 is under assessment. The current life of mine is approved to 2038.

The total approved mining footprint for all three mines across the headwaters of the catchment is 190 square kilometres (km^2) - 70 square kilometres of open cut mines and 120 square kilometres of underground longwall mines[2] [Table 1]. The open cut mining footprint is concentrated predominantly within the valley floor in natural recharge, discharge and alluvial areas. Underground longwall mining causes subsidence that intercepts and depressurises the overlying porous and fractured rock regional groundwater system associated with the Narrabeen Group of sedimentary rocks. The hydrological units associated with the Triassic and upper Permian strata have hydraulic gradients towards the Goulburn River that contribute to the river's base flow.

Total groundwater inflow, based on mine modelling, is predicted to peak at around 48 ML/day over coming years (Table 2). In 2017 the estimated total volume of water captured by the three operational mines averaged 42 million litres per day (ML/day) or 15.6 gigalitres over the year (7 GL surface runoff and 8.6 GL groundwater inflow - Table 3). The harvestable water rights for rainfall runoff for the 190 km^2 of mine land equates to 1.3 GL/year[3] (Table 1). The mines hold a further 1.2 GL surface water licences in the upper Goulburn River and 13 GL of licenses for dewatering of groundwater in the Permian/Triassic strata - Sydney Basin Groundwater Source (Table 2).

The process of rehabilitating the mined landscape includes back filling the open cut pits with overburden crushed waste rock, washery fines and coal rejects buried within lenses of less permeable material. Current planning approval allows for five open cut pits to remain in the landscape. Over time these open pits will hold increasingly saline water requiring ongoing management and security for many generations (Hancock *et al.*, 2005). Water quality in some is predicted to eventually exceed the salinity of sea water (WilpinjongCoal, 2015b). The post mining re-stabilisation and partial recovery of the water table in the highly disturbed mining footprint has the potential to activate and mobilise sequestered salts, heavy metals and organic compounds (e.g. benzene, toluene, ethylbenzene and xylenes (BTEX), phenols) contained within the coal measures and Permian strata (IESC, 2016; Zhang *et al.*, 2016). This represents a significant hazard over time to water quality, particularly when combined with extreme climate variability. There is a risk that saline seepage and spills associated with large rainfall events will be dispersed downstream to accumulate/evapo-concentrate and pollute surface and groundwater in the Goulburn River National Park and Hunter River system.

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[2] Wilpinjong Open Cut (OC) = 27.6 km^2; adjoins Moolarben Coal Mine OC = 32.9 km^2 and underground (UG) = 21.7 km^2. Ulan Coal Mine OC = 15.5 km^2; UG = 102.3 km^2.

[3] Landholders in NSW have harvestable rights that allow up to 10 per cent of the average regional rainfall run-off on land to be captured in dams (intercepted) - https://www.waternsw.com.au/customer-service/water-licensing/basic-water-rights/harvestable-rights-dams

Mine water use, off-site discharge and salt export to the Goulburn-Hunter River system

The estimated volume of water used in mining varies from year to year according to coal production, mining area and climatic conditions. It is a combination of groundwater (incidental and extracted) and intercepted surface water (direct rainfall and runoff). Water is consumed in dust suppression, coal mining and product preparation, and worker ablutions. Mine water input (surface and groundwater inflow) and output (mine demand and excess discharge) is reported annually by each mine as a water balance. It relies on modelling estimations to calculate catchment runoff, direct rainfall, evaporative losses and groundwater inflows (incidental including seepage). Excess mine water make is treated and discharged into the Goulburn River under license managed by the NSW Environment Protection Authority (EPA) as environment protection licences (EPL) and also consumed in pasture irrigation for grazing cattle (UCML, 2017).

The estimated total water intercepted and extracted in the relatively dry year of 2014, as reported in the three mine water balances (Ulan, Moolarben and Wilpinjong Coal Mines) was in excess of 8,500 ML/year (UCML, 2014; MCC, 2014; WilpinjongCoal, 2015a). During 2014 the cumulative mine water usage was around 4,000 ML/year. This equates to about one third of the total annual flow in the Goulburn River as measured at the downstream Coggan stream gauge over the same period (11,951 ML/year at GS210006).

Since development in the mid-1980s Ulan Coal Mine (UCML) has experienced a steady increase in the volume of water produced from 1.3 ML per day in 1988 to over 22 ML per day(UCML, 2016; Woodward-Clyde, 1995; UCML, 2004). In 2016 over 8,000 ML of treated mine water discharged offsite contained an estimated salt load of more than 4,000 tonnes[4] (~11 tonnes per day) exported into the Hunter system (UCML, 2016). Ulan Coal groundwater modelling predicts underground water make will exceed 28 ML per day by 2023 (~10,000 ML/year). This equates to a salt export of 5,500 tonnes per year or 15 tonnes per day at salinity EC 800μS/cm.

Mine water discharged into the headwaters of the Goulburn catchment at Ulan affects salinity levels and salt loads over the 225 kilometres length of the Goulburn River and the Hunter River below Denman. All three mines have licences to discharge excess treated mine water into the upper Goulburn River in varying quantities and quality. Stream salt loads emanating from the Goulburn River influence the function and viability of the Hunter River Salinity Trading Scheme (HRSTS[5]). The Goulburn River, however, is not part of HRSTS despite being the largest tributary of the Hunter River with a direct impact on downstream water quality (Krogh et al., 2013).

