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Our Ref: S187F/020b
Date: 26 September 2014

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Dear Nagindar,

RE: ANGUS PLACE AND SPRINGVALE MINE EXTENSION PROJECTS - RESPONSE TO IESC ADVICE

1. Introduction

We have prepared this letter based on email correspondence between Centennial Angus Place Pty Ltd (Angus Place) and RPS Aquaterra Pty Ltd (RPS) (BELL/CORBETT, 5 September 2014) seeking input to comments received from the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) on the EISs of the Angus Place and Springvale Mine Extension Projects (IESC, 2014ab).

This letter has been prepared to address comments relevant to both Angus Place and Springvale.

2. Proposed Response

The IESC advice is divided into two sections:

- Assessment against its Information Guidelines (IESC, 2013).
- Advice in response to specific questions nominated by the referrer, being jointly the NSW Department of Planning and Environment and Commonwealth Department of the Environment.

2.1 Assessment against Information Guidelines

The proposed response has been segregated with respect to the guideline topics posed by the IESC.

Relevant data and information

As presented in the Groundwater Impact Assessment and Surface Water Impact Assessment (RPS, 2014ab) with respect to Angus Place, there are 17 swamp water level monitoring piezometers currently installed. These encompass Kangaroo Creek Swamp (two locations), West Wolgan Swamp (four locations), Narrow Swamp (four locations), East Wolgan Swamp (two locations), Trail Six Swamp (one location), Twin Gully Swamp (one station) and Tri-Star Swamp (three locations). These piezometers monitor groundwater level and are logged on a daily basis Further detail is presented in RPS (2014a), Section 4.3. Water quality monitoring is undertaken on a fortnightly or monthly basis at East Wolgan, Tri-Star Swamp and Twin Gully Swamp since February 2011. There is also flow monitoring at Narrow Swamp (daily) and at East Wolgan Swamp, Tri-Star Swamp and Twin Gully Swamp on a fortnightly basis. Analysis of flow statistics at each of these locations is presented in Table 3.15 of RPS (2014b). Surface water monitoring within rivers and creeks is presented in Section 3.3.2 of RPS (2014b) including in the Coxs River (four locations with respect to quality and two locations with respect to flow). It is noted that there is a long-term NSW Office of Water gauging station (No. 2121054) located on the Coxs River upstream of Lake Wallace. This gauge monitors daily flow and salinity, as EC.

At Springvale, there are 11 swamp water level monitoring piezometers currently installed. Further detail on the swamp groundwater level monitoring network is presented in RPS (2014c). These encompass Sunnyside Swamp (four stations), Sunnyside East (three stations), Carne West (two stations), Carne Central (one station) and Marrangaroo Swamp (one station). Groundwater levels are logged at these locations on a daily basis. Monthly water quality is undertaken at Sunnyside, Sunnyside East, Carne West, Carne Central and Marrangaroo Swamp and commenced in February 2011. Flow monitoring at Springvale comprises the following sites: Sunnyside (fortnightly at three locations), Junction (daily at one location), Carne Swamp (fortnightly at one location), Narrow Swamp (daily at two locations) and East Wolgan Swamp (fortnightly at one location). Further detail of flow monitoring at Springvale is presented in RPS (2014d). Analysis of flow statistics at each of these locations is presented in Table 3.15 of RPS (2014d). Surface water monitoring within the rivers and creeks is presented in Section 3.3.2 of RPS (2014d), including the Coxs River (two locations with respect to flow and quality).

As outlined in the Groundwater Impact Assessment (RPS, 2014ac), recommended extension of the monitoring network includes installation of flow monitoring locations at all THPSS. It is envisaged this will comprise monitoring multiple locations within individual swamps. It is highlighted, however, that there will be impact due to construction of instrument locations as well as potential for increased traffic associated with access tracks to these monitoring locations. The flow monitoring and the associated monitoring schedules within the existing Water Management Plan, will be reviewed following development consent. The monitoring network will be updated as appropriate and in consultation with the relevant stakeholders.

Application of appropriate methodologies

As presented in the Groundwater Impact Assessment for Angus Place and Springvale Mine Extension Projects (RPS, 2014ac) and the main text of the EIS, the hydrogeological system comprises stacked and segregated groundwater systems recharged by rainfall, locally with respect to shallow and perched systems and regionally with respect to the deep groundwater system. The deep groundwater system, within which the target coal seam is located, is essentially isolated from the shallow and perched groundwater systems. The perched system is supported on low permeability aquitards layers identified within the Burralow Formation. Three dimensional geological mapping of the Burralow Formation, based on analysis of more than 250 boreholes, establishes a clear association between occurrence of shrub swamps and presence of these aquitards plies. Recharge to the perched system is via lateral transmission of percolating infiltration, from rainfall, along contacts between these aquitards. Aquifer interference in the deep groundwater system due to subsidence-induced goaf formation does not lead to depressurisation above the Mount York Claystone. This is supported by the extensive network of Vibrating Wire Piezometers (VWPs) at Angus Place (12 sites) and Springvale (18 sites). The Mount York Claystone is laterally continuous across the site. Modelling indicates that depression in the Lithgow Seam within the deep groundwater system leads to desaturation of the bottom of the Mount York Claystone. Given the base of Mount York Claystone is located approximately in the middle of the Constrained Subsidence Zone (B-Zone) it is highly unlikely that connective fracturing would extend into the Mount York Claystone. As such, there is not a continuous hydraulic connection predicted between the deep groundwater system (below the Mount York Claystone) and the shallow and perched groundwater system (above the Mount York Claystone). As presented in Appendix N of the RPS (2014ac), this is supported through field observation, which generally shows the separation of groundwater responses to mining above and below the Mount York Claystone and a lack of propagation of impacts through the Mount York Claystone. However, it is worthwhile to note that the mining induced depressurization below the Mount York Claystone layer can still cause limited pressure head drops in the groundwater above the Mount York Claystone due to increased downward flow gradient across the Mount York Claystone layer. As part of the preparation of this Response to Submissions, a review of the 'Tametta Model' for ground deformation above a caved longwall panel was undertaken by HydroSimulations (2014a). HydroSimulations (2014a) also compared the 'Tametta Model' to the latest work by Ditton Geotechnical Services (2014) in regard to delineation of the height of continuous fracturing (A Zone) constrained by site geology. The work by Ditton Geotechnical Services (2014) was also peer reviewed by MSEC (2014). These reports are attached with the Response to Submissions.

