ATTACHMENT C: ADDITIONAL INFORMATION REQUESTED BY DRE

Our Environmental Sustainability Unit recommend the following:

1. Existing performance Measures for Waterfall WC-WF54, Wongawilli Creek and Donalds Castle Creek should remain in force.

The performance measures for Wongawilli and Donalds Castle Creeks are minor environmental consequences including:

- minor fracturing, gas release and iron staining; and
- minor impacts on water flows, water levels and water quality.

The impacts observed to date include:

- A fracture in Wongawilli Creek associated with Longwall 9. No flow diversion is associated with the fracture.
- Fracturing and uplift observed in Donalds Castle Creek (RB 33, basal step Swamp 5), exfoliation from the step and associated flow diversion.

The observed impacts on surface water quality, shallow groundwater levels, and catchment hydrologic performances due to the mining of Longwalls 9 to 11 have been consistent with the nature of predicted impacts set out in the SMP and WIMMCP (Attachment O).

2. An additional performance measure, or measures, should be required for other watercourses which is sufficient to either prevent or remediate significant impacts (such as has occurred previously in the WC21 watercourse).

The Strahler stream classification system is commonly used to define the class of a watercourse and was used in the Southern Coalfield Inquiry. Streams are classified based on the number of contributing tributaries, with headwater streams classed as first and second order streams and third and higher order streams being given the classification of ‘streams of significance’. The Southern Coalfield Inquiry recommends that assessments should focus on these higher order streams. Within Area 3B, Wongawilli Creek is classed as a third order stream and Donalds Castle Creek is classed as a second order stream. Other unnamed drainage lines within Area 3B are first or second order streams.

DoPE assigned performance measures to Wongawilli Creek and Donalds Castle Creek because they are the most significant watercourses within Area 3B. The Southern Coalfield Inquiry and also subsequent Planning Assessment Commission reviews of both the Bulli Seam Operations Project and the Metropolitan Coal Project all recommended protection of third and higher order streams, which is the nature of these two streams (DoPE 2016).

WC21 is a first and second order stream and the impacts to WC21 are consistent with Section 4.3.4 of the approved WIMMCP predictions: “Based on previous experience at the mine it is expected that fracturing and surface water flow diversion would occur along Donalds Castle Creek and the drainage lines which are directly mined beneath".

A review of the impacts to WC21 from Longwalls 9 and 10 identified:

- There are 37 mapped pools in WC21 within the 3B mining area (within 400m of mining).
- Ten mapped pools have been impacted (Level 1 change in water appearance). The percentage of pools impacted by change in water appearance in WC21 in the mining area is 27%.
- Three mapped pools have been impacted (Level 2 fracturing and flow diversion). The percentage of pools impacted by fracturing and flow diversion in WC21 in the mining area is 8%.
- Six mapped rockbars in WC21 have experienced fracturing with flow diversion (Level 2).

The area of impacts at WC21 is not large in terms of the total catchment. The overall area directly affected is less than 1 ha, which is a very small proportion of the Metropolitan Special Area's overall total of 90,000 ha (DoPE 2016).

The longwalls in Area 3B have been setback between 75m and 500m from Wongawilli Creek and between 214m and 301m from Lake Avon. This reduction in extraction also reduces subsidence movements at surface features in proximity to Wongawilli Creek and Lake Avon, including the streams LA2, LA3, LA4, LA5, WC7, WC9, WC12, WC15, WC16 and WC18.

The longwalls proposed for Area 3B are planned to be 300m wide and the EA undertaken to support the SMP was undertaken on that basis. The EA and SMP are based on extensive empirical data collected during the mining in Areas 1, 2 and 3A, including Longwalls 8, 9, 10 and 11 which have been successfully extracted with a width of 300m. The WIMMCP (Attachment O) has been revised to take into account a revised subsidence model for Dendrobium (MSEC792) based on measured subsidence resulting from the extraction of Longwalls 9 and 10.