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[4] Empirical relationship used to estimate daily salt load S (tonnes/day) from TDS total dissolved solids (mg/L) and Q (ML/day) based on relationship between measured EC (Electrical Conductivity) and TDS using best fit power law over a wide range of representative data. $TDS = a. EC \times 0.68 \times Q(ML) \times 10^{-3}$.

[5] HRSTS is designed to minimise the impact of saline water discharges by the mining and energy industry on other Hunter River water users and the environment using a system of tradeable credits that allow saline water discharge at high river flow whilst maintaining the Hunter River under 900 μS/cm below Denman.

The licensed cumulative discharge of all three mines equates to a potential salt export of greater than 27 tonnes per day[6]. Ulan Coal Mine under EPL (394) has approval to discharge up to 30 ML/day at a maximum salinity of 800-900 µS/cm (16 -18 tonnes/day); Moolarben Coal Mine EPL (12932) permits 10 ML/day[7] at a maximum 800-900µS/cm (~ 6-10 tonnes/day); Wilpinjong EPL (12425) permits up to 15 ML/day at a maximum 500 µS/cm (~ 5 tonnes/day). This does not include the indirect passive seepage of saline groundwater from disturbed mined areas (unmeasured) or the disposal of saline concentrate reject from reverse osmosis water treatment plants into disused pit and as dust suppressant (UCML, 2016)(MCC, 2016; WilpinjongCoal, 2015b).

A comparison of pre-mining stream discharge (continuous) and salinity data (grab 1969-1982) to recent continuous data (2012-2016) in the Goulburn River at Coggan (mid-point gauging station) (NSW-Office-Water, 2008) reveals a rise in the volume of flows with salinity levels above EC 900 µS/cm. Pre-mining data indicate flow volumes up to 63 ML/day exceeded EC 900 µS/cm, while for the period 2012-2016 flow volumes up to 107 ML/day exceeded EC 900 µS/cm. An increase in the volume of low flows with salinity levels over 900 EC makes Hunter River catchment objectives to hold river salinity under 900 µS/cm increasingly difficult to achieve.

The amount of salt exported by Ulan Coal Mine in water discharges over the four year period May 2012 to June 2016 was estimated to be 12,871 tonnes based on mine annual reports (Table 4). The estimated total salt load in the River at Coggan for the same period was 97,054 tonnes (DPI-Water, 2018). The salt exported from Ulan coal mine equalled 13.3% of the total load in the river at Coggan, however the Ulan Coal Mine footprint covers less than 1.4% of the catchment (above the Coggan gauge) (Table 4). In terms of average annual salt yields per square kilometre the mine discharged 61 tonnes per square kilometre. This is over ten times higher than the average annual salt yield per square kilometre compared to the general catchment above Coggan (6 tonnes /km^2). Comparing salt yields to other Goulburn River tributaries the Ulan Coal mine exported 6 times more salt per square kilometre than either the Wybong Creek or Merriwa River catchments).

Decline in groundwater levels due to mining

The main hydrogeological units present in the Ulan Wollar area are associated with Permian Illawarra Coal Measures, Triassic Narrabeen Group of sedimentary rocks, Jurassic Pilliga sandstone, Tertiary volcanics and Quaternary alluvium. The porous and fractured rock groundwater sources within the Triassic Narrabeen Group, Tertiary basalts and upper Permian strata are at a hydraulic gradient above the Goulburn River. Groundwater flow is towards the lowest point in the landscape, discharging as baseflow into the river. Groundwater can be an important source of surface and subsurface streamflow and support GDE[8]s during extended dry periods. A key finding (6) in the

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[6] This will increase to 30 tonnes if Mod 14 is approved

[7] This will increase to 30 tonnes if Mod 14 is approved

[8] Groundwater Dependent Ecosystems

Bioregional Assessment of the impact of mining on water resources in the Hunter subregion (AustralianGovernment, 2018) states *"Modelled changes in ecologically important flows indicate a higher risk to the condition of riverine forested wetlands along the Goulburn River compared to other riverine forested wetlands in the subregion"*

Regional groundwater levels in the vicinity of mining footprint have shown a significant decline over time due to mine dewatering and groundwater depressurisation. The complete desaturation of Triassic strata has occurred above the mining footprint. For many years Ulan Coal Mine groundwater inflows were consistently under-predicted. There is minimal long term spatial and temporal monitoring of changes to Triassic groundwater levels between the depressurised mined goaf and the bed of the Goulburn River. Since monitoring of Triassic groundwater commenced (2001), declines of 22 metres have been measured on the eastern side of the mined goaf (closest to the river corridor) and 40 meters overlying the goaf (Figure 1-Table 4). Due to the limited baseline surface and groundwater data it is difficult to prove conclusively the degree of interference to flow direction, actual loss of base flow and overall impact on the regional and localised groundwater system over time resulting from mining approvals.

