Illawarra Coal

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Steve Knight
Executive Engineer
NSW Dams Safety Committee
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Dear Steve

Dendrobium's approval to mine within the Cordeaux Notification Area

I refer to your letter 3 November 2014 in relation to the DSCs opinion that Dendrobium is non-compliant with our lease conditions to mine within Cordeaux Notification Area.

Vibrating wire piezometers installed at Dendrobium Mine are maintained by a specialist consultant. The DSC have been supplied this data and the calibration methods embedded within the data spreadsheets since 2005. Various calculation methods and assumptions have been applied over time, including the calibrations discussed in your letter. Since 31 June 2013 corrections have been made to all Illawarra Coal spreadsheets and all data supplied to the DSC has been corrected.

HydroSimulations has completed a comprehensive assessment of hydrological and hydrogeological data in light of recent communication from the DSC regarding mining within the Avon Notification Area (15/07/2014). The outcomes of this assessment have been reported with Illawarra Coal's application for mining Longwalls 12 to 18 within the Avon Notification Area. All recent assessments of groundwater levels undertaken by HydroSimulations have used appropriately calibrated data.

From 2007 to 2009 a number of monitoring holes were instrumented with micro-purge pumps with grout plugs separating target stratigraphic units. It is now understood there is potential for cement contamination of some (but not all) of the water samples. It was thought the contamination would be temporary as the cement cured however this is not proving to be the case.

Illawarra Coal recently trialled bentonite seals in two boreholes and expects to use this improved installation technique for the proposed Area 3B Avon Reservoir monitoring holes. Illawarra Coal has reported all water quality data (including any alkalinity impacted data) since September 2004 and has reported on the contamination issues to the DSC on a monthly basis since August 2013.

The attachment provides detailed responses to the points raised in your letter which demonstrate the company has met the conditions of its lease. Illawarra Coal has applied to mine Longwalls 12 to 18 within the Avon Notification Area. Illawarra Coal has arranged to meet with the DSC to discuss your letter and the application.

Yours sincerely

J Brannon

John Brannon
Head of Corporate Affairs

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Attachment

Background

Dendrobium Mine has previously extracted Longwalls 1 and 2 in Area 1, Longwalls 3 to 5 in Area 2 and Longwalls 6 to 8 in Area 3A (Plan 1). Mining is currently within Area 3B which is partly within the Dams Safety Committee (DSC) Notification Area for Avon Reservoir (DSC Notification Area). Dendrobium has DSC Endorsement for Longwall 11 and Department of Planning and Environment (DoPE) Approval for the extraction of Longwalls 9 to 19.

The Avon and Cordeaux Reservoirs DSC Notification Area Management Plans define the standards, procedures and responsibilities to:

- describe the monitoring requirements to detect potential impacts on the Cordeaux and Avon Reservoirs,
- maintain a system for effectively managing the risk of inflow of stored water into the Mine, and
- protect the long term security of the dams and stored waters from any deterioration that may be caused directly or indirectly by operations associated with Dendrobium Mine.

DSC conditions for mining in the Notification Areas were detailed in correspondence dated 24 December 2008, 22 December 2009, 22 November 2010 and the attached DSC Annexure's 'D' (Standard Mining Conditions), 'D1' (Special Mining Conditions) and 'E' (Frequency of Monitoring and Reporting).

The DSC wrote to Illawarra Coal 15 July 2014 to indicate requirements for mining within the Avon Notification Area. The following requirements have been addressed and reported to the DSC with an updated Avon and Cordeaux Reservoirs DSC Notification Area Management Plan:

- Water chemistry data has been reviewed by an independent expert.
- Boreholes will be established between the mine workings and the Avon Reservoir. The purpose of the boreholes is to monitor the pressure heads in strata and to sample formation waters. Boreholes will be established in time to provide baseline data before Longwall 12 commences.
- Water sampling and analytical programme as well as interpretation will continue while mining progresses in Area 3B.
- A comprehensive review/analysis of water chemistry and piezometer data for Areas 2, 3A and 3B. The review includes a discussion of the deficits in the current sampling regime.