A numerical groundwater model was developed for the mine extension projects by CSIRO using their COSFLOW modelling code. COSFLOW is a finite element model and employs an implicit solution of the

3D Darcy-Richards variably saturated groundwater flow equation. Minimum element size is adopted in the model is 50m and with 20 layers comprising 900,000 elements in total. As is established in the Groundwater Impact Assessment, the predicted impacts to baseflow in COSFLOW are conservative and an opportunity to improve model definition is acknowledged. It is highlighted, however, that this model employs current best practice, including simulation of variably saturated flow but there is a limit to the level of detail that can be included in a model. Monitoring of Temperate Highland Peat Swamps on Sandstone (THPSS), exclusive of historical changes related to mine water discharge to the Newnes Plateau and anomalous subsidence impacts related to geological structure in regard to East Wolgan Swamp, is not consistent with predicted impacts, rather, reflect a naturally variable system that responds dynamically to climate. In regard to IESC's query with respect to including additional THPSS, as indicated in the Groundwater Impact Assessment, Section 6.3.4 of RPS (2014ac), COSFLOW employs a seepage boundary condition at ground surface at each node, except for those explicitly assigned perennial characteristics. As such, there is an 'ephemeral' boundary condition applied at every swamp, valley and watercourse within the model. In MODFLOW terminology, this is equivalent to defining drain, DRN, cells at every node in the model, except for those assigned as perennial, which is akin to the river, RIV, module. Further detail of the COSFLOW boundary conditions is presented in the Groundwater Impact Assessment and the CSIRO Technical Appendix (RPS, 2014ac).

Along similar lines, whilst the impact to the Coxs River is not nominated explicitly in the model such that it can be extracted directly, the seepage boundary condition at ground surface still functions. As presented in Section 6.6.2 in the Groundwater Impact Assessment (RPS, 2014ac), the predicted change in groundwater level along the alignment of the Coxs River is <0.01m and is reasonably interpreted to indicate no predicted change in baseflow.

The water quality impact of the proposed discharge to the Coxs River is addressed in the regional water quality impact assessment, provided as a technical appendix to the Responses to Submissions for the Springvale and Angus Place projects. That work consisted of a whole-of-catchment water and salt balance prepared in GoldSIM based on the Australian Water Balance Model (AWBM). The model is discussed below and further detail is presented in RPS (2014e).

Reasonable values and parameters in calculation

As is established above, the geological database, upon which the groundwater model is constructed, at Angus Place and Springvale is substantive. The current groundwater level monitoring dataset is comprehensive with 12 VWP locations at Angus Place and 18 at Springvale. These sites consist of 6 to 9 sensors each and monitor pore water pressure on a daily basis. In addition to these VWP strings, there are also standpipe piezometers along the topographic ridges which are manually dipped.

The extensions at Angus Place and Springvale propose to continue mining operations that commenced in 1979 and 1995 respectively. As such, calibration of a groundwater model to historical mine inflow and groundwater pressure within overlying strata, as well as the potential impact of adjacent operations, is a substantial site-specific hydrogeological dataset. It is acknowledged, however, that the influence of lineaments on groundwater flow is not currently incorporated in the model. During a future revision of the model predictions, the potential impact of lineaments will be considered. It is considered, however, that these structures are of much greater importance to subsidence predictions, as established in the EIS.

2.2 Response to Specific Questions nominated by the Referrer

The proposed response has been segregated against questions posed to the IESC by the referring agency and the IESC response to those questions. The IESC response should therefore be read in conjunction with the proposed response provided below.

Q1. Does the EIS, and in particular to groundwater model and the treatment of subsidence and fracturing predictions, provide a reasonable assessment of the likelihood, extent and significance of impacts on overlying adjacent swamps?

As is established above, the predicted change to the hydrogeological system due to mining is consistent with the conceptual model insofar depressurisation of the target Lithgow Seam and subsidence-related goaf formation leads to partial desaturation of the Burra-Moko Head Formation and Caley Formation that reside below the Mount York Claystone. Upward propagation of hydrogeological impacts is prevented due to hydraulic isolation of deep groundwater system as compared to shallow and perched aquifer systems. The adopted model representation of the impact of subsidence on hydraulic parameters is conservative and predicted impacts exceed historical observation. The impact of discontinuous near-surface cracking, as presented in the EIS, is considered to be minimal due to the nature of the peat substrate upon which the THPSS reside.

There is ongoing ecological research into the THPSS. That work has established that historical impact of mine water discharge to the Newnes Plateau has altered the hydrologic regime and soil chemistry. Discharge to the Newnes Plateau ceased in April 2010 and future emergency discharges during the mine extension projects are not proposed.

As is established in the EIS, the perched and shallow groundwater system are hydrogeologically independent of depressurisation of the Lithgow Seam and separate representation of the potential impact subsidence-related changes above the Mount York Claystone could be considered. On-going refinement of the subsidence predictions show continuous height of fracturing (A Zone) does not extend vertically beyond the Mount York Claystone (Ditton Geotechnical Services, 2014). DgS (2014) have developed the Geology Pi Term model (presented recently by Ditton and Merrick, 2014) for the Angus Place and Springvale Mine Extension Projects to determine the height of continuous fracturing (HoCF) for the proposed longwalls. The model takes into consideration the local geology factors in addition to the other driving factors for HoCF, namely, panel width, cover depth and mining thickness.

All swamps are included in the groundwater model by virtue of the seepage boundary condition approach adopted in COSFLOW. In a future revision of the model, relevant nodes will be tagged and individual outputs will be presented.

As indicated in response to the general query on site specific data, mining has been on-going at Angus Place since 1979 and Springvale at 1995. Appendix N of the Groundwater Impact Assessment (RPS, 2014ac) presents VWP profiles which confirm depressurisation does not extend above the Mount York Claystone.

Revision of the subsidence predictions to incorporate the Type 1 and Type 2 lineaments was undertaken in the Subsidence Impact Assessment and is described in Section 3.6.2 (MSEC, 2013ab). It is noted in that section that *“the subsidence predictions have been increased by 25% in the locations of these surface lineaments directly above the proposed longwalls”* to account for the effect of the Type 1 and 2 structures. Table 4.1 of MSEC (2013ab) provide the maximum predicted conventional subsidence parameters for the proposed longwalls outside the extents of the Type 1 and Type 2 geological structure zones or surface lineaments. Table 4.1 also provide the predicted localised increased subsidence at the surface lineaments. These increases do not lead to differential longitudinal settlement that could result in change to bed slope of THPSS. The revisions also do not lead to a requirement for change in the adopted, conservative, representation of impact of subsidence in the groundwater model.