Government project approvals require Ulan Coal to produce a surface and groundwater response plan that includes 'measures' for offsetting the loss of base flow to the Goulburn River. Potential and actual losses of base flow are estimates based on modelling[9]. The model relies on incomplete groundwater and stream flow data for the Goulburn River at Ulan (historical and current) to verify and validate (prove) mine predictions. Groundwater modelling for the Ulan Coal Mine now predicts complete dewatering of the Triassic and Permian strata above mined panels, with depressurisation of the Triassic groundwater unit extending 4-5 kilometres and the Ulan Seam over 20 kilometres from underground footprint. The additional impact of the Moolarben and Wilpinjong mines dewatering extends the regional pressure reductions further to the east and southeast. The predicted time to recovery (re-equilibrium of water levels to steady state) exceeds 300 years (MER, 2015)

Groundwater modelling and predicted change due to mining

Mine groundwater modelling is based on a series of conceptual hydrogeological layers, each with assigned parameters estimating the hydraulic conductivity, and horizontal and vertical hydraulic ratios. The permeability parameters applied to hydraulic units is estimated. It can vary considerably, being dependent on limited availability of conductivity data applicable to fractured and porous rock units and modeller preference (Pells and Pells, 2012). For example there are many orders of magnitude differences in the assumed permeability, with K_h/K_v ratios varying from 2 to 5000 between the Moolarben Coal and Ulan Coal groundwater models. The input mine modelling uses a rainfall recharge rate for the Triassic porous rock layers of 0-2% annual rainfall, this is

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[9] Predicted losses to Goulburn River ~ 0.183 ML/day, Talbragar River 0.039ML/day

considerably less than the DPI Water estimate of 5% for annual recharge in Triassic Narrabeen Group aquifers (Pearse – Hawkins *et al.*, 2015). With such a complex range of variables there is significant uncertainty equivalent to many orders of magnitude. Vertical connectivity and flow pathways in Triassic hydraulic units are also influenced by secondary permeability characteristics such as vertical jointing and fracturing. These complex structural features form potential conduits for groundwater flow that are not included in the modelling.

In 2015 Moolarben Coal Mine modelling predicted groundwater inflows to their Underground One mine (UG1) to be less than 1ML/day peaking at around 1.5 ML/day (MCC, 2015). When underground mining commenced in 2017, the actual water make in the first 6 months exceeded 5 ML/day[10] Groundwater modelling was subsequently amended and recalibrated to capture the significant unpredicted mine inflows which increased to over 6 ML/day in 2018. The adjusted modelling now predicts a maximum peaking at 17.27 ML/day in 2025 (MCC, 2017b). This represents a more than 10 fold increase in the maximum water make than originally predicted and a significant increase in interference to the groundwater system by the Moolarben Coal Mine. The question is what is the source(s) of the unpredicted additional groundwater[11]?

Groundwater monitoring piezometers adjacent to Moolarben Coal Mine UG1 and near the Goulburn River (Figure 3, 4, 5) have registered declines since the development of Moolarben Coal UG1 in late 2016, (MCC, 2016; MCC, 2017a)(MCO June CCC). This also coincided with a period of below average rainfall. Piezometer PZ179 (VW[12]28m) monitoring saturated Triassic strata east of UG1 declined by 4.22 metres to June 2018; the lower Triassic/upper Permian PZ179 (VW33m) by 6.05 metres and the Ulan coal seam by 29.9 metres (Figure 4) . Notably the mine experienced over five times the predicted volume of groundwater inflow than initially modelled. In addition there was around a 2.5 metre decline at PZ105c in Triassic and upper Permian strata adjacent to the Goulburn River (January 2017 - June 2018) while monitoring bores in the Triassic/ upper Permian groundwater levels located opposite The Drip dropped by 4 metres (PZ128-36m) & 2 - 5 metres (PZ129-53m) during January 2016 – June 2018 (Figure 5) (MCC, 2017a; MCC, 2016). The hydraulic gradient of the saturated Triassic and upper Permian strata is towards the river – that is groundwater discharge from these strata would normally contribute base flow to the Goulburn River. The relative height of the sediment sand-bed (potential groundwater discharge level) in the Goulburn River is 394m AHD at Ulan Creek confluence, falling to 380m AHD at The Drip and 373m AHD near PZ105c. While below average rainfall may have affected groundwater recharge, it is likely that mine dewatering in UG1 is intercepting and lowering water levels across the Triassic

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[10] MCM Community consultative committee meeting minutes included UG1 water-make of 65 L/s (June 2017) and 70-80L/s (September 2018) during exceptional dry conditions.

[11] In 2017 MCC Annual Review reported a total 1,552 ML of groundwater inflows in June 2017 to compared to 379 ML in 2016; 371 ML in 2015 and 207 ML groundwater seepage in 2013/14

[12] VW – Vibrating Wire monitoring bore that measures groundwater pressure and SWLs

and upper Permian strata. This groundwater flow would previously have discharged as spring water or baseflow to the river.

Monitoring bores PZ105C/105B and PZ179 are located within the extent of saturated Triassic strata in the north as identified by Moolarben Coal. They lie at an elevation and hydraulic gradient that flows towards the Goulburn River (Figure 2). There is a close similarity between PZ105C (Triassic Strata) and PZ105B (identified as upper/middle Permian sediments) in the standing water levels (SWLs), groundwater behaviour and water type suggesting the possibility of hydraulic interconnection. Groundwater monitoring data for PZ105 (Triassic, Permian and coal seam) have consistently shown low salinity levels between 200-500µS/cm and the presence of a valuable high quality, productive groundwater source (MCC, 2016).

There are many perennial springs that discharge from high points in Triassic strata along the Great Dividing Range in the Moolarben, Wollar, Bylong and Widden Valleys that are not fully mapped or assessed. They provide high quality, low yielding groundwater flows to surface waters that act cumulatively to dilute the saline water from the Permian alluvium in the valley floor (Realica-Turner, 2003; Macdonald *et al.*, 2009). These fresh springs are often tapped for domestic water supplies and considered drought proof by local landholders. They support a range of GDE and riparian communities including remnant dry rainforest species that extend down the gullies and creek lines.