Groundwater monitoring is a Secondary Monitoring Control undertaken to determine and assess hydrogeological conditions within the rockmass between the Reservoirs and the Wongawilli Seam in Areas 1, 2, 3A and 3B.

This monitoring aims to detect the impacts of mining on groundwater, assess groundwater flow from stored water and provide verification of the results of hydrological modelling.

The monitoring consists of measuring and recording pressures from a series of piezometers to allow for estimation of a flow direction and quantity through the rockmass (i.e. from the stored water in the reservoir to the longwall extraction). These determinations are inputs used for the analysis of the source of groundwater reporting to the mine workings.

In Areas 1 and 2 groundwater monitoring was heavily focused on the area between the extraction and the Reservoir. The monitoring in Area 3 has been designed to provide regional groundwater data in addition to increased monitoring near the reservoir where access is available.

Calculation of Pressure Heads from VWPs

Vibrating wire piezometer (VWP) data spreadsheets and calibrations have been supplied to the DSC since 2005.

The calculation of pressure head of water over the Illawarra Coal piezometers were placed on a common basis for all piezometers maintained by the consultant, including Illawarra Coal, Tahmoor Colliery and others following a review at Tahmoor Colliery 31 June 2013.

Various calculation methods and assumptions had been applied to the spreadsheets over time. The main reason for this is that initially the earlier piezometer installations were not envisaged to require the accuracy now expected of them or subject to scrutiny to decimetre level.

Since 31 June 2013 corrections have been made to all Illawarra Coal spreadsheets as the need for correction was encountered and all data supplied to the DSC by Illawarra Coal has been corrected.

The assumption applied to early spreadsheets that 1 m head of water = ~10kPa has been replaced with the conversion 1m head of water = 9.8041kPa. This conversion factor is provided in Row 1 of the Illawarra Coal spreadsheets.

The effect of the change to 9.8041kPa from 10kPa corrects an underestimate of water head of 1.998m in every 100m of water head above the measuring piezometer. Using hole DEN94 as an example, the change of calibration from 10kPa to 9.8041kPa results in a change of 0.53m of measured head. These sorts of shifts in calculated water level are not significant in relation to the Dendrobium Regional Groundwater Model which the data supports.

When converting pressure to meters of water: Head of Water (m) = Pressure (kPa)/(density of water (kgm/m^3) x g(local gravitational constant)).

The density of (pure) water varies from 1kgm/m^3 at 4 deg C to 0.9922kgm/m^3 at 40 deg C. In the Dendrobium Area, water temperatures generally vary between 14 deg and 30 deg which introduces an under-estimate of head of between 0.157m to 0.381m per 100m of head. Consideration of water density in the piezometer calculation would make, at best, a relatively small change but would introduce interpretive difficulties around the assessment of density effects due to water chemistry. Presently there is no correction used for the density of water and for the above reason we do not favour implementing this calculation.

The second variable "g" is the local gravitational constant (vertical) at the site. Variable "g" varies nominally from 9.78m/s^2 at the equator to 9.832m/s^2 at the poles. This variation in "g" is due to bulging of the geod at the equator and the effects of centrifugal force from the rotation of the earth that is maximised at the equator.

Published equations estimate the value of "g" at -34.5 deg of latitude (~Dendrobium) at sea level to be 9.7969m/s^2.

An additional correction to the value of "g" needs to be made to correct for elevation (reduction in "g") and the mass of rock between the elevated observation point and sea level datum (increase in "g"). These corrections are small but important and routine in the management of data sets from geophysical surveys.

The conversion factor kPa/kHz^2 used in the conversion of measured VW frequency to pressure is the value cited by the supplier of the piezometer on their calibration sheet. Calibration values obtained at the time of installation by the installer are retained in the spreadsheet for audit purposes.