As is established above, there is an extensive network of water level and quality monitoring of THPSS. There is also flow monitoring at specific swamps and as outlined in the Groundwater Impact Assessment and Surface Water Impact Assessment it is recommended that flow monitoring be instigated at each THPSS including control sites.

Review of hydrological response of swamps is presented in the Groundwater Impact Assessment (RPS, 2014ac), with further detail in Appendix B through E of that assessment. The terminology adopted was Type A (periodically water logged) and Type C (permanently water logged), although on-going research into the hydrodynamic behaviour of these systems indicates this delineation may need to be refined to account for longer term hydrology change at control sites.

As presented in the Groundwater Impact Assessment (RPS, 2014ac), the predicted impact to baseflow from groundwater modelling is conservative, with increases in baseflow due to assumed ramp function. Increasing the density of monitoring network with respect to flow gauging as well as additional water level monitoring will provide the basis for adaptive management of potential impacts. The groundwater monitoring network, and the associated monitoring schedules within the existing Water Management Plan, will be reviewed following development consent. The monitoring network will be updated as appropriate and in consultation with the relevant stakeholders.

Q2. If not, what does the IESC consider is a reasonable assessment of the likelihood, extent and significance of impacts on overlying and adjacent swamps?

As presented in the EIS, historical impacts to THPSS, where they have occurred, relate to previous practice of mine water discharge to the Newnes Plateau. This ceased in April 2010 and future emergency discharges during the mine extension projects are not proposed.

Aside from anomalous subsidence related to geological structure (Wolgan River Lineament Zone) at East Wolgan Swamp, subsidence effect has been observed at Kangaroo Creek Swamp overlying Angus Place Colliery's LW940 and LW950. Mine design was the causative factor. The width-to-depth ratios at this swamp vary between 0.97 above LW940 to 1.04 above LW950 which are greater than those where the proposed longwalls are located beneath Tri Star and Trail 6 Swamps at the Angus Place Mine Extension Project (0.8 to 0.9) and beneath the shrub swamps at the Springvale Extension Project (0.70 to 0.75). The proposed longwalls beneath the shrub swamps in both Angus Place and Springvale mining areas are sub-critical panels while LW940 and LW950 beneath Kangaroo Creek Swamp were critical panels. The likelihood of impacts to shrub swamps has been greatly reduced through the change in the mine design by adoption of sub-critical panels under shrub swamps. This is supported by Springvale Mine's previous extensive experience extracting longwalls with a wide range of void widths which showed sub-critical longwalls exhibited significantly less subsidence effects than the wider critical longwalls due to a reduction in the height of continuous fracturing. The updated predictions of A Zone heights (Continuous Fracture Zone) is presented in DgS (2014) and indicated the A Zone is likely to occur up to the Upper Caley Sandstone (below the Mount York Claystone) for Springvale LW 415 to 423, Springvale LW 424 to 432, Springvale LW 501 to 503 and Angus Place LW 1001 to 1019. The B Zone (Discontinuous Fracture Zone) is predicted to develop in the Burra Moko Head Sandstone (below Mount York Claystone) and Banks Wall Sandstone (above Mount York Sandstone). Further details are presented in DgS (2014). The subsidence predictions presented in the EIS do not indicate differential longitudinal settlement along drainage lines on the Newnes Plateau.

As has been stated above, predicted change to baseflow in THPSS in the COSFLOW model is conservative in context of the hydrogeological systems that have been identified and established by extensive observation dataset in shallow and deep groundwater system.

Augmentation of the monitoring network will provide opportunity for on-going refinement of model predictions.

The stated potential of fracturing of shallow bedrock, including under the swamps, of up to 50mm is conservative and is predicted expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 350 m and 400 m, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. As outlined in Section 5.12.5 of the Subsidence Impact Assessment of each EIS (MSEC, 2013ab), this prediction is at the potential maximum whereas expected fracturing, if it does occur, is likely to be between 5 mm and 25 mm, similar those observed above the previously extracted longwalls at Angus Place and Springvale. As is established in the EIS and DGS (2014), the height of the zone of continuous fracturing does not extend above the Mount York Claystone and therefore potential fracturing at surface is not considered to be significant since THPSS, given their composition, are anticipated to be readily filled. HydroSimulations (2014a) present an analysis of continuous (infinite) fracture model presented in CoA (2014b). HydroSimulations conclude that the impression is given that very large effective permeabilities would result from fracturing when, in application, the continuity of fractures is the critical feature and that a unit value for *f*, fracture surface roughness, is a most unlikely condition.

As indicated in the EIS and Goldney et. al. (2010), it has been established that the impact to East Wolgan Swamp was contributed to by anomalous subsidence but that there was not evidence of connected cracking through to mine workings, rather, surface flows were transmitted laterally. The observed increase in groundwater pressure at 60 to 70m below ground does not necessarily imply pooling of groundwater at that depth below the swamp, rather that there is resistance to vertical infiltration, which was then dissipated laterally as asserted.

MSEC (pers. comm.) state *"East Wolgan Swamp was located above Springvale LW411 (315 m wide) and Angus Place LW960 and LW970 (both 293 m wide), as well as the barrier pillar between these longwalls. The depth of cover beneath this swamp varies between 290 m at the downstream end (above the longwall commencing end) to 330 m at the upstream end. The width-to-depth ratios at this swamp, therefore, vary between 0.9 above LW960 and LW970 to 1.1 above LW411.*

The longwall width-to-depth ratios at East Wolgan Swamp are greater than those where the proposed longwalls are located beneath Tri Star and Trail 6 Swamps at the Angus Place Extension Project (0.8 to 0.9) and beneath the shrub swamps at the Springvale Extension Project (0.70 to 0.75). Centennial Angus Place and Springvale Coal has also developed management plans to minimise the potential for future impacts resulting from mining related surface activities, including mine water discharge and activity on nearby roads."

MSEC (pers. comm.) note the investigation of East Wolgan Swamp by University of Queensland (Fletcher and Erskine, 2014) found that "*The primary cause for vegetation loss appears to be the flow path of mine discharge water through the studied shrub swamp community. This conclusion is supported by the presence of shrub swamp species surrounding impacted areas caused by discharge events which ended in March 2010."*. MSEC (pers. comm.) also comment that the report by Goldney et. al. (2010) notes that impact to Narrow Swamp North *"are very likely due to flow releases from Springvale Mine. Any adverse impacts due to LWM* [Longwall Mining] *and mine subsidence per se, if present, are likely to be completely masked by the major impacts described"* and with respect to Narrow Swamp South *"potential impacts from mine water discharge are a very likely explanation along with possible direct impacts from LWM. Any impacts from LWM are likely masked by the possible significant impacts of mine water discharge."*.