Cease of surface river flow in recent extended dry period

Goulburn River water levels dropped to unprecedented levels beneath the sandy bed during an extended dry period interrupting surface flow for over four months from mid-December 2017 to late April 2018. This was despite significant storm activity that produced intense localised rainfall events during mid December 2017, late February and early March 2018. Monthly rainfall totals for Ulan (Station 062036) recorded 118mm in November, 70mm in December; and over 100mm between late February and early March 2018. A comparison of interpolated 12 monthly rainfalls for the upper Goulburn catchment (1920 - 2018) places the December 2017 – February 2018 rainfall period above the 10th percentile range of annual rainfalls. Statistically this period had a higher annual rainfall than the 1980-81 (pre-mining) and 2006-7 millennium drought declared periods. The cessation of flow directly coincided with the cessation of mine discharge in late December 2017. There were no regulations requiring the mines to ensure environmental flows to maintain the natural flow regime during this extended dry period. The estimated 12-16 ML/day groundwater extracted throughout this period was consumed in irrigation, used for operational purposes and disposed to an open cut pit.

The salt load contained in direct mine water discharge and diffuse groundwater seepage accumulates and concentrates in the river alluvium, sandy stream beds and connected groundwater systems through evaporation until a significant rainfall event flushes it downstream. Localised

storms may intermittently mobilise salt deposits as a pulse or salt slug that moves partially down the river system. First flush flow following extended dry periods from storms and the resumption of mine water discharge, are a likely cause for sudden unexplained spikes in salinity levels in the Goulburn River[13].

A recent Wilpinjong Mine project assessment claimed that the effect of open cut mining on water resources was insignificant as it was "less than 1.5% of the catchment". This generalised view is not useful for assessing regional cumulative effects that are concentrated in the valley floor in key areas of water recharge and discharge. In addition critical impacts on vulnerable streams are most likely during periods of very low flow, or extreme storm events.

Conclusion

Outstanding questions include how much of the surface and groundwater systems altered by mining would have previously sustained river flow during extended low rainfall, drought conditions? Should there be a requirement that mining operations in the upper Goulburn return intercepted groundwater to the river as environmental flows particularly during low flows. How will stream flow during extended dry periods and groundwater connectivity be affected in the post mining period?

The Triassic groundwater system and associated Tertiary basalts are generally regarded as a low yielding, freshwater resource and contributor to stream baseflows. While exhibiting low flux, the volume of groundwater storage of good quality, is significant. Groundwater discharge over time and space from these hydrogeological units provide fresh baseflow to streams and sustain dependent ecosystems during low rainfall periods. They provide high quality, low yielding groundwater flows to surface waters that act cumulatively to dilute the saline water from the Permian alluvium in the valley floor and support a range of GDE and riparian communities.

Mining activities intercepting surface and groundwater in the upper Goulburn will cause a sustained reduction in regional hard rock aquifers predicted to last for centuries. The depressurisation of groundwater system has potential to both reduce river baseflow that sustains stream flow during low rainfall periods and reduce Triassic groundwater discharge that dilutes more saline discharge from Permian sources. The continuous daily discharge of excess mine water is currently masking this loss of baseflow and confusing assessment. However when the mines stopped discharging, as occurred during the millennium and 2017-18 drought, the river abruptly ceased surface flow. The far-reaching consequences of these impacts on the water system post mining, has not been appropriately assessed by industry or government. The approval process allows the assessment of each modification piecemeal; this narrow focus can obscure and under estimate the full cumulative impacts of the overall project and interaction with adjacent mines.

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[13] Immediately following resumption of mine water discharge in April 2018 salinity levels in the Goulburn River spiked at 2090 µS/cm EC at Ulan Coal DS Gauge.

River catchments are complex dynamic systems with synergistic emergent properties[14] where a future condition or state may be more than the sum of component parts. Alterations to parts of a system must take into account the cumulative and catchment-wide consequences including externalities that are often ignored or only superficially assessed (Walker and Salt, 2006; Anderson, 1972; Schramm, 1980; Walker and Salt, 2012). Maintaining essential hydrological processes in a river system requires an understanding and assessment of the cumulative impact of groundwater extraction on connected water systems, downstream receptors and water-users under variable and extreme climatic conditions. This cannot be achieved when mine expansions are assessed on a piecemeal basis; monitoring and reporting relies on self-regulation, and there is minimal independent scientific scrutiny to ensure environmental outcomes are acceptable to the community. Recognising the fundamental role of a functioning and resilient riparian ecosystem involving vital interactions between surface and groundwater and climate is a key challenge to sustainable and integrated resource management (Kalbus *et al.*, 2006).

During and post mining the cumulative pressure from over-extraction, interception and depressurisation of groundwater systems and diffuse and point discharge of saline mine water have ongoing consequences. These are likely to persist many decades, and centuries into the future affecting surface flows, water quality and ecosystem health in the Goulburn and downstream Hunter River. A comprehensive independent assessment of the cumulative impacts of mining developments on the Goulburn catchment is needed to better inform government policies regulating water use, salinity discharge and groundwater interference. This necessitates improvements in the reporting and conjunctive monitoring of surface and groundwater; involvement of the community; and respect for and careful consideration of the precautionary principle, intergenerational equity and cultural/societal mores.(Foster *et al.*, 2003; Richardson *et al.*, 2011; Boulton *et al.*, 2010; Schramm, 1980; Wilford *et al.*, 2010; Sophocleous, 2002).