The field zero Fo, the datum for all calculations of head, is corrected to the same temperature as the calibration temperature used by the piezometer supplier. Where a field zero temperature is unavailable, then no correction is made. Where no field Fo is available then the manufacturer's Fo is used and is clearly identified in the Illawarra Coal spreadsheets.

All calculations include a correction for temperature. Where temperature cannot be measured but a good estimate can be made then this estimate is made and identified in the spreadsheet. Where no temperature data are available and an estimate cannot be made then no correction is made and this situation is identified in the Illawarra Coal spreadsheets.

Many spreadsheets now exceed the ranges possible within an Excel spreadsheet. In this situation, the data is re-sampled at a greater time interval (usually 12 hours) and this reduced dataset is displayed. In this situation the spreadsheet identifies the re-sampled dataset. All original data is retained within the Illawarra Coal spreadsheets.

Some editorial deletion of wild points may be necessary at times. Where this occurs, it is done in the calculation columns and no original field data is deleted.

Analysis of Groundwater Levels

HydroSimulations has completed a comprehensive assessment of hydrological and hydrogeological data in light of recent communication from the DSC regarding mining within the Avon Notification Area (15/07/2014). The outcomes of this assessment have been reported in the application for mining Longwalls 12 to 18 within the Avon Notification Area. The below analysis of groundwater levels is a summary of the above assessment which uses updated groundwater levels using the calibration methodology as discussed above. The assessments of groundwater level undertaken by HydroSimulations have used appropriately calibrated groundwater data.

Groundwater and lake data from Area 2, Area 3A and Area 3B has been analysed with reference to interactions between Lakes Avon and Cordeaux and the groundwater system.

Our conceptual model of interaction between Lake Cordeaux and groundwater in Area 2 is that the shallow groundwater system in the upper Scarborough Sandstone (SBSS) locally discharges to Lake Cordeaux. The potential interaction between the deeper SBSS strata and Wombarra Claystone (WBCS) and Lake Cordeaux closer to and above the Area 2 mine workings is however one of flow from the lake to these strata. The hydraulic data from DEN94, which is located closest to the lake and shows the strongest hydraulic connection with lake water levels, precludes this potential however, and we conclude that there is no evidence of observable migration of lake water into the SBSS towards Area 2 in response to mining.

The Area 2 hydraulic data does not support a proposition that the strong but variable correlation between Lake Cordeaux water levels and groundwater levels in DEN94 post-2007 is due to mining effects. The observed behaviour is more readily explained through natural hydrogeological conditions and behaviour, namely:

- Climatic effects: there is clear evidence that groundwater levels in DEN94 respond strongly during wetter periods and higher lake water levels. There is clear evidence that the lower the lake water level, the poorer the correlation between the lake and groundwater levels in DEN94. This behaviour has been shown to be a continuum, rather than a sudden shift in behaviour post-Area 2 mining. The behaviour is observed in the pre-and post-mining periods in DEN94, and, to a lesser degree, in DEN35;

- At least two likely stratigraphic controls on pressure propagation from lake water level fluctuations out into the SBSS groundwater system. The data indicates this is a strong control on the observed groundwater-lake water level behaviour outlined above. When lake water levels reach aquifer-confining (dense, clayey) sections of the stratigraphic column along the lake shore, the aquifer responsiveness to boundary condition stresses (such as lake water level fluctuations) increases by orders of magnitude, thereby increasing the “apparent” hydraulic connection between the SBSS and the lake as observed in DEN94;

- Evidence that the distance from the lake shore to DEN94 increases with lower lake water levels, and therefore adds to the above noted stratigraphic effects; and
- The possibilities that the permeability of lake-bed sediments decrease with depth in the lake or low k sediments are present in deeper parts of the lake bed. Therefore when lake water levels decline, low k bed sediments cover a greater proportion of the area through which connection might occur, and so connection weakens. This could also contribute to the above observed effects.