Detailed analysis was conducted into options for reducing impacts to the surface, including reducing the widths of the longwalls to a maximum of 180m. This analysis demonstrated that the reduction in subsidence movements achieved through reducing the longwall width to 180m would not significantly reduce the potential for impacts to the surface.

The proposed mine layout for Area 3B considers mining and surface impacts. The only way of "preventing" the impacts observed at WC21 would be to stand off these features and not mine beneath them.

Several layout alternatives for Area 3B were assessed using a multi-disciplinary team including environment, community, mining and exploration expertise. These included variations in the number of longwalls and orientations, lengths, and setbacks of the longwalls from key surface features. These options were reviewed, analysed and modified until an optimised longwall layout in Area 3B was achieved.

Area 3B is part of the overall mining schedule for Dendrobium Mine and has been designed to flow on from Areas 1, 2 and 3A to provide a continuous mining operation. There are a number of surface and subsurface constraints within the vicinity of Area 3B including major surface water features such as Lake Avon, and Wongawilli Creek; and a number of geological constraints such as dykes, faults, and particularly the Dendrobium Nepheline Syenite Intrusion. The process of developing the layout for Area 3B has considered predicted impacts on major natural features and aimed to minimise these impacts within geological and other mining constraints.

No contingent mining areas containing Wongawilli Seam Coal resources with the possibility for extraction are available to Illawarra Coal.

The layouts at Dendrobium Mine have been modified to reduce the potential for impacts to surface features. Changes to a mine layout have significant flow-on impacts to mine planning and scheduling as well as economic viability. These issues need to be taken into account when optimising mine layouts. The process adopted in designing the Dendrobium Area 3B mine layout incorporated the hierarchy of avoid/minimise/mitigate as requested by the DoPE and OEH during the SMP consultation process. Mine plan changes which would result in not mining under first and second order streams would result in significant business and economic impact, including:

- Reduction in coal extracted;
- Reduction in royalties to the State;
- Additional costs to the business;
- Risks to longwall production due to additional roadway development requirements; and
- Constraints on blending which can disrupt the supply of coal to meet customer requirements.

Restricting mine layout flexibility can also have the following consequences:

- Additional energy used to ventilate the mine;
- Increased safety risks such as risk of frictional ignition on the longwall due to less than optimal ventilation;
- Increased power usage, reduced fan lifespan and a requirement to install booster fans;
- Requirement for heavy secondary support density;
- Potential for horizontal stress and vertical abutment concentrations;
- The risk of strata control associated with increased roadway development and longwall install and take-off faces;
- Exposes the workforce to higher risk environments more frequently;
- Results in a large number of equipment movements and interaction with workers and infrastructure; and
- Requires specialised equipment and skilled personnel with limited availability.

Additional performance measures to prevent impacts to first and second order streams would significantly impact the Dendrobium Mine's ability to mine Area 3B.

> *3. Table 1.1 and 1.2 of the Watercourse Impact Monitoring, Management and Contingency Plans need to be revised to more clearly identify the exact monitoring sites and the types and frequency of monitoring undertaken.*

The monitoring sites and the types and frequency of monitoring are clearly identify in the WIMMCP (Attachment O). There was extensive consultation with Government during the development of these plans, including T&I; DoPE; OEH; NoW; and Water NSW.

The WIMMCP was redrafted to take into account feedback during the SMP consultation period as well as the conditions and performance measures included in the Area 3B SMP Approval. The revised WIMMCP was provided to DoPE, OEH, NoW, Water NSW and T&I 10 May 2013. The Wollongong Office of T&I hosted a joint Agency workshops to discuss the Plans (27 May 2013 and 16 December 2013) with the following agencies attending DoPE, OEH, Water NSW and T&I. Following the workshops the Agencies provided submissions. The Plans were revised on the basis of the agreed outcomes from this workshop and taking the submissions into account.

The WIMMCP (Rev 1.4) was approved by the Secretary 10 August 2015. The approved Plans have been revised on eight occasions during extensive consultation with Government, the latest being October 2015.