The adopted ramp function presented in the Groundwater Impact Assessment is conservative. The ramp function refers to the assumed change in hydraulic conductivity, both horizontally and vertically and is used to represent potential change in hydraulic properties from subsidence. The formulation of the ramp function was based on initial coupled mechanical deformation and flow modelling within COSFLOW; however, was simplified during model calibration due to computational time constraints. As presented in the EIS and directly to the NSW Office of Water, the 'Base Case' predictions lead to modelled decline in water table level beneath topographic ridges which then results in increase in baseflow in some swamps. Historical observation from standpipe piezometer installed along the topographic ridges does not support this hypothesis. Of note, in plots of contours of predicted drawdown, there is no drawdown outside of longwall extents. The reason for this is because the ramp function was only applied to model nodes directly above respective longwalls. Accordingly, the predicted impact to water table level below topographic ridges is considered conservative and monitoring will continue to be undertaken to confirm this assertion.

HydroSimulations (2014b) also note "*Predictions of baseflow loss to THPSS may be <u>overestimated</u> within the groundwater model due to the likely existence of a low-permeability base at each swamp that supports perched water conditions. The model scale cannot readily accommodate these features, so the model has a worse-case assumption of good hydraulic connectivity between perched and regional water table conditions."*

IESC's comment on model resolution is discussed above. The suggestion that inclusion of potential change in storage due to <50mm wide near-surface fracturing is noted, however, is not considered to be significant, given that the scale of the THPSS being modelled are 1,500m or so in length. It is clearly established by MSEC (2013ab, 2014) and DgS (2014), reviewed by MSEC (2014), that continuous fracturing does not extend above the Mount York Claystone and as per HydroSimulations (2014a), the concept of continuous (infinite) fracture model presented in CoA (2014ab) is not well founded.

Whilst the representation of near-surface processes could be improved in a future revision of the model, model predictions are consistent with conceptual understanding of the hydrogeological system at Angus Place and Springvale that there are three groundwater systems and that depressurisation of the Lithgow Seam is hydraulically isolated to the hydrogeological process governing recharge to the THPSS. As stated previously, monitoring has been on-going at Angus Place and Springvale for a considerable period and calibration of mine inflows and pore water pressures in overlying strata to the substantive observation dataset is considerably more robust than hydraulic properties inferred from local scale laboratory or packer test results. Details of testing undertaken at Angus Place and Springvale are presented in Section 4.10.2 of RPS (2014a) and RPS (2014c) respectively. It is also highlighted, as well, that the geological database upon which the groundwater model is based, comprises an extensive library of coring.

Q3. What strategies does the IESC consider are available to avoid or reduce the likelihood, extent and significance of these impacts?

Subsidence related impacts have been minimised through mine design. There has been significant effort invested by Angus Place and Springvale to prioritise avoidance and reduction of potential impacts and constraints of surface features and geological and geotechnical issues, while considering mine safety, feasibility and optimisation. Sensitive surface features have been avoided where Project viability was not at risk. At Springvale the proposed longwalls (LW416 – LW432) which lie beneath THPSS (Sunnyside East, Carne West, Gang Gang South West, Gang Gang East, Pine Swamp, Pine Swamp Upper, Marrangaroo Creek, Marrangaroo Creek Upper and Paddys Creek Swamps) are designed to be sub-critical panels with void widths of 261m resulting in void width to depth of cover (W/H) ratios <1.00. The mine design has avoided Carne Central, Barrier, Sunnyside and Nine Mile Swamps.

At Angus Place, as for the Springvale, the longwalls (LW1004 – LW1006, LW1016 – LW1017) proposed beneath the shrub swamps Tri Star Swamp and Trail 6 Swamp will be sub-critical panels with void widths of 261m. Twin Gully Swamp has been avoided by shortening of LW1010. The adopted panel widths under the shrub swamps have been designed to reduce the predicted height of continuous fracturing, dependent on the depth of cover. Details of updated predicted heights of continuous fracturing (A Zone) are presented in DgS (2014).

As is established in the Subsidence Impact Assessment and the Surface Water Impact Assessment, there is no significant predicted change in longitudinal profile along watercourses on the Newnes Plateau that support THPSS.

Mining experience at Angus Place and Springvale does not concur with IESC's assertion of a significant time delay between progression of the longwall and observed subsidence.

MSEC (pers. comm.) note that "*The two lowland swamps cited in the Southern Coalfields appear to refer to Drillhole and Flat Rock Swamps. Investigations of these swamps identified that impacts had developed at these swamps prior to mine subsidence and that they were also affected by physical disturbances. Tomkins and Humphreys (2006) were engaged by the Sydney Catchment Authority to assess the erosion in swamps on the Woronora Plateau, including Flat Rock and Drill Hole Swamps, and concluded that human disturbance in the catchment and the previous erosion prior to the commencement of known mining and ground subsidence were the contributing factors. These findings were supported by the Southern Coalfields Inquiry (DP&I, 2008).*

Flat Rock and Drillhole Swamps should not be used as examples of how swamps recover from mine subsidence related impacts, as these swamps showed existing erosion and scouring prior to mining and had physical disturbances from natural causes (i.e. fire, heavy rainfall and drought) and human activities (i.e. construction of roads and installation of monitoring boreholes))."

As presented, Angus Place and Springvale propose a program of monitoring of subsidence consistent with best practice. This monitoring will coincide with on-going investigation into best practice ecological monitoring and survey, including local-scale remote sensing methods. Both mines have a long history and excellent track record of deploying the most up to date methods to its operations, as is evidenced by the use of the CSIRO to undertake groundwater modelling as well as the engagement of various academic institutions with respect to ecological research and/or review. An ACARP study (Project C20046, Fletcher and Erskine, 2014) recently published reports on the monitoring of surface condition of upland swamps subject to mining subsidence with very high-resolution imagery. This work was undertaken by University of Queensland in collaboration with Angus Place and Springvale.

Q4. Which, if any, of these strategies does the IESC recommend, and why?