Our conceptual model of lake-groundwater interaction between Area 3A and the Sandy Creek Arm of Lake Cordeaux is that there was likely a natural (pre-mining) downward groundwater hydraulic gradient within both the Hawkesbury (HBSS) and the Bulgo Sandstone (BGSS), and from the HBSS to the underlying BGSS. This was also observed in Area 3B. Mining within Area 3A (Longwalls 6, 7 and 8) has increased the downward hydraulic gradients in most Area 3A BGSS monitoring bores. Despite this increased downward potential groundwater flow rate in response to mining, this does not appear to have increased the groundwater flow rate from the HBSS and/or Lake Cordeaux down into the BGSS. This is supported by the lack of observed drawdown effects adjacent to the lake in the shallower parts of the groundwater system (HBSS and BGSS). Shallow HBSS and BGSS heads in the area adjacent to the lake remain above lake levels in the pre- and post-mining periods; based on this and the supporting geochemical data it is concluded that mining has not induced groundwater flow from the Sandy Creek arm of Lake Cordeaux into the shallow groundwater system.

Our conceptual model of lake-groundwater interaction between Area 3B and Lake Avon is that there was a natural (pre-mining) downward groundwater hydraulic gradient within both the HBSS and the Colo Vale Sandstone (CVSS), and from the HBSS to the underlying CVSS. This was also observed in Area 3A. Whilst there is evidence that mining within Area 3B (Longwalls 9 and 10) has increased the downward hydraulic gradients in a majority of Area 3B monitoring bores, this is not the case in the area adjacent to Lake Avon, in which the shallow groundwater system (HBSS) locally discharges to Lake Avon in both the pre- and post-mining periods.

Groundwater levels from all 219 Dendrobium piezometers were recently reviewed in the calibration of the Dendrobium Regional Groundwater Model. The Root Mean Square error for groundwater levels of 3.9% is within the typically used criterion of 10%. The mean head error (13.6 m) is within the range of accuracy of vibrating wire piezometers when used in groundwater models with simplified stratigraphy with an accuracy of around +/-20 m.

Groundwater Sampling Contamination

Dendrobium DEN94 is a diamond drill hole (DDH) in Area 2 and it was one of the first boreholes that Illawarra Coal trialled micro-purge pumps for taking water samples from specific strata at depth. In this hole the pumps are hanging in the column of water, within the target stratigraphic unit (Scarborough Sandstone). There is an issue with this type of installation in that there is possible draw of water from above and below the pump unit and therefore the water sample is a mixture of the target strata and water within the water column. For DEN94 this is less of an issue in that all pumps target groundwater from the same overall stratigraphic unit.

The data from DEN94 proved reliable and pumps have subsequently been installed in additional holes in Area 3A and 3B. These subsequent installations were targeting multiple strata units and therefore the issue of drawing water from above and below the target stratigraphic unit was increased. The monitoring holes may also have VWPs installed to measure groundwater pressure. In these circumstances it is not appropriate to have a water column open between the stratigraphic units as the pressure would equalise between them, rendering the pressure data unusable.

In 2007 six additional holes were instrumented DDH85, 92, 93, 96, 97 and 98 each with two or three pumps targeting the Hawkesbury and Bulgo Sandstones. These holes were instrumented with

micro-purge pumps with grout plugs separating the target stratigraphic units. The advantage of the micro-purge pumps was in housing multiple pumps in different stratigraphic horizons, otherwise it required one hole per pump and there was no benefit compared to dipping for samples.

In 2008 and 2009 a further seven holes were instrumented DDH103, 108, 111, 114, 115, 118 and 125. Illawarra Coal has not installed any additional borehole pumps since 2009 due to the growing understanding of the potential for the cement based grout to contaminate the water and make it hyper-alkaline.

Initially it was postulated that the hyper-alkalinity would be temporary and that multiple sampling and associated draw-down would be sufficient to remove the contaminated water and subsequently obtain representative groundwater samples. This is proving not to be the case and the effect of the grout is persisting. The issue is further complicated by the fact that not all pumps produced hyper-alkaline water, even within the same hole. Illawarra Coal has engaged specialists in this field to investigate the matter further.