All monitoring sites are individually named and associated with either an impact or reference monitoring site in Table 1. Table 1 describes the site type, monitoring frequency and the parameters tested. Sections 2.5 – 2.12 of the WIMMCP provide further details of the monitoring program and include 59 detailed plans of monitoring types and locations.

The WIMMCP provides a comprehensive and appropriate description of monitoring sites and the types and frequency of monitoring for Dendrobium Area 3B.

> *4. Other agency comments be assessed to determine if the Contingency and Response Plan of the Swamp Impact Monitoring, Management and Contingency Plans is adequate, noting that this is not in a traditional TARP format.*

The SIMMCP (Attachment L) has been revised on eight occasions during extensive consultation with Government, the latest being October 2015. The TARP in the approved SIMMCP (Rev 1.4) was accepted as drafted by DoPE.

> *5. Existing performance measures for Swamps should be reviewed taking into account feedback from agencies with specialist swamp knowledge.*

The SIMMCP (Rev 1.4) was approved by the Secretary 10 August 2015. The approved Plan has been revised on eight occasions during extensive consultation with Government, the latest being October 2015. The performance measures in the approved SIMMCP were accepted as drafted by DoPE.

> *6. The Swamp Rehabilitation and Research Program requirement is supported by DRE and should remain as a condition of SMP approval. The finalisation and implementation of the Program should be progressed as a priority.*

Condition 15 of the Area 3B SMP requires the development of a Swamp Rehabilitation Research Program . A draft SRRP was provided to key Government Agencies (including OEH, WaterNSW and T&I) 03 October 2013 for comment. Submissions on the draft SRRP have been provided by DoPE, T&I, OEH and Water NSW. The SRRP was revised on the basis of the agreed outcomes from the consultation.

Illawarra Coal met with DoPE 18 February 2015 and it was agreed that Illawarra Coal would undertake additional work on the SRRP. Dendrobium Mine provided the latest revision of the SRRP to DoPE 22 August 2015.

> *7. Potential impacts on groundwater need to be assessed by the appropriately qualified and experienced groundwater experts. In particular, it is important that the potential for a significant connection between surface and deep groundwater is fully explored and confirmed as not being a significant risk.*

In 2015 HydroSimulations completed an assessment of the estimated height of connected fracturing at Dendrobium Mine (Attachment I). The assessment included:

- The effects of longwall mining and subsidence on overburden strata;
- A summary of previous research in relation to estimating the extent of the deformed strata above longwall mining, both in general and at Dendrobium Mine;
- Revised estimates of the height of connected fracturing for Dendrobium longwalls using the Ditton 'Geology Model' (Ditton and Merrick, 2014) and the Tammetta (2013) method.

The assessment concluded that the Ditton 'Geology model', as outlined in Ditton and Merrick (2014), is the most appropriate method for estimating the vertical extent of connected fracturing above longwalls at Dendrobium Mine. This is supported by the research above Longwall 9 by Parsons Brinkerhoff (2015) and earlier studies by GHD (2007) and Heritage Computing (2011).

There are numerous models for the height of fracturing and height of desaturation. A review of these matters was conducted for the Bulli Seam Operations Project Response to PAC deliberations (Hebblewhite 2010).

The results of water analysis from the surface, the strata and the mine workings and the interpretation of the height of connective fracturing from water fingerprinting was peer reviewed by Parson Brinckerhoff (2012). The peer review states that "the use of standard hydrogeochemical tools clearly demonstrated the geochemical difference between water from the Wongawilli Coal Seam and goaf, and the overlying sandstone formations and surface water from Lake Cordeaux". Although the report acknowledged limitations of the available data, this review is based on one of the most comprehensive datasets available in the Southern Coalfield.

In January 2015 SRK Consulting conducted a detailed independent review of the Dendrobium water chemistry data, to:

- Assess the level of detail, quality of science, depth and technical appropriateness of the water chemistry data.
- Evaluate associated interpretations in relation to underground operations of Dendrobium Mine, with specific focus on how these address the question of hydraulic connectivity between the mined areas and the reservoirs.