As stated above, mining experience at Angus Place and Springvale does not concur with IESC's assertion of a significant delay between mining and observed subsidence. Figure 1 shows a subsidence profile for the extracted LW1, LW401 – LW412 at Springvale Mine. It is noted extraction of LW413 had not commenced and cumulative impacts from its extraction is not shown in the subsidence. As noted in Table 3.4 of the Springvale EIS the void widths of LW1, LW401 – LW409 ranged between 254 and 266m while the void width of LW410 – LW412 was 315m. The subsidence data show that the development of subsidence is predictable, with approximately 70% of measured subsidence occurring within one month of undermining, 95% is completed within 18 months of extraction and 100% within 3 years. Of note is that the measured maximum subsidence is consistent with the predicted mean profile.

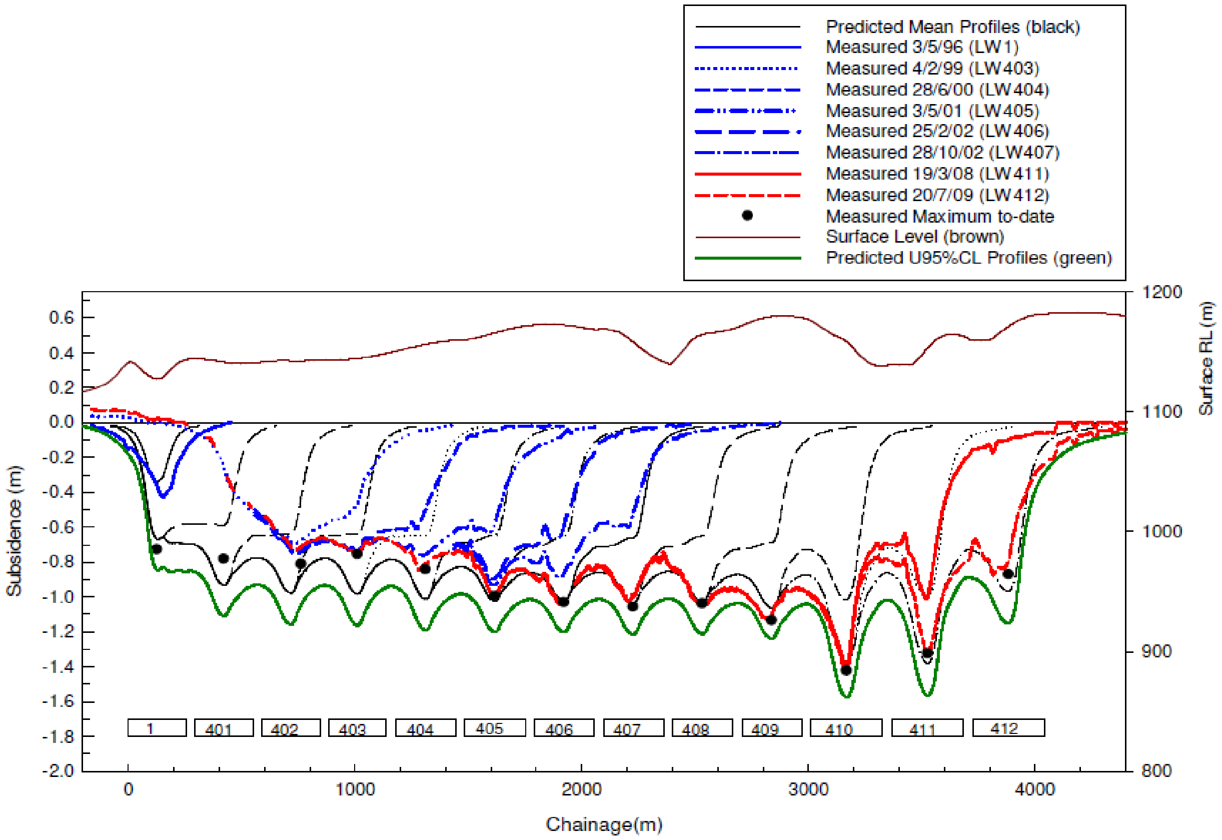

Figure 1: Subsidence Profile of Extracted LW1 and LW401-LW412 at Springvale Mine

Section 8.3.4 of the EIS describes in detail the alternative mine layouts which were considered, including:

- Changing distribution of longwalls to avoid undermining THPSS
- Shortening longwalls to avoid undermining THPSS
- “Splitting” longwall mining blocks to avoid undermining THPSS.

None of the alternate mining layouts noted above represent a viable business case for Springvale. Springvale’s proposed mine plan has avoided Carne Central, Barrier, Sunnyside and Nine Mile Swamps. Similarly, Angus Place has avoided Twin Gully Swamp from its proposed mine plan. The longwall panels beneath the shrub swamps at both Angus Place and Springvale have been designed to exhibit sub-critical behaviour and previous mining experience at Springvale provide evidence that sub-critical panels result in significantly less subsidence effects than the wider critical longwalls through reduction in the height of continuous fracturing (refer DgS (2014)).

Mining has been successfully undertaken at a number of shrub swamps (West Wolgan Swamp, Narrow Swamp, Sunnyside West Swamp, Sunnyside Swamp, Junction Swamp, Kangaroo Creek Swamp South) listed below with no significant mining-induced impacts observed. It is noted that Appendix B of the Groundwater Impact Assessment (RPS, 2014ac) provides detailed discussions on the potential impacts to THPSS (Junction Swamp, Sunnyside Swamp, Sunnyside West Swamp/Heath Swamp, West Wolgan Swamp) from mining at Springvale Mine.

- **West Wolgan Swamp** – this swamp was undermined by Angus Place LW930 and LW940 between 2006 and 2007. Figure 6 in Corbett et. al. (2014) and Appendix B of the Groundwater Impact Assessment, showing hydrographs of the four swamp piezometers along with the Cumulative Rainfall Deviation (CRD) for the period July 2005 to March 2013, indicate that the swamp is periodically water-logged (standing water levels respond to rainfall). The data also indicate that there have been no significant impacts to swamp hydrology in response to longwall mining. This observation is consistent with the findings of Goldney et. al. (2010).