Ecoengineers identified the issue associated with the cement based grout used to seal the sections of hole between the sand packs that contained the pumps and recommended a solution. Geosensing has also identified other techniques associated with fresh drilling water (not recycling) to ensure sample integrity from borehole pumps.

Illawarra Coal recently trialled bentonite seals in two borehole installations and expects to use the improved drilling and installation techniques to install the Dendrobium Area 3B groundwater quality monitoring holes planned adjacent to Avon Reservoir.

Illawarra Coal has reported the contamination issues to the DSC on a monthly basis since August 2013. The following extracts are from a recent monthly report provided to DSC.

> *Generally, such anomalies were also indicated by a tell-tale rise in pH and EC whenever those tritium values were obtained; presumably as a result of leaching of incompletely cured cement from within the fine cracking of the respective cement plug though which the withdrawn water had passed.*
>
> *Moreover, the water is also consistently hyperalkaline (pH >12). In our opinion, it is therefore also likely that poorly competent cement (or cement/bentonite) plug 'packers' situated above and/or below this depth had cracked and the sampled 'groundwater' (if that is what it is) was being drawn through one and/or both of them thereby rendering it highly alkaline.*

All water quality data is maintained in a comprehensive Excel spreadsheet. Our records show the spreadsheet was initially provided to the DSC in September 2004 and then regularly as requested since then. The spreadsheets supplied to the DSC include the hyper alkalinity impacted data.

Addressing Contamination Issues and Interpretation of Water Analysis

In our analysis of water chemistry any of the micro-purge pumps returning pHs over 8.5 are closely assessed for a cement contamination issue. Where contamination is expected further weight is given to the tritium analysis and chloride (Cl) levels. As there is negligible Cl in cement and Cl solubility is only supressed above about pH 10.5 – 11, the Cl assessments can be undertaken even with the cement contamination. Cl is a fully conservative tracer and hence can be used when integrating regional flow modelling with geochemistry. Tritium data and analysis is not affected by the cement contamination.

In respect of the comments and recommendations in Table 1 it should be noted that:

- Pumps which provide water of pH generally above 9.0 provide valid data for tritium and chloride only – S1870 @ 160 m BGL; and

- Pumps which provide water of pH above 11.5 provide valid data for tritium only - S1907 @ 167 m BGL, S1911 @ 138 m BGL, and marginally S1970 @ 109 m BGL.