Based on the review SRK concluded that the observed geochemical trends are not consistent with a high degree of hydraulic connectivity between the underground workings and the surface water bodies.

In 2016 Hydrosimulations conducted an assessment of the height of connected fracturing above the seam at Dendrobium Mine (Attachment G).

The extents of mining-induced fracture zones are dependent on a number of factors including the thickness and geology of the overburden material and the dimensions of the longwall.

Tammetta (2013) refers to a zone of ‘Complete Groundwater Drainage’ or ‘Collapsed Zone’, taken to be where the pressure head falls to zero (corresponding to the Ditton AA and A Zones), and a saturated Disturbed Zone (corresponding conceptually to Ditton’s B Zone). Both models have a continuous fracture zone that is arched in cross-section.

Both authors have found a relation between the height of some representation of the "fracture zone" and three key attributes of the mining system:

- mining height [T (Ditton) or t (Tammetta)];
- cover depth [H (Ditton) or h (Tammetta)]; and
- longwall panel width [W (both authors)].

Ditton (2012 and then Ditton and Merrick, 2014) presents two semi-empirical formulas. The first “geometry” model uses only the parameters described above. The second, “geology” model includes a term to account for the integrity of a spanning roof block (effective spanning thickness, t’).

The Ditton formulas for fractured zone height (A) for single-seam mining (Ditton and Merrick, 2014) are:

- Geometry Model: A = 2.215 W’0.357 H0.271 T0.372 +/- [0.16 - 0.1 W’] (metres)
- Geology Model: A = 1.52 W’0.4 H0.535 T0.464 t’-0.4 +/- [0.15 - 0.1 W’] (metres)

where W' is the minimum of the panel width (W) and the critical panel width (1.4H).

The 95th percentile A-Zone heights are estimated by adding aW' to A, where a varies from 0.1 for supercritical panels to 0.16 (geometry model) or 0.15 (geology model) for subcritical panels.

The Ditton models have been validated to 35 measured Australian case-studies (including Tahmoor, Dendrobium, Metropolitan, West Wallsend, Newstan, Mandalong, Springvale, Able, Ashton, Austar, Berrima, and Wollemi/North Wambo Mines) with a broad range of mining geometries and geological conditions included.

Several studies have been undertaken at Dendrobium Mine to assess the existing fracture height above mined longwalls in order to identify and calibrate the predictive height of fracturing the model used. These studies present evidence in support of assumptions regarding the height of fracturing above longwalls at Dendrobium Mine.

In order to constrain estimates for heights of connective fracturing and the mechanisms for inflow to the mine, Hydrosimulations looked at the following sets of monitoring data:

- Groundwater pressure drawdown in response to mining.
- The Dendrobium Mine water balance, which provides an estimate of groundwater flow into each of the mining areas (1, 2, 3A and 3B).
- Chemical fingerprinting of various water sources which provide information on the origin of mine inflow waters.
- Available research, including the Longwall 9 height of connective fracturing research.

Together, these various lines of evidence support a model in which mine-related fracturing and depressurisation do not propagate to the surface and there is no evidence for rapid surface-to-seam water pathways. Significant depressurisation is apparent above longwall panels, extending to about the mid to upper part of the Bulgo Sandstone (in Area 3A), and locally to the lower part of the Hawkesbury Sandstone in Area 3B (Attachment G).

The groundwater pore pressure in deep formations is monitored using vibrating wire piezometers. The Tammetta's (2013) study on the height of fracturing above longwall mines used this approach to identify the height above the longwall goaf at which the pressure effectively dropped to zero (atmospheric pressure), indicating free drainage within a vertically connected fracture zone (analogous to the 'A' zone).

Hydrosimulations reviewed the pressure responses in the vicinity of the mine to identify the height of "significant depressurisation" above mined panels at Dendrobium Mine.

The main conclusions from this assessment are:

- There are numerous 'little or no depressurisation' points below the calculated Tammetta H level, which is conceptualised as the height of complete groundwater drainage. This suggests that the Tammetta (2013) method overestimates the height of complete drainage at Dendrobium.
- The majority of points that indicate either "some" or "significant" depressurisation plot below the Ditton A 95th percentile line. However, some points plot above this line, particularly for Longwall 6 and beyond.