- **Narrow Swamp** – this swamp was undermined by Angus Place LW920, LW940 and LW950 between 2004 and 2010. Narrow Swamp lies in the valley which identifies the western flank of the

Wolgan River Lineament. Licensed mine water discharge into this swamp, via Springvale LDP005, occurred between 1997 and 2010. Figure 17 of Corbett et. al. (2014) shows a graph of mine water discharge at LDP005 compared to two downstream flow monitoring stations at Narrow Swamp. A similarity of the trend of the mine water discharge volumes compared to the flow monitoring data exists and confirms that the three longwall panels (LW920 in 2004, LW940 in 2007 and LW950 in February 2009) which have passed under the swamp during the mine water discharge period have caused no significant loss of flow in the swamp. Goldney et. al. (2010) noted:

- *"Narrow Swamp South (Site 5): A significantly impacted THPS which we attributed to a combination of mine water discharge and sediment movement. … Any other minor impacts due to LWM may be masked by the greater impacts".*
- *"Narrow Swamp North (Site 9): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded. … We attributed this swamp's destruction to mine water discharge, since this appears to be the only viable explanation."*

Figure 18 of Corbett et al (2014) shows hydrographs from four Narrow Swamp piezometers (NS1 – NS4), the timing of mine water discharge, the longwall mining period and the CRD. Although the timing of the mining was similar to the time the mine water discharge was ceased, the figure shows the dominant influencing factor was mine water discharges. Following the cessation of mine water discharges the hydrograph trends are observed to be strongly influenced by rainfall. The responses are typically immediate and of short duration as indicated by spikes in the hydrograph trends. An analysis of the pre-mining baseline data (between March 2007 and March 2008) showed the swamp was periodically water-logged prior to mining. It remains periodically water-logged following mining.

- **Sunnyside West Swamp** – this swamp was undermined by Springvale's LW412 and LW413 between 2009 and 2010. Figure 7 of Corbett et. al. (2014) and Appendix B of the Groundwater Impact Assessment provide the hydrograph of the one piezometer (SW1) installed within the swamp and the CRD plotted for the period July 2007 to July 2013. The figure shows a strong correlation between the standing water level beneath the swamp and the CRD. i.e. the data indicate the swamp is periodically water-logged. The data also indicate that that there have been no significant impacts to swamp hydrology in response to longwall mining.

- **Sunnyside Swamp** – located below Springvale LW414 was not directly undermined, but is located adjacent to critical longwalls LW413 and LW415. Longwall mining was conducted to the east, west and south of Sunnyside Swamp between August 2009 and October 2012. The groundwater level and surface water flow data for Sunnyside Swamp has been compared with that for Carne West Swamp, which lies to the east of current mining areas and represented a control location at the time of data collection. Figure 4 of Corbett et al (2014) and Appendix B of the Groundwater Impact Assessment provide hydrographs of the five Sunnyside Swamp piezometers and two Carne West Swamp piezometers. These two studies showed that the water levels from the piezometers show marked responses to rainfall and that no water level impacts to Sunnyside Swamp due to longwall mining in the vicinity could be identified. In addition, surface water flow rates from Sunnyside Swamp before, during and after mining within the angle of draw were compared with those from Carne West Swamp (unaffected by mining) and trends were found to be very similar. The surface water flow rates data are presented in Figure 5 of Corbett et al. (2014). The data clearly show that there has been no impact to surface water flows in Sunnyside Swamp as a result of longwall mining within the angle of draw.

- **Junction Swamp** – this swamp was undermined directly by two adjacent longwalls (LW408 and LW409) at Springvale between May 2003 and April 2004. Figure 2.19 of the Springvale EIS and Appendix B of the Groundwater Assessment provide hydrographs of three piezometers installed within Junction Swamp for the period July 2002 to July 2013 and the CRD. The figure shows there is a strong correlation between the standing water levels beneath the swamp and the CRD over the monitoring period, indicating that the swamp is periodically water-logged. The data also indicate that there have been no significant impacts to swamp hydrology in response to longwall mining ie the standing water levels post mining is similar to pre-mining levels.

- **Kangaroo Creek Swamp South** – this swamp was undermined by Springvale LW401 in 1996. An aerial assessment of the Newnes Plateau Shrub Swamps by Blue Mountains City Council (Hensen, 2010) as 'Caring for Country Save Our Swamps 2010 Project' has noted the overall condition of the Kangaroo Creek Swamp South as 'Good', which is the highest category in the assessment report.

As noted in Section 2.6.2.7 of the EISs subsidence effects to aspects of swamp hydrology have been noted at Kangaroo Creek and East Wolgan Swamps. Goldney et. al. (2010) note that the subsidence impacts to Kangaroo Creek Swamp (undermined by Angus Place LW940 and LW950) were impacted by mining based on an assessment of the hydrographs of the piezometer KC1 which was undermined in 2008. However, photo-monitoring undertaken at three locations along the Kangaroo Creek listed below for periods noted and discussed in detail elsewhere in the Response to Submissions:

- Kangaroo Creek Dam (30 December 2009 to 8 June 2012) located downstream of Kangaroo Creek Swamp South – showed dam has contained water on 22 out of 24 monitoring occasions (conducted monthly or bi-monthly).

- Kangaroo Creek Waterhole (from July 2005 onwards) located within the Kangaroo Creek Swamp – showed only three monitoring events out of 41 monthly or bi-monthly monitoring events where there was no water in the waterhole (February 2014, June 2014 and August 2014), and these events show strong correlation to deficit in rainfall in the period.

- Kangaroo Creek Downstream (30 August 2012 to 18 September 2013) location is not mined as yet and is downstream from the Kangaroo Creek Waterhole (see above). Photo monitoring at this location over the period shows presence of water at the location on all monitoring occasions confirming no water has been lost from the Kangaroo Creek ecosystem.

Despite the sudden reduction in groundwater level observed in June 2008, unrelated to rainfall, at KC1 piezometer downstream of Kangaroo Creek Waterhole, the photo monitoring undertaken at this location shows no loss of water from the swamp ecosystem.

Goldney et. al. (2010) confirm the impacts to East Wolgan Swamp vegetation and stability are attributable to both subsidence and mine water discharge. The impacts to East Wolgan Swamp were also investigated by the University of Queensland (Fletcher and Erskine, 2014) which found that "*The primary cause for vegetation loss appears to be the flow path of mine discharge water through the studied shrub swamp community. This conclusion is supported by the presence of shrub swamp species surrounding impacted areas caused by discharge events.*"

As already discussed, historical impacts due to mine water discharge to the Newnes Plateau will not reoccur since there is no discharge proposed to the Newnes Plateau.

Q5. Is the groundwater model suitably robust, and are the resulting quantitative predictions accurately and reasonably described?

Hydraulic testing already presented in the Groundwater Impact Assessment indicates permeability of strata within the deep groundwater system is low. As established above, there is an extensive network of VWPs which demonstrate depressurisation of the Lithgow Seam does not propagate through the Mount York Claystone. These observation are presented in Appendix N of the Groundwater Impact Assessment (RPS, 2014ac). Historical impact of mining is of far higher magnitude than local-scale testing such as packer testing or falling head tests/slug tests on standpipe piezometer and/or laboratory permeability testing on core samples. The comment from the IESC, however, is taken on-board and the plausibility of a program of hydraulic testing on existing standpipe piezometers installed into the shallow groundwater system will be assessed.