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[14] Philosopher G. H. Lewes, wrote "...The emergent is unlike its components insofar as these are incommensurable, and it cannot be reduced to their sum or their difference."

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ATTACHMENTS

Table 1: Mine size- (open cut & underground) and rainfall runoff harvestable rights

	Approved Mine footprint/disturbance		Est. Harvestable Rights - surface water (7ML/km^2)
	Open Cut + disturbed (km^2)	Underground Mine footprint (km^2)	
Ulan Coal Mine Ltd (UCML)	15.59	102.3	825.2
Moolarben Coal (MCC) *	29.1	21.7	355.6
Wilpinjong (WCM) **	27.6	0	193.2
Total	**72.29**	**124**	**1,374.0**

Table 2: Cumulative mine water licences and predicted surface and groundwater take/inflow

	Mine Water Licences and discharge					Predicted Water Inflow	
	Upper Goulburn River Water Source	**Wollar Alluvial Aquifer source**	**Sydney Basin - North Coast Ground-water Source**	**Talbragar Ground-water Source**	**Lic. daily water discharge (ML/day)**	**Max. daily predicted GW inflow ML/day**	**Max. annual predicted SW + GW inflow ML(in year)**
Ulan Coal Mine Ltd (UCML)	600	-	7,060	1,454	30	27.7	10,220 (2023)
Lic.irrigation					*1,694/year*		
Moolarben Coal (MCC) *	9	218	2,950	-	10	17.3	6,780 (2025)
with Mod 14					*20*		
Wilpinjong (WCM) **	550	474	3,121	-	15	3.12	3,128 (2020)
Total	**1,159**	**692**	**13,031**	**1,454**	**55-65**	**48**	**19,149**

Total Licences for groundwater extraction (ML/Year) **15,336** **42** **ML/day**

** MCC modification lodged 2017 to increase licensed discharge to 20 Ml/day*

Table 3: Mine Annual Review 2017 - water demand, inflows and discharge based on reported 2016-17 Mine Water Balance.

Coal Mine Annual Review (2017)	**Annual Mine water usage ML/year**	**Groundwater Inflows/ Extraction (ML/year)**	**Surface water (rainfall / runoff) (ML/year)**	**Mine water discharge Goulburn River (ML/year)**
Ulan Coal Mine Ltd (UCML) 2017	2,455	5,997	2,536	5,606
Used for Irrigation				1,787
Moolarben Coal (MCC) 2017	3,493	1,602	1,002	0
Wilpinjong (WCM) 2017**	2,300	1,009	3,436	640
Total	**8,248**	**8,608**	**6,974**	**8,033**

Table 4: Catchment vs mining area and annual salt yield km^2/ year May 2012 – June 2016

	Total catchment area (km^2)	Salt yield May 2012-2016 (tonnes)	Annual salt yield (km^2/ year)	% Upper Goulburn catchment size
Ulan Coal mining footprint	45	12,871	61	1.35%
Goulburn catchment above Coggan (GS210006)	3,340	97,054	6	98.7%
Merriwa Catchment (GS 210066)	684	38,765	12.1	
Wybong Creek (GS210040)	676	37,533	11.9	

Table 5: Height and decline of groundwater monitoring piezometers Ulan Coal Mine since installation.

Triassic Piezo	Year installed	SWLs (mAHD)	SWLs 2017 (mAHD)	Decline (metres)
PZ04A	2001	408.74	398.59	10.15
PZ10A	2005	420.08	380.27	39.81
R755A	2001	412.42	390.46	21.96
PZ08C	2005	410.92	397.18	13.74
PZ07	2005	422.02	395.4	26.62
PZ24B	2005	402.04	399.4	2.64