Possible reasons why the Tammetta (2013) H heights consistently over-estimate the heights of groundwater depressurisation at Dendrobium are:

- The database used by Tammetta (2013) did not cover the area for which we now have data (particularly Area 3B);
- There may be differences in interpretation of data in respect of what constitutes depressurisation. In the Hydrosimulations study "significant depressurisation" refers to a decline in pressure equivalent to 25 m head or more over a period of a year (including decline of pressure head to zero). It is therefore conservative with respect to "complete depressurisation".

Groundwater inflow to the underground mine cannot be measured directly, but is inferred via a detailed daily water balance for each of the four Dendrobium Mine areas.

Analysis of the inflow to each mine area shows:

- Area 1: a mild correlation with the rainfall trend but not with individual rainfall events.
- Area 2: a clear correlation with high rainfall events (>200 mm across 1-2 days).
- Area 3A: During active mining, groundwater inflow increases linearly with time and the cumulative area mined. Following the completion of Longwall 8, the rate of inflow has an apparent correlation with rainfall trends, but not clearly with individual rainfall events.
- Area 3B: There is no apparent correlation between residual or daily rainfall and mine inflow. As with the active mining phase in Area 3A, the mine inflow rate in Area 3B is most strongly correlated with the cumulative area mined, and to a lesser extent, the rate of mining.

Hydrosimulations conducted an assessment of water fingerprinting and provenance at Dendrobium Mine (Attachment G). Water quality results and interpretation from surface waters, shallow and deep groundwater and from the underground mine workings and goaf are reported monthly to Government.

Na/Cl ratio (as an indicator of major ion water chemistry) and tritium from each water source has a distinct character. Mine seepage has a composition that is consistently distinct from surface water (having an elevated Na/Cl ratio and low tritium), but is most similar to deep groundwater from the Bulli Coal Seam. Additionally, mine inflow water typically has an electrical conductivity of 800-3000 µS/cm (brackish), whereas surface water is typically fresh (<100 µS/cm).

The mine water chemistry provides a powerful natural tracer for water samples. The Hydrosimulation study concluded the following:

- Mine water is predominantly, if not entirely, comprised of groundwater from the coal seams and deep sandstone formations.
- Mine water and surface waters have distinct characteristics and mine waters do not display intermediate compositions that would indicate mixing of groundwater with a significant component of surface water.
- Due to the natural variability in tritium levels in surface and groundwater, it is not possible to rule out a small component of surface water ingress.
- There is no significant correlation between inflow rate and chemical parameters such as EC, Na/Cl and tritium content. Peaks mine inflow at Area 2 can therefore not simply be attributed to surface water inflow.

Estimates of mine inflow clearly show some correlation with rainfall trends. The correlation is distinctly related to high rainfall events for Area 2, whereas other areas show a weaker and broader correlation with cumulative residual rainfall trends. These correlations suggest a mechanism whereby mine inflows that are higher than a nominal baseline are driven by elevated piezometric heads, which in turn are caused by high net recharge compared with long term discharge from the aquifer systems.

The data do not imply a direct link between the surface and the mine. The consistency of water chemistry parameters in mine waters such as tritium, EC and Na/Cl indicates that mine inflows do not contain a significant surface water component, and high inflows cannot simply be explained by a proportional increase in surface water ingress. The data do not allow us to rule out any surface water contribution because very small fractions of surface water (<10%) may not be apparent given the limits of precision and the natural range in source compositions. However, it can be concluded that there is apparently no direct and rapid pathway between the surface and the goaf. Otherwise the changes in tritium and EC would be noticeably greater. The same conclusion was reached by Parsons Brinckerhoff (2015) in a study that showed that potassium salt and dye tracers injected into the Hawkesbury and Bulgo Sandstones directly above Longwall 9 were not detected in goaf waters, even up to six months after the test.