The conceptual hydrogeological model was based on an extensive program of investigation and implies that depressurisation of the target Lithgow Seam is hydrogeologically independent to the perched groundwater system upon which the THPSS reside. Predicted impacts to baseflow in the groundwater model for Base Case and Truncated Ramp 2 relate to assumed impact of subsidence on hydraulic properties.

As outlined, it is proposed to augment the existing monitoring network at each THPSS, in particular flow measurement at multiple locations, potentially monitored daily. As explained already, COSFLOW adopts a seepage boundary condition at every surface node and therefore each swamp and watercourse is already included in the model but is not reported separately. Swamp-scale modelling is already being planned as part of a program of further ecohydrological research through the University of Queensland, however, as has been established, the shallow and deep groundwater system are not hydrogeologically connected. As noted by HydroSimulations (2014b), "*as the swamps are typically 500 to 1000m apart, a finer model would still have to be sub-regional to account for broader interactions and truncated model boundaries could impact edge effects*".

The suggestion of the IESC to potentially use daily time-steps in a groundwater model is outside of current practice. For context, this is because the time-scale of movement of groundwater is months to years, whereas surface water processes operate on a time-scale of hours to days. This view is consistent with HydroSimulations (2014b). To explain, if the aquifer material was sand (K = 10m/d) and the hydraulic gradient was 1% and the effective porosity was 15% then the average linear groundwater velocity would only be 0.66m/d. In comparison, the velocity of surface water flows is typically of the order of 1m/s (~0.66m/s). Direct coupling of surface water flow and groundwater modelling is plausible, however, potential increase in temporal resolution is likely to be drowned out by lack of full knowledge of heterogeneity at the swamp scale. A swamp-scale, variably saturated flow model, informed by appropriate gauging, will support an improved understanding of the ecohydrology of the THPSS, however, is outside of this current impact assessment. An alternative approach is use of a daily rainfall-runoff model such as the Australian Water Balance Model (AWBM), where groundwater flow processes are not modelled explicitly using finite element or finite difference numerical methods, rather the groundwater store is added to or depleted from, based on calibrated relationships. Again, this type of modelling is beyond the current impact assessment but is recommended to be included alongside the swamp-scale model approach.

As presented above, seepage boundary conditions are included at each surface node in COSFLOW and therefore each swamp, watercourse and valley is included in the model, however, is not able to be reported separately. In order to address the question of the potential impact to the Coxs River, the impact was calculated by extraction of the modelled change in groundwater level along the alignment of the river. Modelling indicates the change in groundwater level was <0.01m (1cm) and therefore it is concluded there is no modelled impact to flow in the Coxs River (refer Section 6.6.2 and 7.1 of the Groundwater Impact Assessment (RPS, 2014ac) and Section 4.2.6 of Adhikary and Wilkins (2013)). This conclusion is supported by the conceptual model insofar the recharge of the deep groundwater system is via outcrop of various coal seams on the floor of the valley of the Coxs River. Implicitly, the Coxs River is a losing stream. Section 4.2.6 of Adhikary and Wilkins (2013) confirms this hypothesis, however, with some limitations due to interpolation needed from the model mesh. i.e. water table is 2 to 5m below ground surface along the alignment of the Coxs River.

Despite being a conservative prediction, the predicted 'take' from surface watercourse due to groundwater interference is presented in Table 8.5 of the Groundwater Impact Assessment (RPS, 2014ac) for the purpose of licensing through the NSW Office of Water.

Q6. Are the cumulative water quality impacts of discharges to the Coxs River accurately and reasonably described?

To address this query as well as queries from the Sydney Catchment Authority (SCA) and the Environmental Protection Authority (EPA) and the NSW Office of Environment and Heritage, a regional water quality impact assessment was undertaken as well as a Site Specific Trigger Value (SSTV) Assessment as per the ANZECC (2000) methodology. These studies are reported in RPS (2014e) and RPS (2014fg) respectively. Direct toxicity assessments have been undertaken and the results of those assessments are described elsewhere in the Response to Submissions.

To summarise, the outcome of the SSTV assessment was that there is elevated concentrations of copper and zinc, however, these are also elevated in background, upstream source waters. With respect to nutrients, the water quality of discharge at Angus Place LDP001 has a median nitrate concentration of 0.64mg/L, which is less than the default ANZECC (2000) trigger value of 0.7mg/L with respect to toxicity. At Springvale, the concentration of nitrate is not currently measured at Springvale LDP009 but groundwater quality from Bore 6 has a median nitrate concentration of 0.42mg/L, as reported in the Water Management section of the main EIS.

The impact of the closure of Wallerawang Power Station is addressed in the regional water quality impact assessment (RPS, 2014e). In summary, the predicted salinity concentration under the proposed water management strategies lie within the historical range except at immediately upstream of Lake Burragorang. The predicted salinity immediately upstream of Lake Burragorang is, however, less than the default ANZECC 95th percentile protection guideline value of 350µS/cm (234mg/L, assuming a conversion factor of 0.67). The predicted impact to flow of proposed water management strategies is not significant in the Coxs River but mine water discharge does dominate flow in Kangaroo Creek and Sawyers Swamp Creek respectively.

Q7. Is the information provided sufficient to predict any changes to either water quality or water quantity in the Coxs River at Kelpie Point which would arise as a result of the mining operation? (Kelpie Point – station no. 563000 – is located on the Coxs River close to its entry location into Warragamba Dam. The Sydney Catchment Authority has undertaken flow and quality monitoring at this location for extended periods).

The regional water quality impact assessment, RPS (2014e), presents the predicted impact of proposed water management strategies on the Coxs River down through to Lake Burragorang (Warragamba Dam). Modelling indicates a minor increase in median salinity in Lake Burragorang from 85mg/L to 97mg/L due to the proposed water management strategy.