Code		Pump		Mean		Cement	Tritium	% 'modern'	Comments
S	DEN	Depth	Unit	pH	EC	issues	samples	water	and Recommendations
Area 2									
1886	94	22	SBSS	7.25	511	No	21	3.9±2.5	No sand pack or grout to provide isolation. Maintenance upgrade for the site.
		30	SBSS	7.30	530	No	22	3.9±2.1	No sand pack or grout to provide isolation. Maintenance upgrade for the site.
		38	SBSS	7.57	586	No	20	3.4±2.4	No sand pack or grout to provide isolation. Maintenance upgrade for the site.
Area 3A									
1870	85	10	HBSS	5.39	81.6	No	12	60.8±9.2	Sample annually.
		16.5	HBSS	5.86	94	No	12	24.9±5.6	Sample annually.
		160	BGSS	9.74	401	Yes	9	11.8±2.3	Faulty grout. Sample annually tritium & chloride only.
1907	103	10	HBSS	5.46	67.8	No	9	58.2±3.3	Sample annually.
		23.5	HBSS	5.61	98.9	No	10	70.3±7.6	Sample annually.
		167	BGSS	12.20	4891	Yes	9	20.5±2.6	Faulty grout. Sample annually tritium only & chloride if pH<11.5.
1888	96	7.3	HBSS	5.26	114	No	6	77.9±9.6	Sample annually.
		53	HBSS	12.58	11840	Yes	0		Faulty grout, abandoned
		199	BGSS	10.62	1702	Yes	0		Faulty grout, abandoned
1934	115	55	HBSS	6.23	142	No	7	3.4±2.0	Sample annually.
		86	HBSS						Dry
1879	92	10	HBSS	5.23	92.3	No	4	88.6±1.5	Sample annually.
		58	HBSS	6.15	163	No	4	3.9±2.8	Sample annually.
		210	BGSS	NIL	NIL	No	0		Dry
Area 3B									
1911	106	10	HBSS	4.92	100	No	10	89.7±16.9	Sample annually.
		138	HBSS	11.53	806	Yes	4	23.9±4.2	Faulty grout. Sample annually tritium only & chloride if pH<11.5.
		260	CVSS	NIL	NIL	Yes	0		Dry
1929	111	10	HBSS	5.54	107	No	5	11.1±2.9	Sample annually.
		44	HBSS	7.20	270	No	5	1.7±1.3	Sample annually.
		204	CVSS	8.24	406	Yes	4	18.5±2.3	Minor grout issues, sample quarterly.
1932	114	10	HBSS	7.52	176	No	1	6.8±1.6	Sample quarterly.
		98	HBSS	6.56	153	No	3	1.6±0.0	Sample quarterly.
2001	125	63	HBSS	6.33	196	No	7	1.4±1.0	Sample quarterly.
		106	HBSS	7.51	346	No	8	3.8±3.5	Sample quarterly.
Area 3C									
1970	118	43	HBSS	6.31	149	No	10	38.9±4.6	Probable modern water at depth, sample annually.
		109	CVSS	10.63	615	Yes	10	39.7±8.1	Probable modern water at depth. Faulty grout, sample annually tritium only & chloride if pH<11.5.
		230	SBSS						Dry

Table 1: Review of Dendrobium Groundwater Sampling Boreholes

Continued Sampling and Analysis

The Underground Water Sampling and Analysis Procedure (DENP0048) outlines the water 'fingerprinting' sampling and analysis methodologies in which samples of water inflowing to the working faces and selected discharge sites are taken and analysed for chemical composition and algal content by NATA approved laboratories.

The characteristics of the underground waters are compared to samples from the surface and aquifers in the overburden strata (Scarborough, Bulgo, Hawkesbury and Colo Vale Sandstones) to determine the origin of water entering the mine.

Current and proposed groundwater monitoring locations are provided in Plans 2 to 4.

Additional Monitoring and Site Maintenance

Dendrobium DEN94 has been in use since 2007 and in that time it has been struck by lightning, the calibration methodologies have been modified and it is now operating on its third replacement logger. Due to the importance the DSC places on the data collected from this site Illawarra coal propose to undertake the following maintenance overhaul at the monitoring site:

- re-establish the survey datum for the site
- withdraw the piezometers and accurately remeasure the cable length and consequently its location in the hole
- while on the surface, remeasure its zero calibration values
- once the piezometers are installed and logging, measure the true standing water level by dip meter
- reconcile dip meter to piezometer

- document all findings and reconcile the data spreadsheet

The current and proposed Dendrobium groundwater monitoring locations are provided in Plans 2 to 4. Three new groundwater monitoring holes are proposed and these are located next to the eastern bank of Lake Avon, between the lake and Area 3B mining.

The proposed groundwater monitoring bores adjacent Longwalls 12 and 13 will be installed early in 2015 and the third hole will be installed at a later date, taking into account the monitoring results from the first two holes. This will allow for any improvements in borehole design based on the first two holes.

The proposed monitoring holes (Avon Dam Hole 1 and 2) will be drilled into the Bulgo Sandstone. Piezometers will be installed in the Bulgo, in the lower Hawkesbury Sandstone and the upper Hawkesbury Sandstone. Micro purge sampling pumps will be installed in the lower Hawkesbury Sandstone. Bentonite packs will be used to separate the target strata rather than cement to reduce the potential for contamination of water samples.