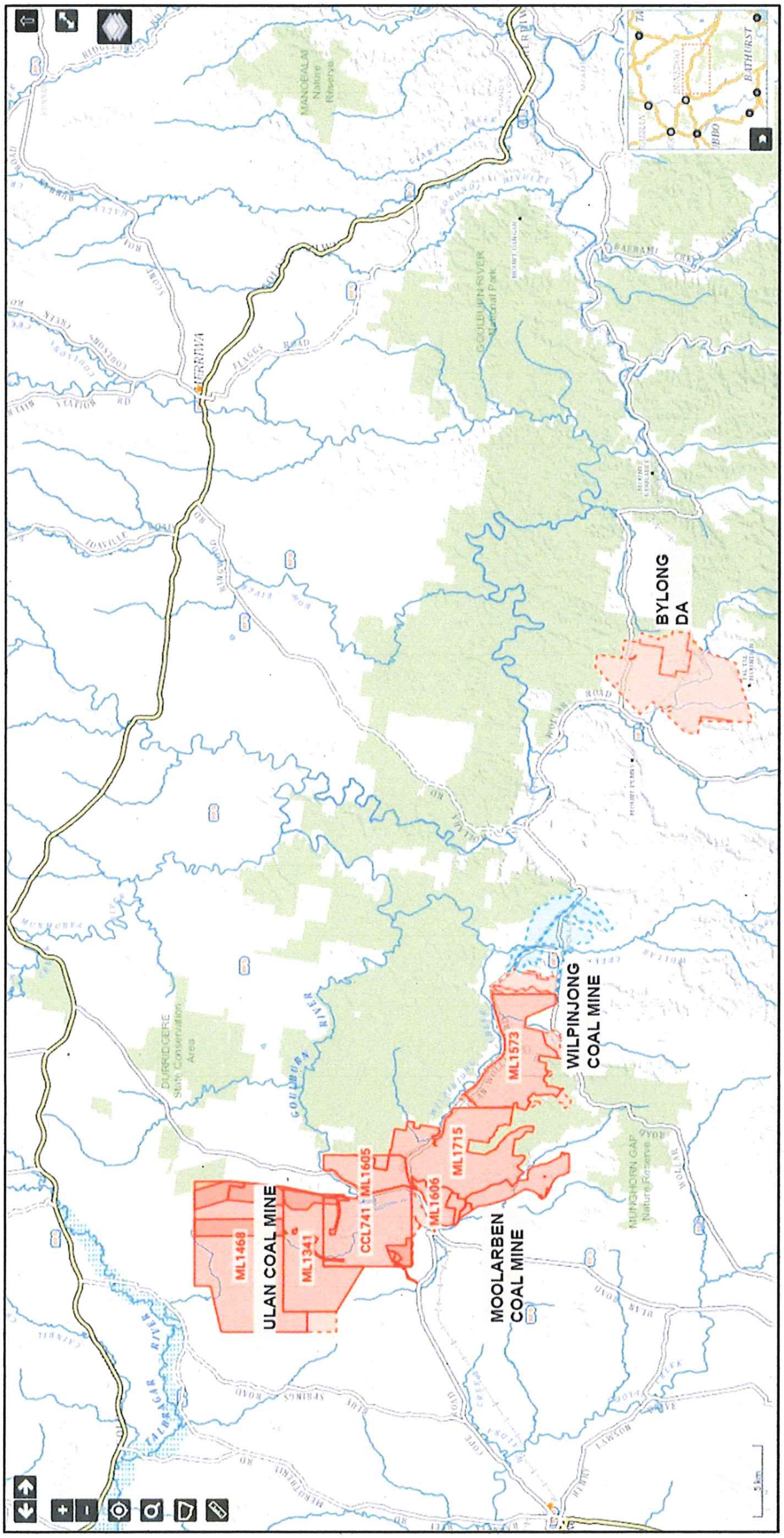
BYLONG
DA
WILPINJONG
COAL MINE
ML1573
ML1715
ML1605
ML1606
CCL741
ML1341
ML1468
ULAN COAL MINE
MOOLARBEN
COAL MINE
GOULBURN RIVER
National Park
DURRIDGERE
State Conservation
Area
MUNGHORN GAP
Nature Reserve
MANOBALAI
Nature
Reserve
MERRIWA
GOULBURN RIVER
TALBRAGAR RIVER
BATHURST
5 km

Figure 1 – Location of Ulan CM, Moolarben CM and Wilpinjong Coal Mine (MinView NSW).

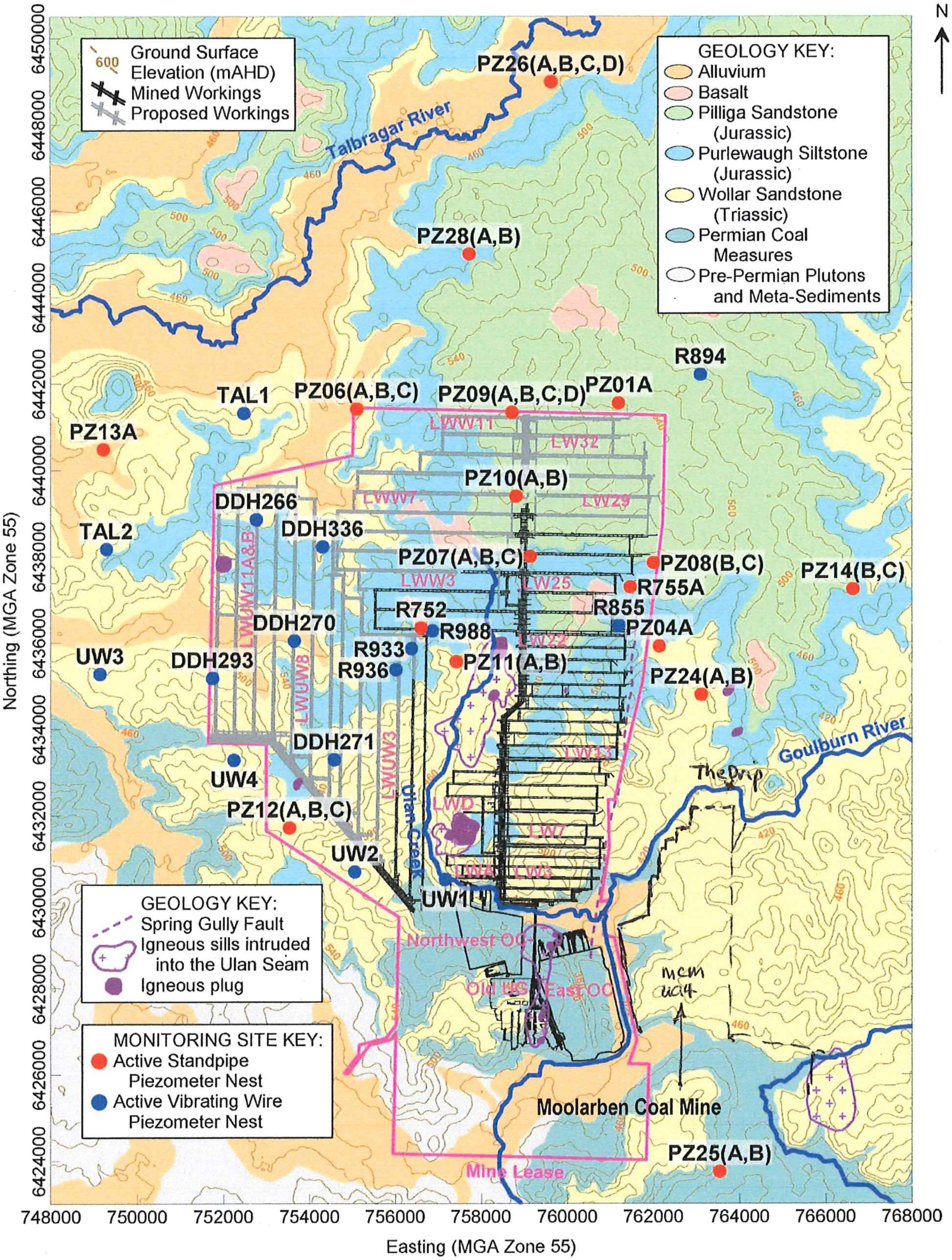

Figure 2: Location Ulan Coal Mine active groundwater monitoring sites (UCML, 2015)

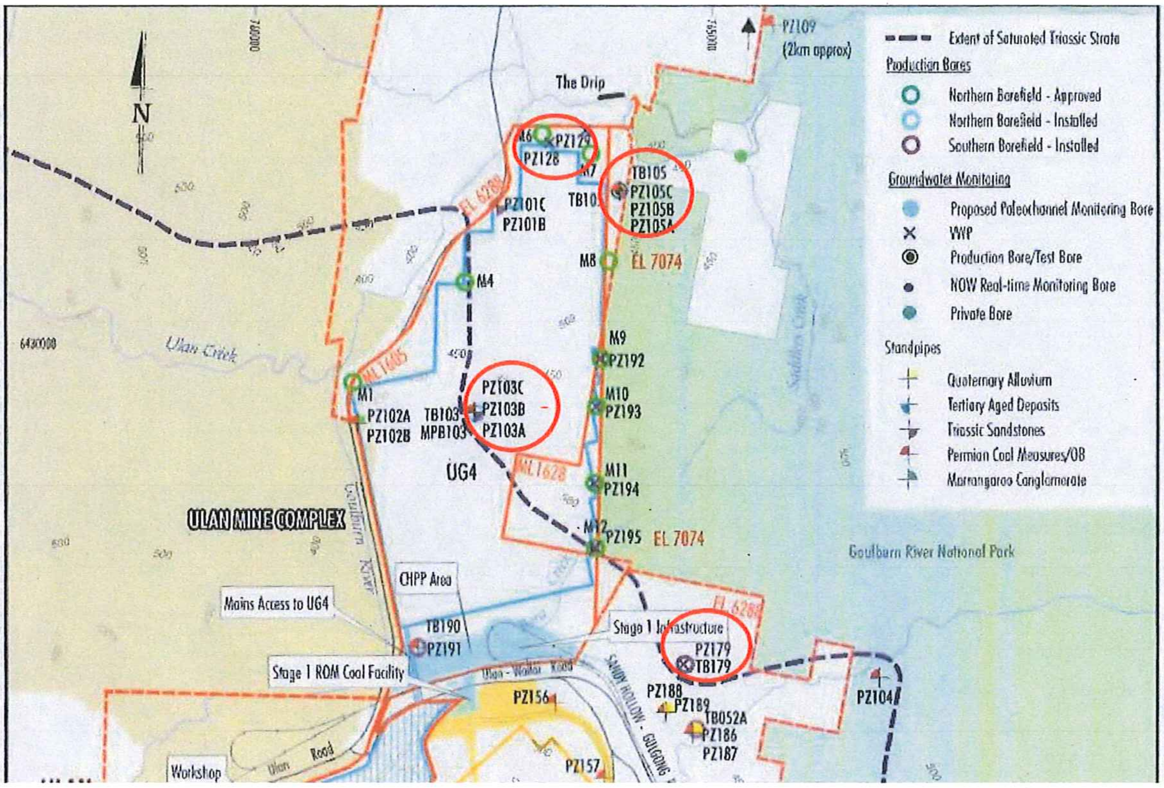

Figure 3- Location of Moolarben Coal Mine monitoring bores and Goulburn River

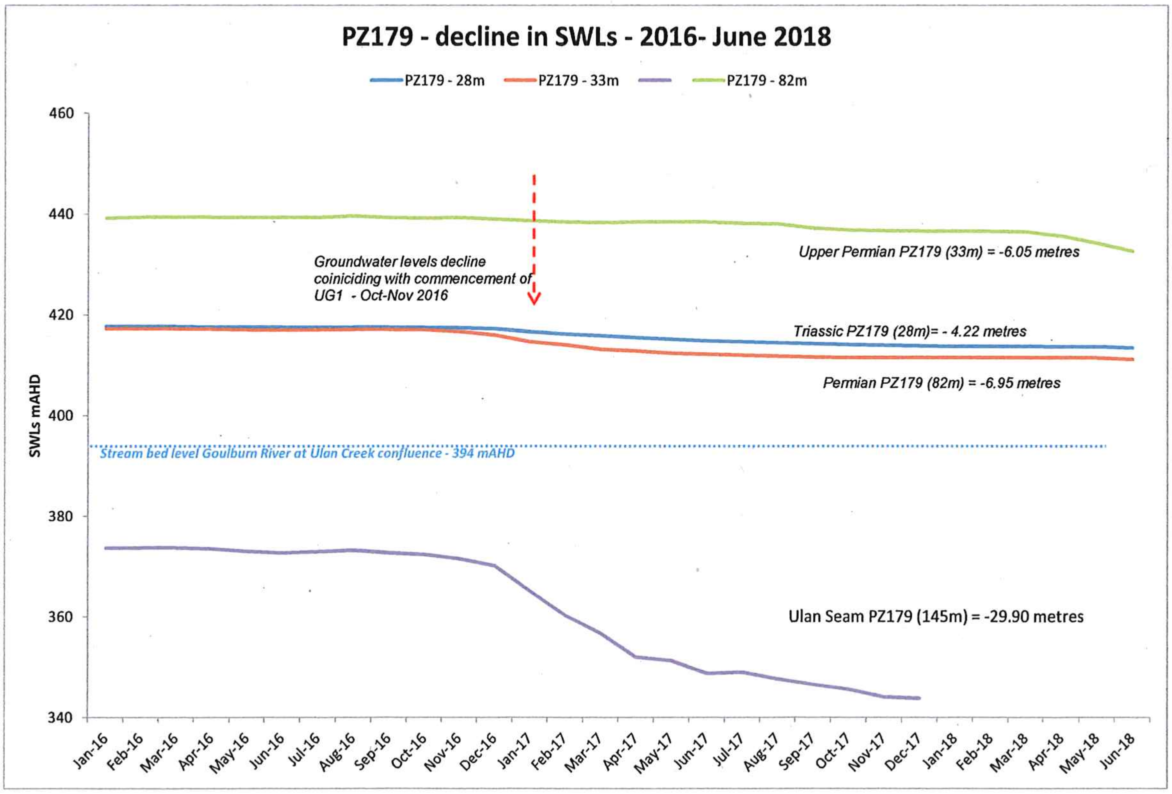

Figure 4 – Moolarben Coal monitoring piezometer PZ179 (east of UG1) decline in SWLs 2016-2017

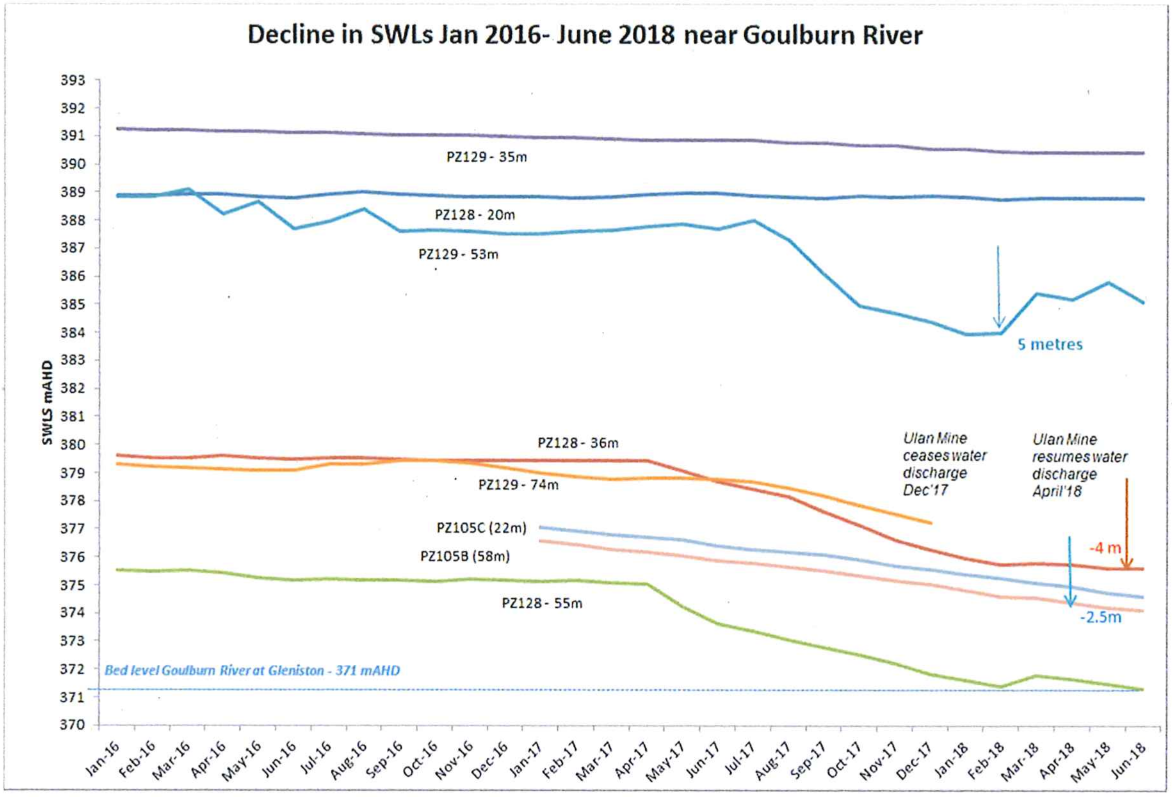

Figure 5: Decline in groundwater levels January 2016 – June 2018 following the commencement of underground mining at Moolarben Coal Mine. SWLs Triassic & upper Permian 2016-2018 - monitoring bores PZ128, PZ129, PZ105 compared to river water level.