Table 2.1 presents a summary of the model results (impact to flow, ML/d) from the top of the catchment downstream through to Lake Burragorang. It is noted that NUL refers to the Null Case (mining at Angus Place and Springvale ceases), WS1 refers to Water Strategy 1 (Angus Place and Springvale discharge separately to Kangaroo Creek via LDP001 and Sawyers Swamp Creek via LDP009 respectively), WS2a refers to Water Strategy 2a (Angus Place discharging to Springvale LDP009 via the existing Springvale Delta Water Transfer Scheme (SDWTS) pipeline, to the extent available0 and WS2b refers Water Strategy 2b (Angus Place discharging to Springvale LDP009, with upgrade of the SDWTS pipeline to 50ML/d when combined mine water make exceeds 30ML/d). Results presented in Table 2.1 comprise mean daily flow, with range (in brackets) from minimum to maximum.

Table 2.1: Summary of Predicted Daily Flows (ML/d) in the Coxs River catchment.

Location	Node	NUL[1]	WS1[1]	WS2a[1]	WS2b[1]
Kangaroo Creek and Coxs River above Wangcol Creek/Blue Lagoon					
Kangaroo Creek downstream of Angus Place LDP001	#011	0.5(0.0-458)	26.1(5.4-474)	2.9(2.0-460)	2.5(2.0-460)
Coxs River above Wangcol Creek/Blue Lagoon	#056	1.4(0.0-1613)	27.4(6.9-1629)	5.1(2.0-1616)	3.4(2.0-1616)
Sawyers Swamp Creek					
Sawyers Swamp Creek downstream of Springvale LDP009	#014	0.2(0.0-170)	14.4(0.0-186)	28.0(3.0-199)	28.0(3.0-199)
Sawyers Swamp Creek above Coxs River	#166	0.2(0.0-223)	14.5(0.0-239)	28.2(3.0-252)	28.2(3.0-252)
Lake Wallace					
Coxs River above Lake Wallace	#047	10.3(4.4-5,577)	47.9(13.3-5,607)	as per WS1	as per WS1
Lake Wallace	#074	n/a	n/a	as per WS1	as per WS1
Lake Lyell and above Lake Lyell					
Coxs River above Lake Lyell	#154	12.7(0.1-10,223)	48.7(6.7-10,254)	as per WS1	as per WS1
Lake Lyell	#174	n/a	n/a	as per WS1	as per WS1
Thompsons Creek Reservoir					
Thompsons Creek Reservoir	#272	n/a	n/a	as per WS1	as per WS1
Lake Burragorang and above Lake Burragorang					
Coxs River above Lake Burragorang	#225	75.7(2.7-65,977)	86.9(9.0-68,789)	as per WS1	as per WS1
Lake Burragorang	#280	n/a	n/a	as per WS1	as per WS1

1. The format of presented model results is median (minimum to maximum).

Table 2.2 presents the predicted daily salinity, as TDS (mg/L), from the top of the catchment through Lake Burragorang.

Table 2.2: Summary of Predicted Daily Salinity (mg/L) in the Coxs River catchment.

Location	Node	NUL[1,2]	WS1[1]	WS2a[1]	WS2b[1]
Kangaroo Creek and Coxs River above Wangcol Creek/Blue Lagoon					
Kangaroo Creek downstream of Angus Place LDP001	#011	50(50-68)	789(75-804)	698(55-804)	664(55-804)
Coxs River above Wangcol Creek/Blue Lagoon	#056	50(50-89)	761(63-804)	538(57-804)	498(57-804)
Sawyers Swamp Creek					
Sawyers Swamp Creek downstream of Springvale LDP009	#014	50(50-50)	761(50-804)	799(160-804)	800(160-804)
Sawyers Swamp Creek above Coxs River	#166	51(50-379)	751(50-804)	799(154-804)	799(154-804)
Lake Wallace					
Coxs River above Lake Wallace	#047	599(107-771)	755(111-797)	as per WS1	as per WS1
Lake Wallace	#074	321(91-552)	604(79-747)	as per WS1	as per WS1
Lake Lyell and above Lake Lyell					
Coxs River above Lake Lyell	#035	231(50-540)	552(67-740)	as per WS1	as per WS1
Lake Lyell	#174	223(127-462)	422(145-566)	as per WS1	as per WS1
Thompsons Creek Reservoir					
Thompsons Creek Reservoir	#272	276(237-471)	477(314-613)	as per WS1	as per WS1
Lake Burragorang and above Lake Burragorang					
Coxs River above Lake Burragorang	#225	90(50-217)	153(52-503)	as per WS1	as per WS1
Lake Burragorang	#280	85(73-97)	97(74-112)	as per WS1	as per WS1

1. The format of presented model results is median (minimum to maximum); 2. It is noted that minimum salinity in water quality model was 50mg/L.

From the above, the predicted impact of proposed water management strategy Angus Place and Springvale on Lake Burragorang is a slight increase in median salinity from 85mg/L to 97mg/L.

Further detail is presented in RPS (2014e).

Q8. If so, what are the predicted changes to water quality water quantity in the Coxs River at Kelpie Point and what are the consequences for stored water within Warragamba Dam?

The regional water quality impact assessment (RPS, 2014e) presents the predicted impact to flow and salinity at Kelpie Point (equivalent to node #225 in that model). That study was prepared in response to queries received from the SCA and NSW EPA about the consequences of the closure of Wallerawang Power Station to predicted impacts.

In summary, the impact to flow is not significant at this location. The impact to water quality, as salinity, under the proposed water management strategy is outside the range of historical observation, however, is below the default ANZECC trigger value for 95% protection of aquatic ecosystems (350µS/cm, 234mg/L assuming a conversion factor of 0.67).

As indicated above, the proposed water management strategy has insignificant impact to storage volume in Lake Burragorang and predicted impact to salinity is a minor increase from 85mg/L to 97mg/L. Further detail is presented in RPS (2014e).

Q9. What water treatment options does the IESC recommend and/or consider feasible to reduce the salt and contaminant levels of mine water discharged to the Coxs River?

A water quality treatment option study was prepared in response to a Pollution Reduction Program (PRP) attached to Angus Place's Environmental Protection Licence (EPL467). The outcome of that study was there is not currently an economically feasible treatment method for salinity. As indicated above, the SSTV analyses have identified elevated concentrations of copper and zinc in proposed mine water discharge but these are also are elevated in background watercourses. The concentration of nutrients, specifically nitrogen and phosphorous, are elevated in proposed mine water discharge and are elevated in comparison to background levels, but the observed concentrations are small compared to the impact of other anthropogenic land use activities in the Coxs River catchment such as grazing.

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4. Closing

We trust this information is sufficient for your purposes, however should you require any further details or clarification, please do not hesitate to contact our office.

Yours sincerely
RPS Water

Justin

Dr Justin Bell
Principal Environmental Engineer

cc:
enc: