Pells Sullivan Meynink
Engineering Consultants
Rock-Soil-Water

G3 56 Delhi Road
North Ryde NSW 2113
P: 61-2 9812 5000
F: 61-2 9812 5001
mailbox@psm.com.au
www.psm.com.au

Our Ref: PSM2015-004R
Date: 21 June 2013

Director
Development and Building
Wyong Shire Council
PO Box 20
WYONG NSW 2259

ATTENTION: LIN ARMSTRONG

Dear Lin,

RE: CONTRACT NO. CPA/219532 – WALLARAH 2 COAL PROJECT EIS REVIEW – GROUNDWATER, SURFACE WATER, FLOODING AND SUBSIDENCE IMPACTS

Pells Sullivan Meynink (PSM) is pleased to submit our report for the above project.

If you require any further information please contact the undersigned.

For and on behalf of
PELLS SULLIVAN MEYNINK

DEREK ANDERSON

Distribution: Electronic Copy [Wyong Council]
Original held by PSM

Wyong Shire Council

CONTRACT NO. CPA/219532 – WALLARAH 2 COAL PROJECT EIS REVIEW

GROUNDWATER, SURFACE WATER, FLOODING AND SUBSIDENCE IMPACTS

PSM2015-004R June 2013

EXECUTIVE SUMMARY

The following summarises the main findings of the report presented herein. The findings are based on the proposed W2CP underground longwall coal mine which comprises the following:

- Permanent decline access tunnel from Buttonderry site to the mining area.
- Permanent Main Headings between the northern and southern zones of longwall panels and along the north eastern edge of the first longwall panels to be mined.
- Permanent works designed not to collapse or subside.
- A total of 33 longwall panels to be mined over the first 28 years of operation, which on average may be expected to take about a year each to mine.
- Relatively wide, by mining practices chain pillars left between each longwall panel. After coal is extracted from each longwall panel, the rock above the roof of the panel collapses forming the goaf and results in surface subsidence above the mined area. The coal forming the chain pillars is designed to yield and 'soften' the expression of surface subsidence into a more even profile.

It is assumed the reader has a basic knowledge of the layout of the proposed W2CP and a rudimentary understanding of longwall coal mining.

REGULATORY

WACJV has sought Development Consent for the W2CP underground mine under the new Division 4.1 of Part 4 of the *Environmental Planning and Assessment Act 1979 (*EP&A Act*)*. This Division provides for a new planning assessment and determination regime for State Significant Development in NSW. The earlier submission sought by WACJV in 2010 was undertaken through the now repealed Part 3A of the EP&A Act.

PSM understand that under this Consent application, detailed plans, such as Subsidence Management Plans (SMP's) are not required to be prepared until much later in the approvals process.

With regard to SMP's, a new set of guidelines is currently being prepared by the NSW Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS, 2011 - formerly Department of Primary Industries - Mineral Resources (DPI-MR)) for *'Preparation of a Subsidence Management Plan application where a project approval under the EP&A Act 1979, with an extraction plan condition, is in force'*. However, at this time we understand that the current *Guideline for Applications for Subsidence Management Approvals* (DTIRIS*, 2003)* remains valid.

SUBSIDENCE

Subsidence is the prime and most readily notable impact of underground longwall mining. The extent and magnitude of subsidence has a controlling influence on potential damage to property and the extent and nature of flooding and movement of surface water.

The prime result of mining are the expected number and severity of impacts across the 245 properties within the area affected by the predicted subsidence, viz:

- 83% of properties being unaffected;
- 12% requiring very minor to minor repair;
- 5% requiring substantial to extensive repair; and
- <0.5% requiring a complete rebuild (ie. about 1 property).

These impacts are based on predictions of subsidence comprising:

- Vertical subsidence up to 2.6m with less subsidence predicted in residential areas to the east and more subsidence within forested areas to the west.
- Tilts up to 15mm/m concentrated above the edges of the panels and over forested areas.
- Tensile strains up to 4mm/m concentrated near the edge of panels. About 99% of these strains are expected to be less than 2.5 mm/m.
- Compressive strains up to 5.5 m/m concentrated about 50m inside the panel edges. About 99% expected to be less than 3.3 mm/m.
- Far field movements up to ~60 mm horizontally at a distance of around 1km from mining diminishing to less than 25 mm at a distance of 2 km.

The subsidence prediction used for W2CP was developed using three key components:

1. The predictive model developed using the empirical Incremental Profile Method (IPM) by the specialist subsidence consultant MSEC;
2. The method used to calibrate the empirical predictive model by the consultant Strata Control Technology (SCT); and
3. Chain pillar performance.

Firstly, the situation at the proposed W2CP is unique in as much as it would be a deep underground coal mine in Newcastle Coal Measures, which have traditionally been mined at relatively shallow depths. It is from these experiences that the IPM has had to draw empirical data from. That is, the experience from shallow underground coal mining in similar geology to the W2CP from the Newcastle Coal fields along with the experience from mining at similar depths to the W2CP from the Southern Coal Fields, which are in a different geological environment.

As a result, the predictions of subsidence by MSEC, based on the empirical IPM approach was calibrated against computer based modelling by SCT and it is the result of this combination of empirical mining experience and computer modelling calibration that forms the prime aspect of the review herein.

In summary we conclude that:

- Based on our discussions with W2CP, we understand that something like 4 to 5 panels would need to be extracted before a full model calibration exercise could be undertaken to assess the validity of the subsidence prediction and modelling undertaken.
- The reliability and accuracy of the SCT method is unknown as:
  - There is a reliance on extrapolated inputs to which the method has been shown to be sensitive.
  - The model is calibrated to site-specific data, and not to a small number of measurements from other sites.
  - The sensitivity to most input parameters is not presented.
- Due to the empirical nature of the method the Incremental Profile Method (IPM) is only as reliable as the data to which is it calibrated, in this case the SCT model results. Therefore the reliability and accuracy of the IPM is in doubt.

  This is to some extent recognised by MSEC who in the EIS state:

  "*A thorough calibration…will only be achieved after subsidence monitoring data is obtained and analysed".*
- The use of one predictive model to calibrate another is generally unwise and not widely regarded as best practice.
- The IPM is stated as being conservative and likely to over predict impacts. The evidence for this conservatism and the expected magnitude with respect to W2CP are not provided. Indeed all indications are that the model development is centred around matching expected conditions and not exceeding or over-predicting them.
- There is a reliance on pillar compression after extraction resulting in a smoother subsidence profile. However, the basis for this assumption appears to conflict the Geological Report (Appendix G), where significant variation in both roof and floor conditions is expected across the site.
- The EIS acknowledges that pillar compression may not occur but does not quantify the impacts or changes in impact should this not occur.
- First longwall will prove that this pillar compression assumption is valid.
- No less than 3 longwalls (L1N to L3N) and more likely 4 to 5 longwalls are required before the pillar compression theory can be verified.

We accept that these predicted impacts are in agreement with expectations based on measured subsidence impacts elsewhere, and the Newcastle and Southern Coalfields in particular.

We are in general agreement that should the predicted level of subsidence occur, the type distribution and severity of impacts on houses, buildings and infrastructure is likely to be similar to that stated in the EIS.

We do not agree that the prediction represents a conservative estimate of subsidence impacts as all the evidence presented in the EIS suggests the prediction represents the most likely impacts. We consider that the model, calibration and application of the prediction does not provide sufficient guidance as to the sensitivity and reliability of the method and may, therefore, fail the Director General's "reasonable level of confidence" test.

In general we did not find any omissions or evidence to suggest that subsidence due to W2CP is likely to be significantly different to that predicted by the EIS. Our main concern is the lack of certainty around the predictive method and the likely variation in prediction based on observed variations that are already known and potentially those unknown.

GROUNDWATER

The conclusions reached by EIS are primarily the result of the input parameters adopted for their numerical modelling. These input parameters are primarily driven by the unsuitable method by which the makeup of the rock and its defects have been sampled and are not consistent with available data or modelling within the EIS. Further, modelling assumes recharge of the water system based on average climatic conditions.

The EIS implies that water inflow to the mine, of up to 2.5ML/day would largely come from water stored in the ground. However, it avoids the fact that water stored in the ground comes from somewhere, and is currently in equilibrium with natural recharge. A valid way to consider this matter is encapsulated in the following quotation from Dr Rick Evans, principal hydrogeologist of Sinclair Knight Merz, viz:

> *"There is no free lunch here. It's very simple – every litre of water your pump out of the ground reduces river flow by the same amount".*

Australian Financial Review,
24 May 2007

Other points to note are:

- We cannot define precisely what portions of which rivers will be affected by leakage losses from the near surface alluvial lands into the deeper rock mass;
- We cannot say, with confidence, how many years it will take for the impact of underground extraction to reflect in surface flows; and
- The EIS states that the mine will not fully recover groundwater pressures for over 500 years.

These points, combined with the uncertainty on the input parameters to the groundwater modelling there is a high probability that leakage losses from the alluvial lands will impact the surface water. Given the high likelihood or even near certainty that climate impacts would be sufficiently severe at some point implies that it may affect visible flows for long periods.

On balance, the findings from the EIS are at the least a limited and probably unconservative view of potential impacts. This means that, at present, it is not known with an acceptable level confidence what the likely impacts of the Wallarah 2 longwalls will be on groundwater resources, and on groundwater that feeds into the streams of the Dooralong and Yarramalong Valleys.

FLOODING

The results of the flood assessment appear reasonable given the limits of the prediction of subsidence and can be considered as “best practice”.

The discussion on the impacts of the W2CP on flooding are made in relation to the 1% AEP event (1 in 100 year) and would only fully come into effect after mining has been completed. It is important to note that the assessment of flooding is dependent on the expected subsidence and so any change to mine plans, or the prediction of subsidence through any validation process will result in changes to the extent and impact of flooding.

Results of the flood modelling for the 1% AEP flood event indicate that subsidence from the current W2CP mine plan is likely to result in only relatively minor increases in the depth and extent of flooding compared to current, pre-mining estimates with a total of about 35Ha of additional land becoming affected across the whole W2CP area.

The changes to flooding extents will have an adverse effect on up to 10 properties. The impact is assessed to be up to 5% of additional land area inundated for 4 of these Properties and up to 20% of additional land area for the remaining 6 properties.

In terms of impacts on residential dwellings, a total of 5 properties that were not previously impacted by the 1 in 100 year flood level are now impacted by flood water depths of between 4cm and 1.27m above floor level. These are assessed as being Major impacts in the system of ‘*Flood Impact Categories’* adopted by the EIS. In addition to these dwellings, a further one dwelling is Categorised as being subject to a Major Impact, in this case the expected 1 in 100 year flood level increase by up to 41cm above current, pre-mining predictions.

In the moderate flood impact category, a total of 8 dwellings will see a rise in the currently predicted inundation levels due to the 1%AEP event by between 3cm and 17cm. A further 3 dwellings will have the level of clearance, or freeboard between the predicted flood level and dwelling floor level reduced to values of between 4cm and 28cm.

Minor impacts are expected to occur to a total of 10 dwellings and comprise increased levels of flooding above floor level by between 1cm and 4cm and reduced levels of freeboard above flood levels.

Further to the dwellings described above, a total of 14 dwellings are expected to have no significant change in flood impacts while a total of 49 properties will see a slight reduction in flood impacts.

Other impacts of the subsidence on flooding are flood peak flows are anticipated to be slightly reduced with a minor increase in the duration of the peak, although the EIS notes these as being insignificant.

Flooding will impact a total of 30 primary and secondary access roads in the project area. Of these only 6 primary access route low points will be adversely impacted by the mine. Adverse impacts comprise increased duration of flooding of between 1hour and up to 27 hours. The latter time pertains to the crossing (D50) located toward the southern end of Jilliby Road just north of the intersection with Watagan Forest Drive.

Mitigation of the impacts of flooding can readily be undertaken by the WACJV. Detailed plans for each location and/or dwelling are not provided at this stage of the process and are only required after approval has been given.

At this time, the only indication of the extent of potential mitigation is in relation to the Major and Moderate Impact Categories.

Preliminary descriptions of possible mitigation works presented in the EIS comprise:

- Raising or relocating dwellings;
- Raising Sandra Street to increase the upstream flood retarding storage;
- Construction of grassed earthen levees around dwellings to provide a minimum freeboard of 0.3m; and
- Construction of new replacement dwellings.

The purchase of dwellings is mentioned as an option, but is not linked to any dwellings in the EIS, nor is any mechanism or process for such an option canvassed.

In terms of primary access points, the six adversely affected locations can be raised after subsidence has occurred to mitigate the adverse effect. In some instances, the works may require new culvert works to facilitate passage of flood waters past the obstacles.

Council must be conscious of the longer term maintenance requirements of any mitigation measures.

The discussion on potential flood mitigation measures remain at a feasibility level but are considered appropriate and to constitute “best practice” for this level of appraisal. Detailed assessment will be required if planning approval is given and this must ensure all the Director General’s requirements are met.

LOSS OF SURFACE WATER

Loss of surface water from streams in either the Yarramalong and/or the Dooralong Valley will have a direct impact on the availability of water in the Wyong River downstream of the proposed mine which is used as part of the water supply to the Wyong and Gosford Local Government Areas. Further, loss of surface water will also affect businesses such as turf farming and supply of water to local bores.

The assessment of loss of surface water is entirely dependent on the inputs to groundwater modelling and the impacts on groundwater flow by the mine. The EIS concludes that there will be very little impact on leakage from the near surface alluvial lands due to the very low permeability of the rock below the alluvial lands and, that what loss does occur will be readily compensated for by surface recharged.

These statements are based on two assumptions. Firstly, that average climactic conditions prevail and secondly, a favourable view of the permeability of the rock below the alluvial lands. The latter point is discussed above under the topic of groundwater modelling, but suffice to say there is considered to be a high level of uncertainty and a lack of factual evidence to confirm the parameters used.

With regard to the first point above, for the EIS to be relevant, it must also consider the variation in inputs to the surface water supply in extended dry periods. The review in this report considers the flow in Jilliby Jilliby Creek between 1972 and 2013 to illustrate the sensitivity of the stream flow to climate and to small variations in flow volumes, viz:

- The median flow rate in the creek is about 4.5 ML/day.
- Flows of less than 1ML/day occurred for 24% of the time
- Flows of less than 0.1 ML/day for 10% of time.

The predicted water inflow to the mine of up to 2.5ML/day represents more than half of the average flow for Jilliby Jilliby Creek and is greater than the flows recorded for 40% of the time since 1972.

These flows are put into perspective when records of consecutive days, since 1972, where low flows considered. The five longest periods of consecutive days when flow was less than 1 ML/day and 2 ML/day range from 112 up to 190 days. This shows that when dry periods occur, the flow in the creeks can be expected to be at a level that may be readily affected by leakage losses from the alluvial lands.

Further, a review of the climate during this period reveals that while some periods of drought did occur such as the Millennium Drought, it does not include the experience of the more intense droughts of World War 2, and the time of Federation.

PONDING

Current predictions of subsidence indicates three locations where increased bowls of storage in ponds along Jilliby Jilliby Creek (2 No.) and Little Jilliby Jilliby Creek (1 No.) are expected to result in longer and/or more frequent periods of drying downstream and similarly of wetting upstream of the newly created pond.

The expected extent to which the stream and adjacent lands may be impacted upstream and downstream of the pond is difficult to predict, but is not expected to be more than 500m and in all likelihood would be less than say 100m. Given the generally cleared/settled nature of the floodplain areas, the potential for drying conditions to adversely impact native flora and fauna is minimal. Any impacts should be able to be effectively managed with suitable monitoring and timely response in mitigating any adverse effects.

These conditions are expected to prevail until such time as the streams re-establish a continuous stream bed. This is highly likely to occur where the ponds occur in the more silty and sandy alluvial soils along the creeklines, but may be much restricted if the ponds occur in areas of heavy clay. The timeframe for these changes depends on the soil types and also the flow velocity and frequency where the stream is ephemeral.

The potential for ponding in Wyong River is considered negligible under the anticipated subsidence.

Subsidence profiles along the Hue Hue Creek have not been provided and so assessment of impacts of mining have not been made.

BOREFIELDS

Borefields have been developed at Woy Woy, Somersby, Mangrove Creek, Ourimbah and Mardi for use by the CCWC as a drought contingency measure. Of these, only the single, 150m deep bore at Mardi is potentially going to be impacted by the W2CP. This bore is about 3km from the southern extent of the mine.

The Mardi bore is thought to extend into the rock of the Tuggerah Formation, or possibly to the top of the Munmorah Conglomerate. The main coal seam in this location is at a depth of about 450m to 500m.

The EIS predicts piezometric drawdown levels in the location of bore will not occur during the period of mine operations. However, drawdown of up to 5m may occur after a long period of time (500 years after mining).

These predictions appear to assume that nearly all of the water inflow to the mine is from that stored in the ground. Hence the predicted drawdown is expected to represent a worst case. If, as we consider likely, a portion of the water flowing into the mine comes from the alluvial lands above the mine, then the impacts at locations such as the Mardi bore will be less than predicted by the EIS.

EROSION AND ENVIRONMENTAL IMPACT

The EIS notes that there is active erosion occurring along the banks of the Jilliby Jilliby Creek, but also that the impacts of the project on surface water resources can be mitigated through implementation of:

- Property Flood Management Plans a water quality monitoring programme for streams in the W2CP area; and
- A stream stability monitoring and management programme.

As with the subsidence and flooding, the W2CP is not required to prepare detailed management plans at this stage of the process but has included some indication on the approach and works within the specialist reports. Broadly the set of works and frequency suggested is considered appropriate but requires a significant amount of detail to allow any worthwhile appraisal to be undertaken of its likely effectiveness. However, it is not clear whether the approach is to be entirely "reactive" in nature, or whether it will include some form of "pro-active" works.

We recommend that the WACJV should endeavour act to prevent erosion rather than repair it where appropriate, as this would be best practice.

The ability of the mine, locals, Council, or other authority to say what is adverse and what would or could have been expected to occur pre-mining will be virtually impossible to ascertain and so the question is what should be done in terms of mitigation or preventative works. This also impacts on who is responsible for undertaking the works. In order to prevent this, and other similar issues from resulting in futile and circular arguments that result in nothing being achieved or done, specific and measurable/quantifiable targets must be agreed and established so all parties understand where they stand if the mine is approved.

RISK ASSESSMENT AND ADAPTIVE MANAGEMENT

In terms of groundwater impacts and to a lesser extent surface subsidence, the EIS presents an abridged assessment of the potential impacts and hazards posed by the W2CP. This situation arises as the EIS only considers risks that have been modelled by the specialist consultants and is thereby limited by the specialist assumptions and either lack of or limited sensitivity assessments. This is not considered appropriate at this stage of the assessment where transparency as to the entire gamut of potential impacts should be canvassed.

Further, the consequence rankings at the high end of assessment have been combined and limit the risk assessment process by requiring that severe, long term and/or potentially irreversible impacts must also be wide spread to warrant a high ranking.

In order to begin to allow the impacts of the project to be managed via adaptive management, the understanding of the impacts and risks must be robust and comprehensive, and quantitative in nature, not qualitative as is the case here.

The risk assessment should consider the level of risk associated with all aspects of the W2CP, and in particular those that:

- Are associated with a high level of severity in terms of consequence,
- Have a high degree of uncertainty surrounding the assessment/modelling,
- Have consequences that either may not/cannot be able to be remediated, mitigated or managed once they are observed, or
- Represent a significant degree of community concern.

The results of a rigorous, qualitative risk assessment could then be considered with respect to acceptable levels of risk, and/or a cost/benefit assessment. The latter of which may, or course result in high consequence impacts with a low risk and/or cost impact being disregarded in the final assessment of the project. However, as stated above, they all need to be considered and presented so an informed judgement/decision can be made.

In terms of the aspects of the project covered in this report, we would recommend the following be subject to a detailed risk assessment process.

1. Ground Water Impacts – test the sensitivity of the baseflow water losses with respect to hydraulic conductivity, level of subsidence induced by mining and environmental factors such as drought.

2. Subsidence Impacts – test the magnitude and location of subsidence effects with respect to items such as variability of the roof conditions of the mine and strength of pillars.

If the impacts of the mine are to be managed via adaptive management then a risk assessment is essential in order for the process to be:

i. Correctly focused; and
ii. Establish realistic and measurable targets.

Following this, and possibly with the assistance of a cost/benefit assessment, for an adaptive management plan to be effective it must be based on targets for monitoring and assessment that are:

- specific;
- measurable; and
- agreed between all parties.

Further, the targets must be accompanied by agreed responses otherwise the management system would be reduced to an impotent and disingenuous process.

Agreed responses may be as minor as “continue to monitor / watch” to potentially quarantining coal below the alluvial areas or even as strong as “cease mining”.

MANAGEMENT PLAN DEVELOPMENT/APPROVAL CONDITIONS

Measures to mitigate and/or remediate the impacts of subsidence, increased flooding of dwellings and erosion are discussed in the EIS. However, the discussions are relatively general in nature and can only be considered appropriate for the feasibility stage of the project.

The EIS and regulatory requirements are such that detailed Subsidence Management Plans (SMPs) need only be developed in consultation with landowners, Council and other stakeholders for adversely affected properties and streams after any approval has been granted. This would be expected to invoke the "Adaptive Management" approach for the project, for which there are very significant concerns given the level of uncertainty and lack of a comprehensive risk assessment for all of the possible project impacts.

This report provides guidance on matters such as monitoring, validation and further assessment requirements, particularly in areas where information is unclear or uncertainty on data and/or impacts is high.

The guidance provided is intended for consideration by approving authorities in the assessment of the EIS and, if applicable the setting of conditions for the approval of the W2CP.

CONTENTS

FIGURES

1. INTRODUCTION

The report presented herein provides a review of the Environmental Impact Statement (EIS) prepared by Hansen Bailey on the Wallarah 2 Coal Project (W2CP) for the proponent, Wyong Areas Coal Joint Venture (WACJV).

The review particularly considers specialist reports presented in the Appendices to the EIS in relation to the likely impacts of the proposed longwall coal mine development on:

- ground subsidence
- the groundwater regime
- surface flooding
- the surface water regime.

The reader should also be aware of PSM's earlier review (Reference 2) of the proponents original Environmental Assessment (EA) presented in 2010. Parts of that document remain relevant to this assessment as many aspects of the EIS are similar to the EA and are repeated where appropriate.

Further to the above, the findings of the Parliamentary Assessment Committee (PAC) report published November 2010 (Reference 3) and the subsequent assessment and refusal by the NSW Department of Planning (Reference 4) dated March 2011 should be noted. In particular, the Director General (NSW Dept. Planning) reports that:

> *Recommended conditions presented in the PAC's report rely heavily on an adaptive management approach to impacts from the project, and the development and implementation of a significant list of environmental management plans. ….. Many of these issues have also been raised in public authority submissions, which have suggested an inability to conclusively determine the environmental impacts of the project based on the information provided in the Environmental Assessment.*

The Director General also notes that:

> *The Department accepts that there will always be a level of uncertainty associated with predictive modeling and assessment of large-scale development proposals, and that the adaptive management approach is an effective tool that is used to refine, mitigate and manage the long term impacts of mining in NSW. However, the Department stresses that a reasonable level of confidence around the type and magnitude of likely environmental impacts must be achieved before adaptive management and management plans can be applied.*

In scenarios where there is significant uncertainty and/or a substantial consequence arising from the uncertainty, the only responsible practice to assess the impact of the uncertainty is to undertake a detailed risk assessment considering the likelihood of an event as well as the consequences of each scenario.

2. SCOPE OF WORK

The scope of work for this study was set out in our letter PSM2015.002L (March 2013) comprises the assessment of the following.

i. The impacts of the project and the resultant surface subsidence on surface water and ground water within and adjacent to the mining area.

ii. The adequacy and accuracy of subsidence predictions.

iii. Impacts on deep aquifer systems and water table elevations at the ground surface.

iv. Adequacy of any proposed Groundwater Management Plan and any conditions recommended should development consent be granted for the project.

v. Contingency plans to manage any release of oxidised metals due to fracturing of drainage lines.

vi. The adequacy of any measures proposed to manage or mitigate any unwanted or unexpected effects of subsidence under the alluvial floodplain of Jilliby, Jilliby Creek or Little Jilliby Jilliby Creek where new wetlands/depressions are potentially created.

vii. Adequacy of groundwater monitoring processes.

viii. Potential loss of water from streams caused by leakage to deeper hard rock systems.

ix. Confirm whether the EIS provides a comprehensive and technically robust assessment of potential groundwater, surface water, flooding and subsidence impacts from the Project

x. Identify any potential important aspects or issues that have not been fully and adequately investigated and assessed

xi. Identify areas of uncertainty and further investigations and assessments required prior to Project determination and/or during the construction, operation and closure stages of the Project

xii. Assess as far as possible whether the information provided in the EIS has been prepared in a manner consistent with Australian and International standards and best practice guidelines

3. BACKGROUND

The W2CP proposes to develop an underground longwall coal mine below parts of the Yarramalong and Dooralong Valleys and the Hue Hue Creek catchment, all upstream and west of the F3 Freeway. Figure 1 shows the proposed areas for underground extraction as well as the location of the surface works at the Buttonderry site and the Toohey's Road site.

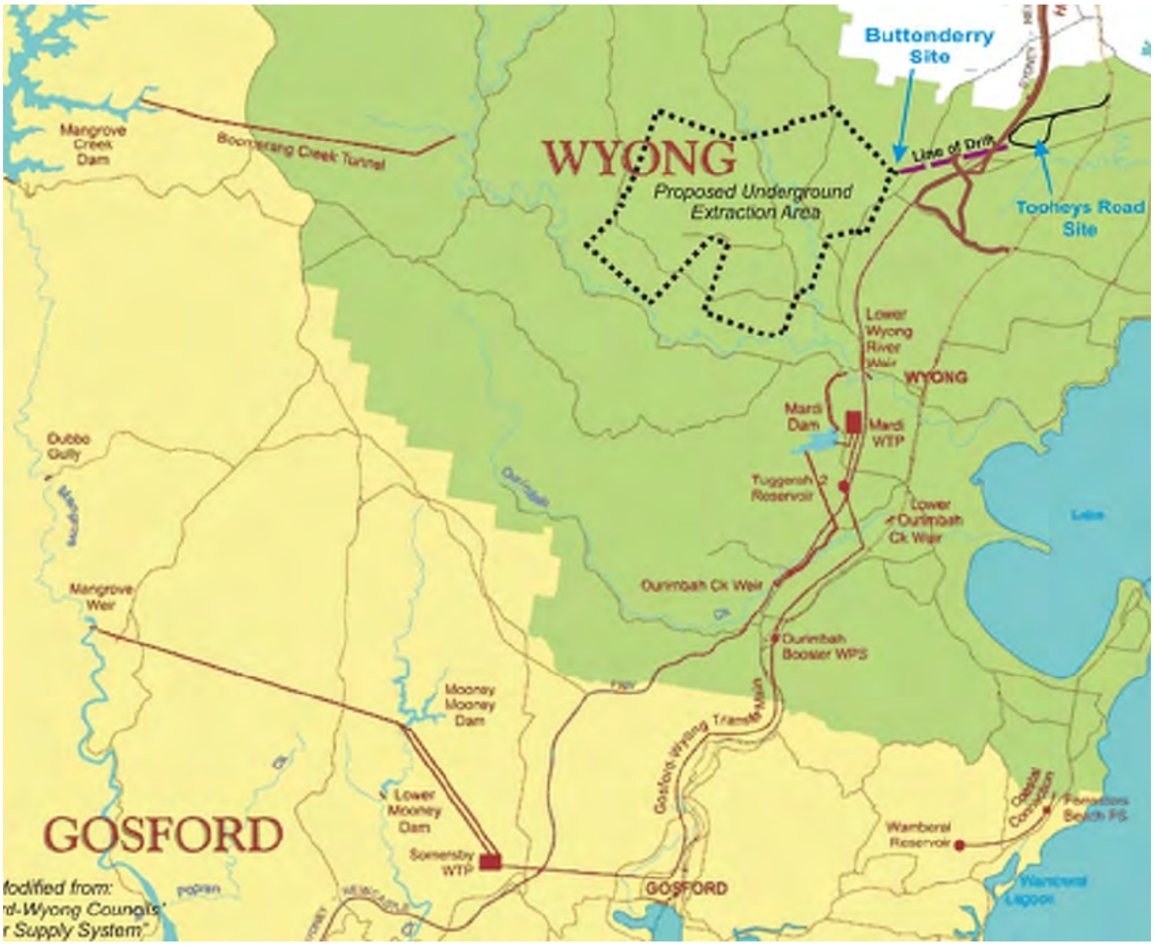

Figure 1: Mine location

Coal is to be extracted using longwall mining commencing in the eastern part of the mine and generally working to the west. The mine workings will be to a depth of between about 350m to 450m below the populated valley areas up to a maximum of about 690m below some of the higher, forested ridgeline areas above the valleys, particularly toward the western part of the mine.

Figure 2 shows a diagrammatic representation of the stratigraphy at the proposed mine.

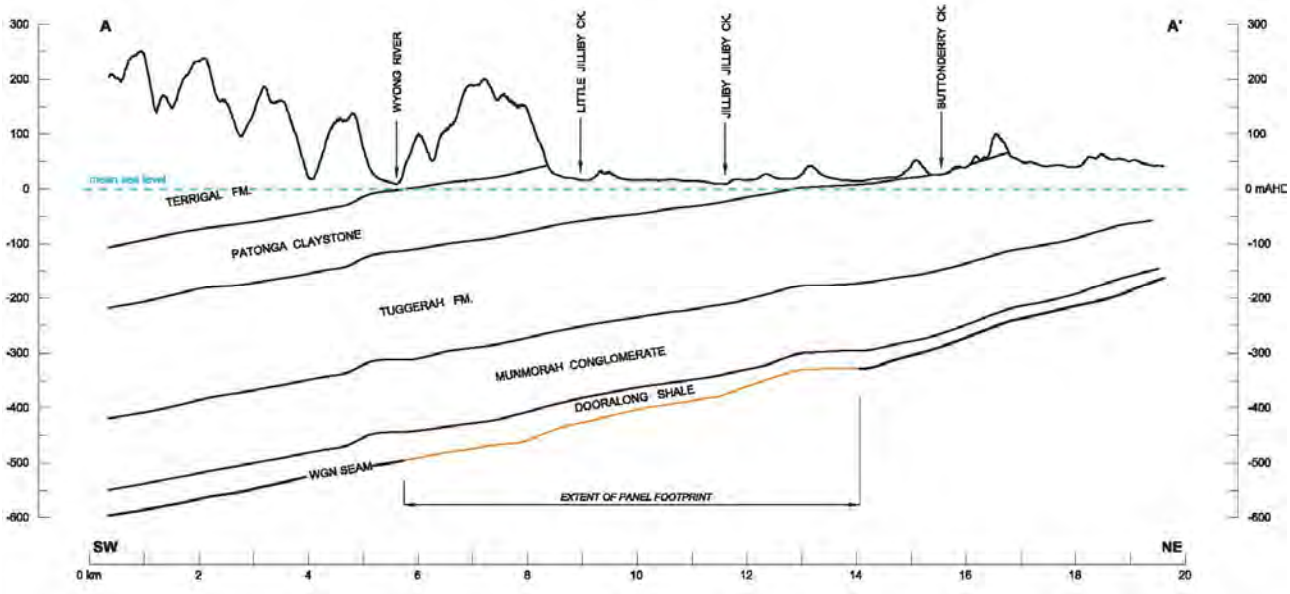

Figure 2: Diagrammatic cross-section of coal seams

Coal is to be removed from the mine via a conveyor in a drift tunnel from the north-east part of the mine (below the Buttonderry Site) to the surface facilities at the Tooheys Road site. From there, the as-mined coal will be transported off site by rail. No washery is required.

4. MINE PLAN

The proposed W2CP mine plan comprises a total of 46 longwall panels of which 33 are proposed to be mined in the first 28 years. Figure 3 shows the proposed layout of the longwall panels.

Mining is to commence at the north-eastern part of the underground workings and extend to the west with the initial mining to be undertaken in the Hue Hue Mine Subsidence District. Figure 4 shows the proposed mining sequence.

The proposed mine plan comprises:

- extracted coal height 3 to 4.5m
- longwall panels widths between
  - 125m wide and 175m at the initial Hue Hue panels
  - 175m and 205m in the floodplain areas
  - up to 255m in the western forested hills
  - longwall panels lengths of between 1.4km and 3.4km
- solid chain pillars of coal left between longwall panels of 45m to 75m width.

Further, while the first 11 longwall panels are being mined, development works for the "permanent" main headings will continue to the west and southwest below the alluvial valleys and Wyong State Forest.

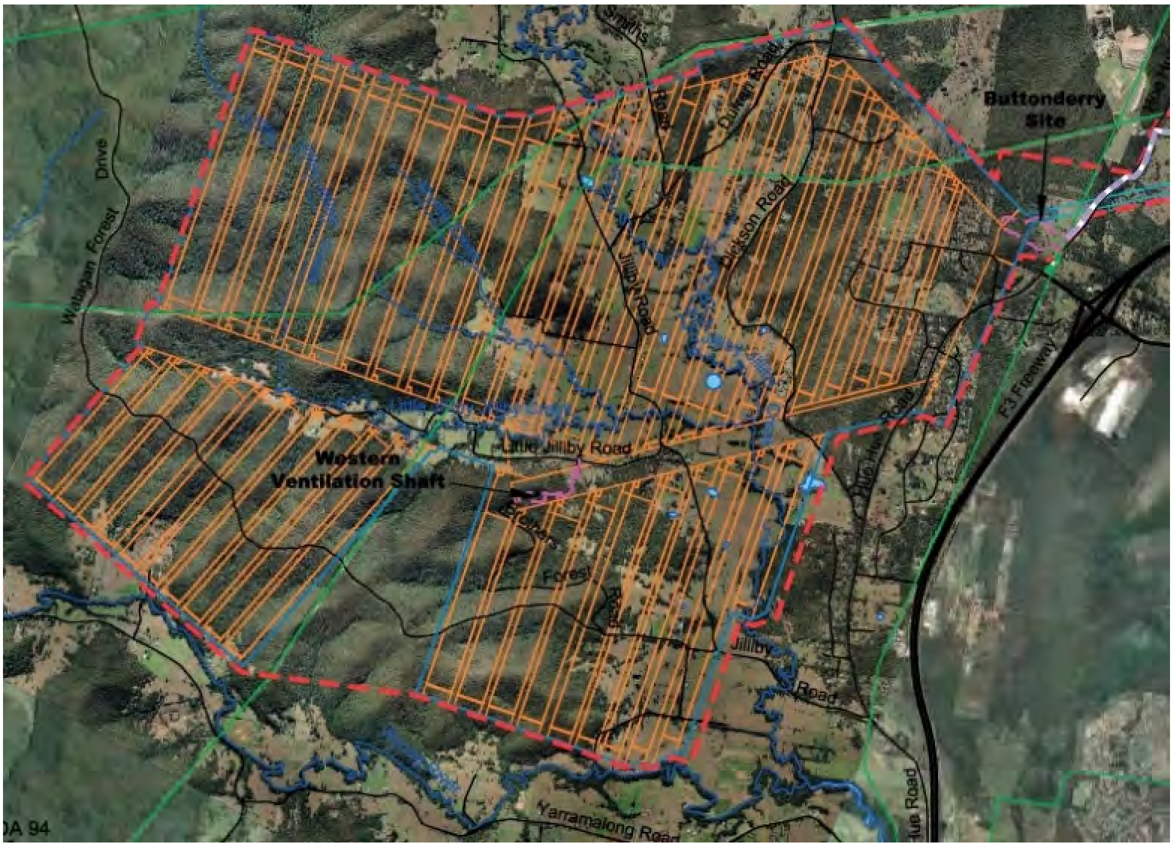

Figure 3: Proposed Mine Layout

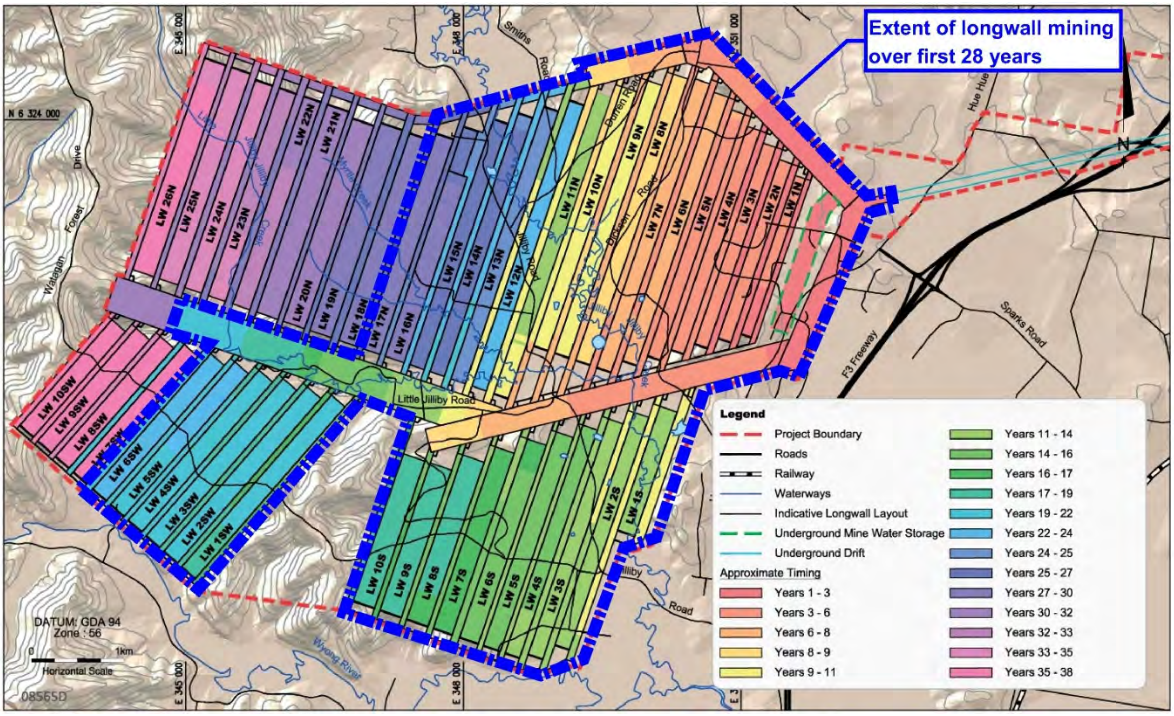

Figure 4: Proposed Mining Sequence

5. REGULATORY

WACJV has sought Development Consent for the W2CP underground mine under the new Division 4.1 of Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). This Division provides for a new planning assessment and determination regime for State Significant Development in NSW. The earlier submission sought by WACJV in 2010 was undertaken through the now repealed Part 3A of the EP&A Act.

PSM understand that under this Consent application, detailed plans such as Subsidence Management Plans (SMP's) are not required to be prepared until much later in the approvals process.

With regard to SMP's, a new set of guidelines is currently being prepared by the NSW Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS, 2011 - formerly Department of Primary Industries - Mineral Resources (DPI-MR)) for *'Preparation of a Subsidence Management Plan application where a project approval under the EP&A Act 1979, with an extraction plan condition, is in force'*. However, at this time we understand that the current *Guideline for Applications for Subsidence Management Approvals* (DTIRIS*, 2003)* remains valid.

6. RISK ASSESSMENT

Appendix F of the EIS sets out a simplistic risk assessment for the environmental risks associated with the project. In this report, we have focused on the subsidence and in particular groundwater components of that assessment.

The risk assessment presented in Appendix F is based on the framework which is repeated below in Tables 1A to 1C. While this framework appears acceptable, the consequences set out for the natural environment at the higher, or serious end (ranking 1 and 2) appear to limit the ability of the assessment to properly assess the consequences.

This view is based on the fact that the two highest rankings are lumped together and lead the assessment to only consider "widespread and unconfined" impacts. The EIS is unclear if this implies that the potential loss of creek flows in the Dooralong Valley (for example) is, or isn't a widespread or unconfined issue. The end result is that this type and scale of impact has only been given a ranking of 3 in the risk assessment in Appendix F.

Further to the above, the risk assessment is essentially an abridged one in that it only presents scenarios that reflect the assumptions of the specialist studies and consequently inherently reflect the limitations or lack of sensitivity assessment in those studies. These issues are discussed further in the following Sections of this report.

TABLE 1A
MATRIX FOR ASSESSING LEVEL OF RISK

Likelihood	Consequence				
	1	2	3	4	5
A	Extreme – 1	Extreme – 2	High – 6	High – 10	Medium – 15
B	Extreme – 3	Extreme – 4	High – 9	Medium – 14	Medium – 19
C	Extreme – 5	High – 8	High – 13	Medium – 18	Low – 22
D	High – 7	High – 12	Medium – 17	Low – 21	Low – 24
E	High – 11	Medium – 16	Medium – 20	Low – 23	Low – 25

TABLE 1B
LIKELIHOOD SCALE

Level	Descriptor	Description	Indicative Frequency (expected to occur)
A	**Almost certain**	The event will occur on an annual basis	Once a year or more frequently
B	**Likely**	The event has occurred several times or more in your career	Once every three years
C	**Possible**	The event might occur once in your career	Once every ten years
D	**Unlikely**	The event does occur somewhere from time to time	Once every thirty years
E	**Rare**	Heard of something like the event occurring elsewhere	Once every 100 years

TABLE 1C
CONSEQUENCES SCALE

Severity Level	Consequences Types				
	Health & Safety	Natural Environment	Social/ Cultural Heritage	Community/Govt/ Reputation/Media	Legal & Regulatory
5	No medical treatment required or requiring first aid treatment at the most	Minor environmental effects (near the source, confined and quick to reverse)	Minor medium-term social impacts on local population. Mostly repairable	Minor, adverse local public or media attention or complaints	Minor legal issues, non-compliances and breaches or regulation. Low potential for impact
4	Objective but reversible disability requiring hospitalisation	Moderate, short-term effects on environment (near the source, reversible and confined)	On-going social issues. Permanent damage to items of cultural significance	Attention from media and/or heightened concern by local community. Criticism by NGOs	
3	Moderate irreversible disability or impairment (>30%) to one or more persons	Serious but confined medium term environmental effects near the source	On-going serious social issues. Significant damage to structures/items of cultural significance	Significant adverse national media/public/NGO attention	Serious breach of regulation with investigation or report to authority with prosecution and/or moderate fine possible
2	Single fatality and/or severe irreversible disability (>30%) to one or more persons	Very serious, long-term environmental impact that is widespread and unconfined, leaves major damage		Serious public or media outcry (international coverage)	Major breach of regulation. Major litigation. High potential for prosecution
1	Multiple fatalities, or significant irreversible effects to >50 persons				Significant prosecution and fines. Very serious litigation including class actions. Suspended or reduced operation

7. SUBSIDENCE PREDICTION

This section contains our view of the accuracy and adequacy of subsidence predictions. It is primarily based on material presented in Appendices G and H and with reference to Appendix C where required. These appendices are:

Appendix C. Geology Report – prepared by (WACJV)

Appendix G. Subsidence Modelling Study – prepared by (SCT)

Appendix H. Subsidence Impact Assessment – prepared by MSEC

Our assessment includes discussion undertaken with W2CP representatives on 17 June 2013 and consideration of the review by B.K Hebblewhite of the work presented in appendices G and H. Reference to additional material used in this review is shown as required.

Predicted Impacts

Predicted impacts are provided in Appendix G and H and summarised as follows:

- Subsidence up to 2.6m with less subsidence predicted in residential areas to the east and more subsidence within forested areas to the west, Figure 5.
- Tilts up to 15mm/m concentrated above the edges of the panels and over forested areas, Figure 6.
- Tensile strains up to 4mm/m concentrated near the edge of panels, Figure 7. About 99% of these strains are expected to be less than 2.5 mm/m, Figure 7.
- Compressive strains up to 5.5 m/m concentrated about 50m inside the panel edges, Figure 8. About 99% expected to be less than 3.3 mm/m.
- Far field movements up to ~60 mm horizontally at a distance of around 1km from mining diminishing to less than 25 mm at a distance of 2 km.

Far field movements are due to regional movement towards mining in response to the 'sag' of the ground due to subsidence. Far field movement is mainly horizontal, directed towards the goaf and diminishes exponentially with distance from mining as shown in Figure 5. Strains are usually relatively small (less than 0.5mm/m) reflecting an *en masse* movement of the ground. Far field movement is difficult to predict and generally undertaken by examining historical data and the distance of mining. The current historical data set used by MSEC to estimate horizontal movement (and provided in Appendix H) is reproduced in Figure 9.

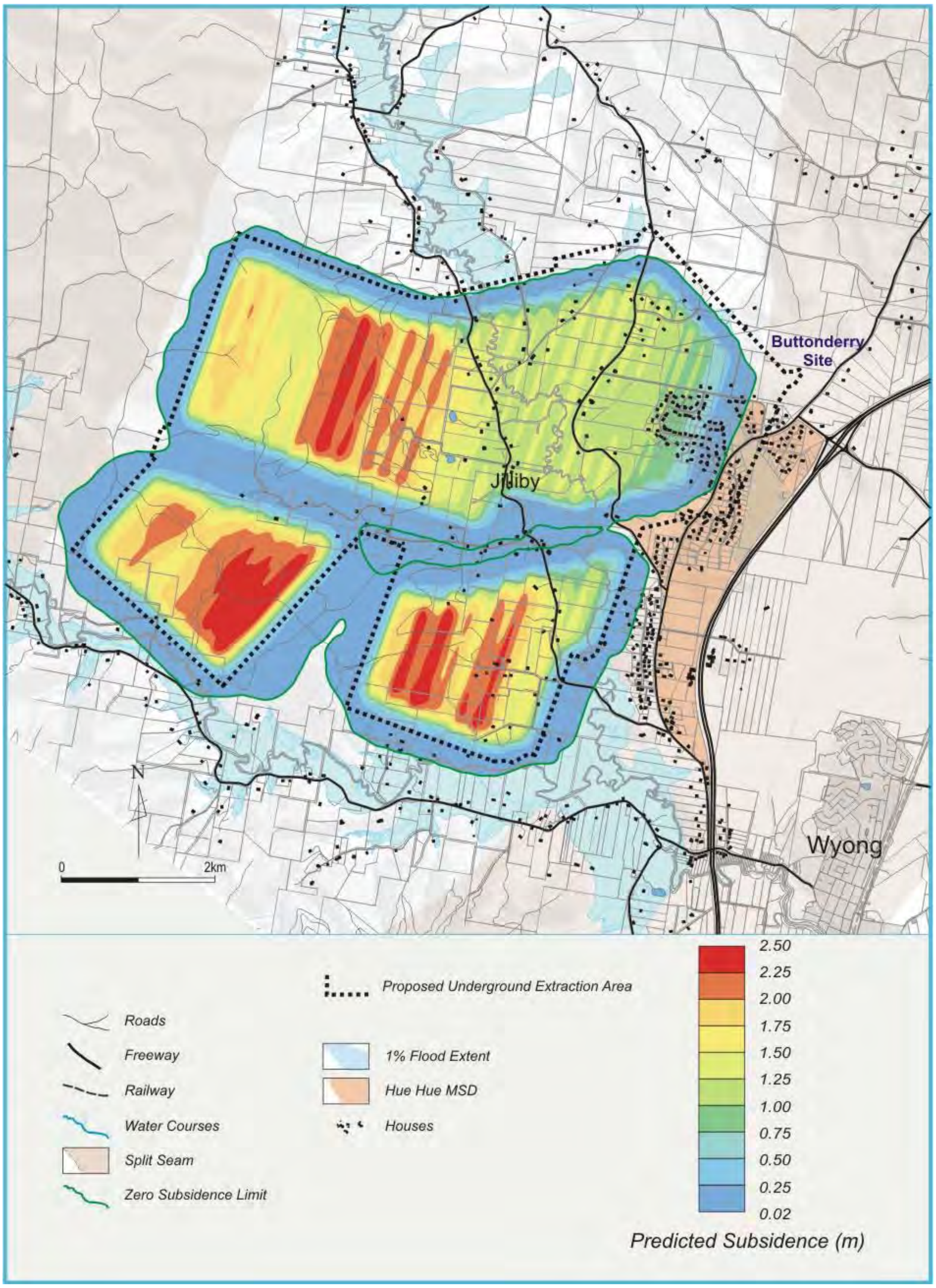

Figure 5: Predicted Total Subsidence Contours

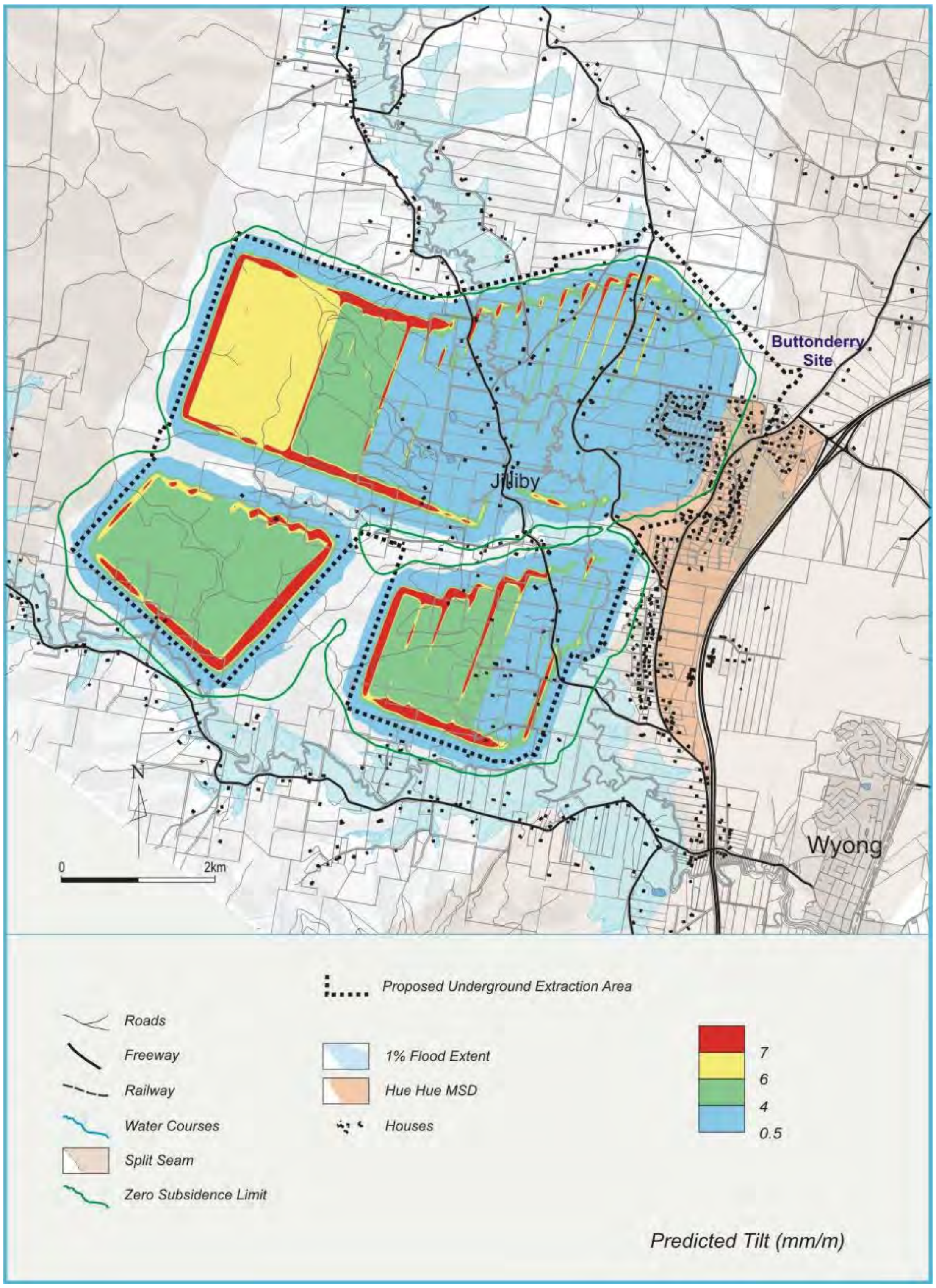

Figure 6: Predicted Total Tilt Contours

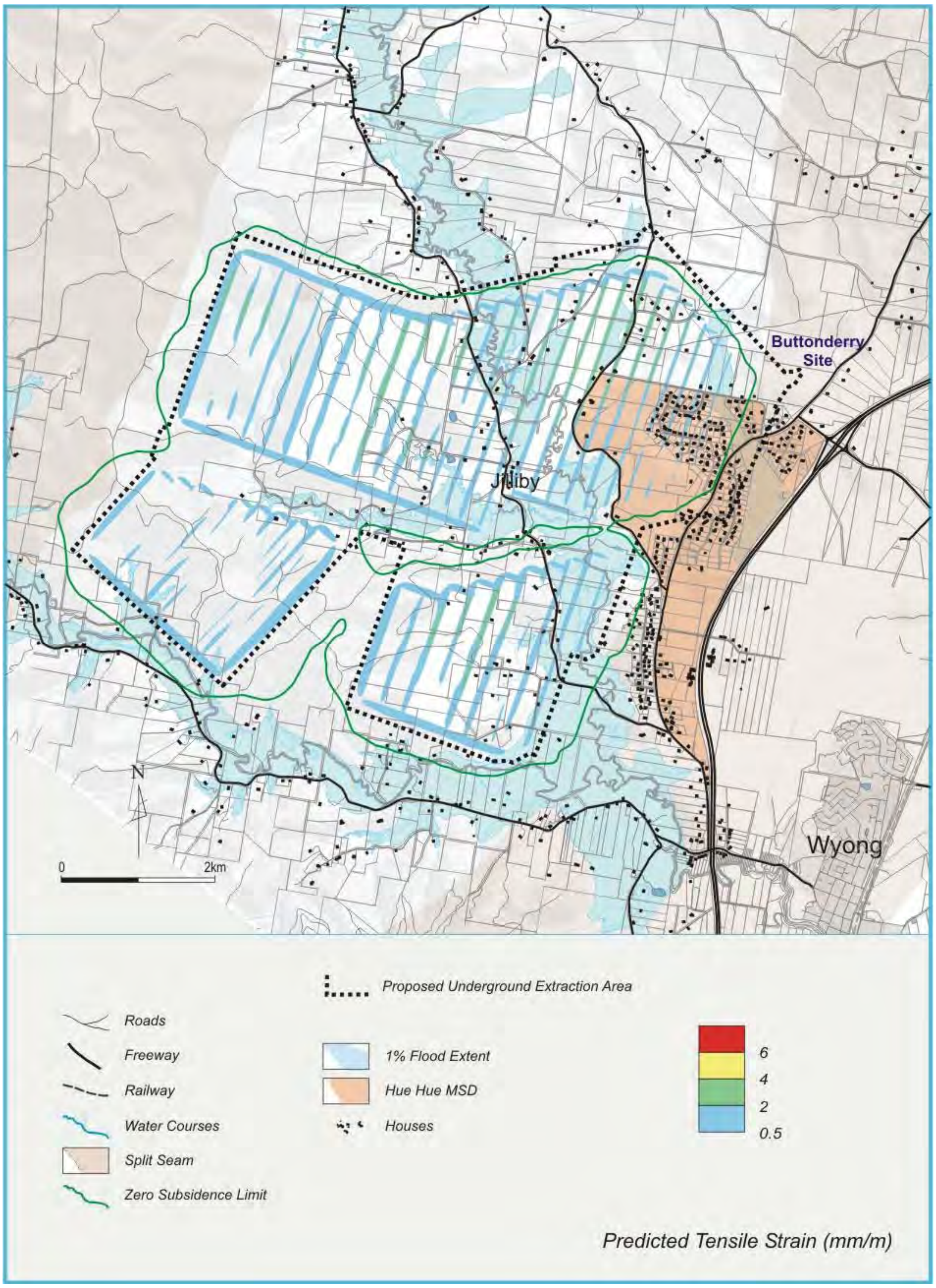

Figure 7: Predicted Total Tensile Strain Contours

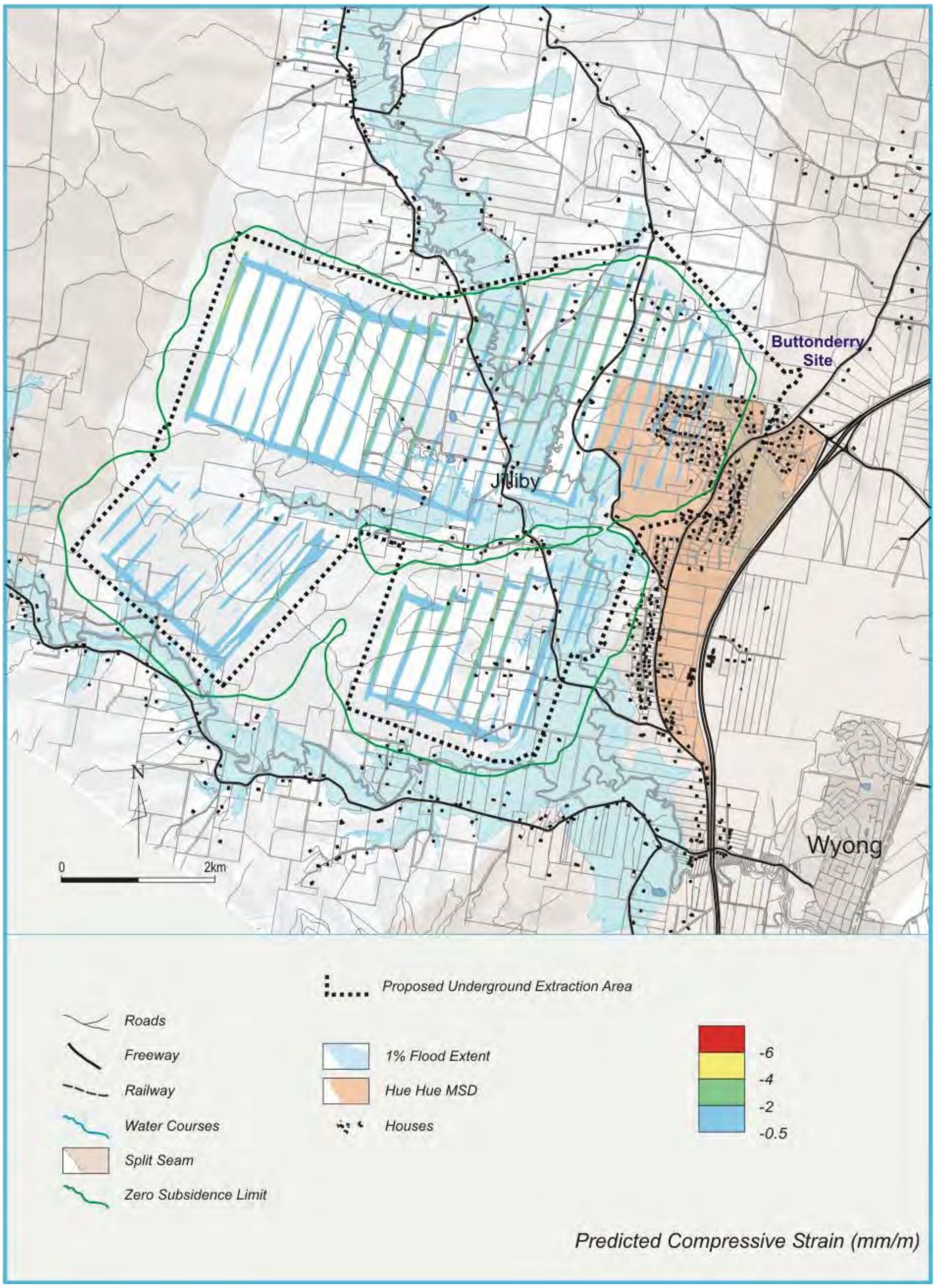

Figure 8: Predicted Total Compressive Strain Contours

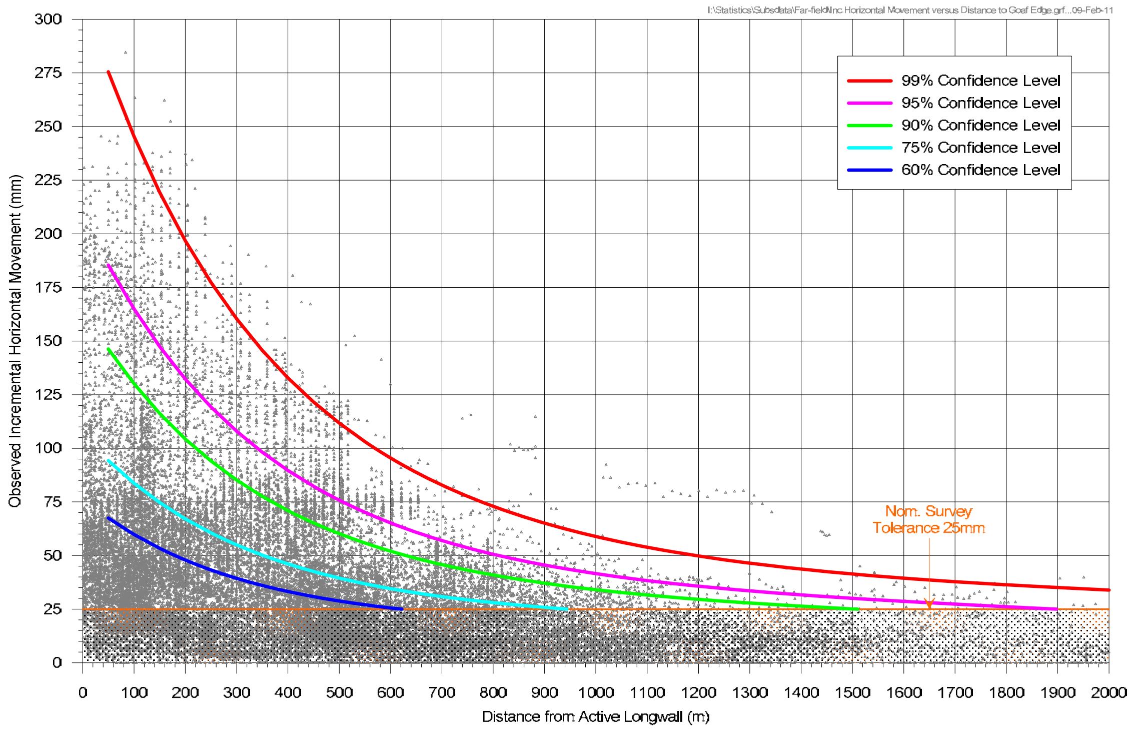

Figure 9: Expected far field horizontal movement based on historical measurements

In terms of impacts, MSEC predictions indicate that of the 245 houses within the study area:

- No houses will exceed the Mine Subsidence Board (MSB) tilt limit of 4mm/m within Hue Hue Mine Subsidence District (MSD).
- Some minor damage is anticipated elsewhere with 13 houses predicted to exceed the MSB tilt limit of 7mm/m within the Wyong MSD.

The expected number and type/extent of repair is shown in Table 2. A summary of impacts expected for other key infrastructure is shown in Table 3.

TABLE 2
ASSESSED IMPACTS FOR THE HOUSES WITHIN THE SUBSIDENCE AS STATED BY THE EIS

REPAIR CATEGORY				
GROUP	**NO CLAIM OR ADJUSTMENT**	**VERY MINOR - MINOR REPAIR**	**SUBSTANTIAL - EXTENSIVE REPAIR**	**REBUILD**
All houses	202	30	12	≅ 1
(total of 245)	(83%)	(12%)	(5%)	(<0.5%)

MSEC anticipates that modifications to the mine plan may occur prior to the approval and commencement of mining and therefore its predictions are subject to change. Such changes, however, are not anticipated by MSEC to result in significant changes to the number and severity of affected houses as shown in Table 3.

TABLE 3
SUBSIDENCE EFFECTS SENSITIVITY ANALYSIS AS STATED BY THE EIS

ASPECT	CONSEQUENCES
Rock formations and steep slopes	The increased tilt is minor compared to the natural gradient and therefore, slope failure is unlikely. Tension cracking on steep slopes may occur, but will still be lower than the cracking observed elsewhere at shallower depths of cover.
Roads	The change in grade is unlikely to significantly affect the drainage of roads. The extent of cracking will increase.
Road bridges	Tilts and curvatures remain very low and are unlikely to cause any impacts. Bridges will need to be able to tolerate the higher valley movements. The movement joints may need to be modified if they cannot withstand the higher closure movements.
Water Infrastructure	Subsidence effects are too low to cause impacts on Treelands Drive Reservoir and pipelines, including Mardi - Mangrove Creek Dam Pipeline.
Transmission lines	Increased stresses on the 330 kV transmission line towers needs to be taken into account when designing mitigation measures for these towers. Subsidence effects are too low to materially impact the 132 kV transmission line. Preventative measures such as roller sheaves and intermediate poles may be necessary.
Telecommunications cables	The maximum tilt increases to 30 mm/m which is unlikely to result in significant impacts to telecommunications cables if suitable management strategies are implemented. The conventional ground strain will increase to 4 mm/m tension and 6 mm/m compression, well below that effectively managed elsewhere.
Rural buildings	Tilts are unlikely to impact the stability and integrity of structures. Increased curvatures will increase the incidence of impacts on structures. However, these impacts will be minor in nature and could be repaired using normal building maintenance techniques
Farm Dams	Change in freeboard will increase to a maximum of 500 mm. This is unlikely to affect dam stability, but may alter the dam storage capacity. Doubling strain and curvature will increase the incidence of cracking in farm dams. Cracking is not expected to be significant and can be repaired where necessary.
Residences	Increased tilts and curvatures will result in a higher incidence of impacts and more significant impacts. Residences are expected to remain safe (i.e. unlikely to experience "sudden and immediate" impacts).
Water Tanks	Increased tilts will result in a higher incidence of serviceability impacts. These can be rectified by re-levelling the tanks. Increased curvatures and strains are unlikely to affect water tanks because they are raised above the ground.
Recreational facilities	There are expected to be 44 pools experiencing tilts greater than 3 mm/m. A number of pools are likely to suffer damage requiring remediation. The maximum tilt experienced by tennis courts is unlikely to affect the serviceability of the courts.

7.1. The Predictive Method Approach

The subsidence prediction used for W2CP may be divided into three key components:

1. The predictive model.
2. The method used to calibrate the predictive model.
3. Chain pillar performance.

A description of each of these components with respect to the Wallarah 2 proposal (W2P) follows.

7.2. The IPM Model

The predictive model employed at W2CP is the Incremental Profile Method (IPM). The IPM is an empirically based method which relies upon the interpolation of a large number of reliable measurements of mine subsidence impacts including subsidence, panel geometry, extraction height, depth of cover and panel sequence amongst others. The means of interpolation is undertaken on an observational basis whereby empirically relationships are derived largely through statistical analysis and not by physical, geological or mechanical means.

When calibrated to reliable measurements relevant to the site to which it is applied, the IPM is generally considered industry best practice. Standard profiles obtained using the MSEC IPM are shown in Figure 10.

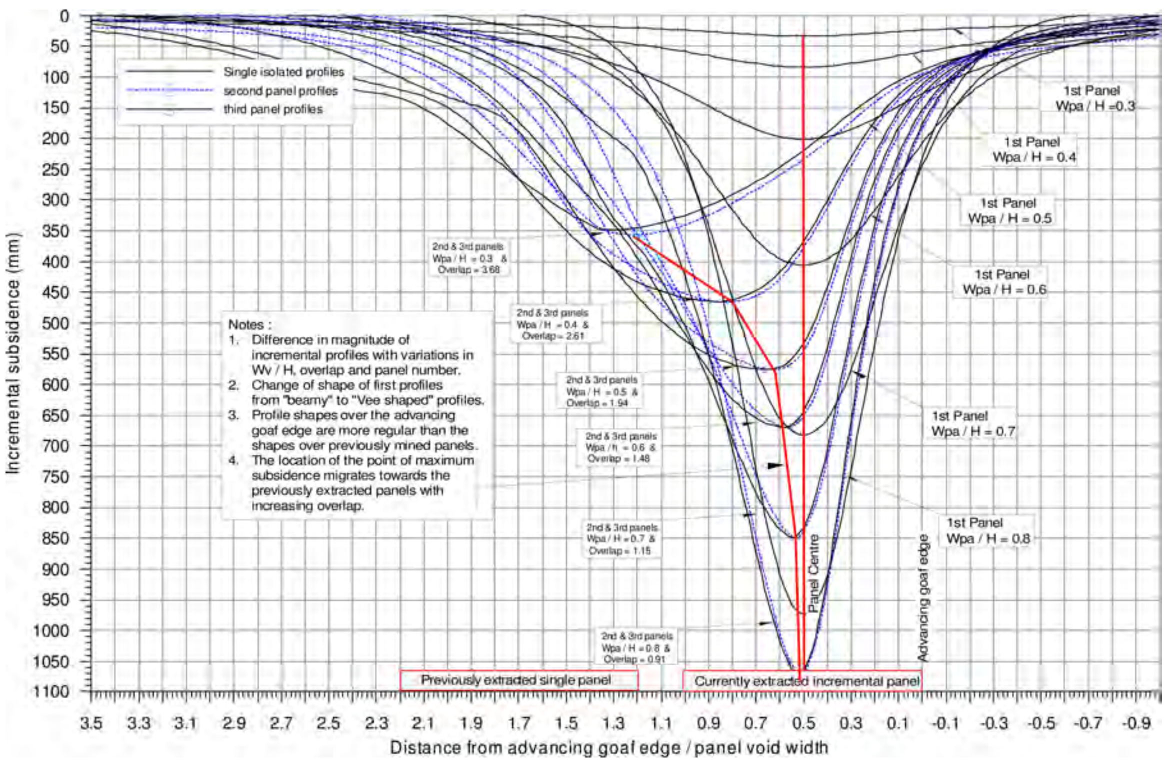

Figure 10: Incremental Subsidence Profiles obtained using the Incremental Profile Method

The accuracy of the IPM depends upon the robustness of the empirical relationships and the quality and suitability of the data. The MSEC (2007) IPM method is known to contain at least 11 parameters which must be derived from a sufficient quantity of data relevant to the site for which the prediction is being undertaken.

The MSEC 'empirical database' typically contains such parameters as:

- Longwall geometry including depth of cover and panel width.
- Measured surface response such as subsidence, tilt and strain.
- Extraction height, panel sequence and centreline offset distance.

The MSEC IPM does not include consideration of geotechnical or geological parameters such as lithology, strength, joint characteristics and the like. However, if the database is sufficiently large then refinement in terms of region specific response (due to, for example, regional geology) can be incorporated to some extent. The MSEC IPM is known to have a wider application over the Southern Coalfield due to the significantly higher proportion of subsidence impact measurements from this area.

The IPM developed by MSEC is divided into two parts:

1. 'Conventional subsidence' which is that component principally related to longwall geometry and observed subsidence and independent of topography (this has sometimes been referred to previously as 'systematic subsidence')
2. 'Unconventional subsidence' which is that component which appears to be influenced by topographic effects whereby hills valleys cause additional movements, such as a reduction in subsidence (sometimes termed 'upsidence') or additional horizontal movements, such as valley closure.

Unconventional subsidence requires a secondary set of empirical relationships which are commonly related to valley width, valley depth and perpendicular and transverse offsets to mining. MSEC recognises that conventional subsidence is captured more reliably by their IPM than unconventional subsidence.

In many cases the MSEC IPM has been found to reliably predict subsidence which increasing accuracy for sites which correspond to a larger proportion of the empirical database.

There are instances, however, where the IPM has not adequately predicted subsidence. A recent example of this occurred at Tahmoor, NSW in 2008. In this case actual subsidence was approximately twice that predicted by the MSEC IPM, the prediction itself being already considered "conservative". This failure of the IPM occurred despite the mine having its own extensive empirical subsidence database of 23 previous longwall panels and their recorded impacts.

Extensive geomechanical modelling of Tahmoor by SCT (Gale, 2011) examined the sensitivity of subsidence to a range of parameters not included in the IPM, including:

- Unconfined Compressive Strength (UCS)
- In-situ stress
- Bedding and joint density (frequency)
- Joint stiffness
- Joint strength

All of the above were found to have an influence on subsidence to varying degrees. A reasonable fit was eventually confirmed based on significant reductions in joint stiffness and strength. The approach used by Gale (2011) is essentially identical to that used to calibrate the MSEC presented in the EIS in Appendix G and discussed in Section 0.

MSEC have acknowledged in the EIS that their current empirical database is not adequate for W2CP as it does not contain sufficient data to reliably predict the following combination of site conditions.

- Proposed W2CP depths of cover of up 690 m, which considerably exceeds the depths of cover for most mines in the Newcastle Coalfield and the Southern Coalfield, where depths of cover typically extend up to 550 m.
- The MSEC empirical database is weighted towards the Southern Coalfield with typical extraction thickness of approximately 3.0 m and typically bounded by reasonably strong strata, whereas the W2P includes plans to operate at extraction thicknesses of between 3.0 m and 4.5 m bounded by comparatively weak strata in some areas.
- Geological evidence showing no significant evidence of thick, strong, continuous conglomerate units commonly found in the Newcastle Coalfields and generally considered responsible for a reduction in conventional subsidence.
- Geological evidence suggesting a relatively weak roof-pillar-system compared to that in the Southern Coalfields.

In response to the above MSEC has undertaken an alternative means of IPM calibration as described below.

7.3. The IPM Calibration Method

WACJV commissioned SCT to undertake a series of numerical analyses to predict subsidence at specified locations. The studies were based on stress analysis techniques to predict the geo-mechanical behaviour as selected locations based on the following:

- The strata was idealised as a series of horizontal layers in 2D section based on logging and testing of a few (three) select boreholes
- Strength variation across the sites was inferred from sonic velocity correlated to UCS measured in these boreholes.
- In-situ stress and elastic modulus were estimated by generic specific correlations with UCS.
- The section was discretised into 1 m by 1 m regions within which constant conditions are assumed such as strength.
- Numerical analysis techniques were then used to predict the responses of the 2D section to changes, namely the simulated extraction of coal at the target depth.

The theoretical response is understood to be dictated in part by the geotechnical models used in the finite difference analysis package, FLAC, augmented by changes developed by SCT. We understand that this model process is identical to that presented by Gale (2011) with modification based on site specific measurements of material properties, insitu stress and geometry.

The model is shown to reasonably predict the measured surface and subsurface displacement at Ellalong longwall 2 and surface displacement at South Bulli, Appendix H. Both of these cases present different longwall depth, geometry and geology to proposed mining.

Three site specific realisations of their model are presented by SCT for predictive purposes. There are:

- The 'Hue Hue' Road case representing 125m and 155m wide panels below the Hue Hue Mine Subsidence District.
- The 'Valley' case representing 175m wide below the Dooralong Valley.
- The 'Forest' case representing 255m panels below the Jilliby State Conservation Area.

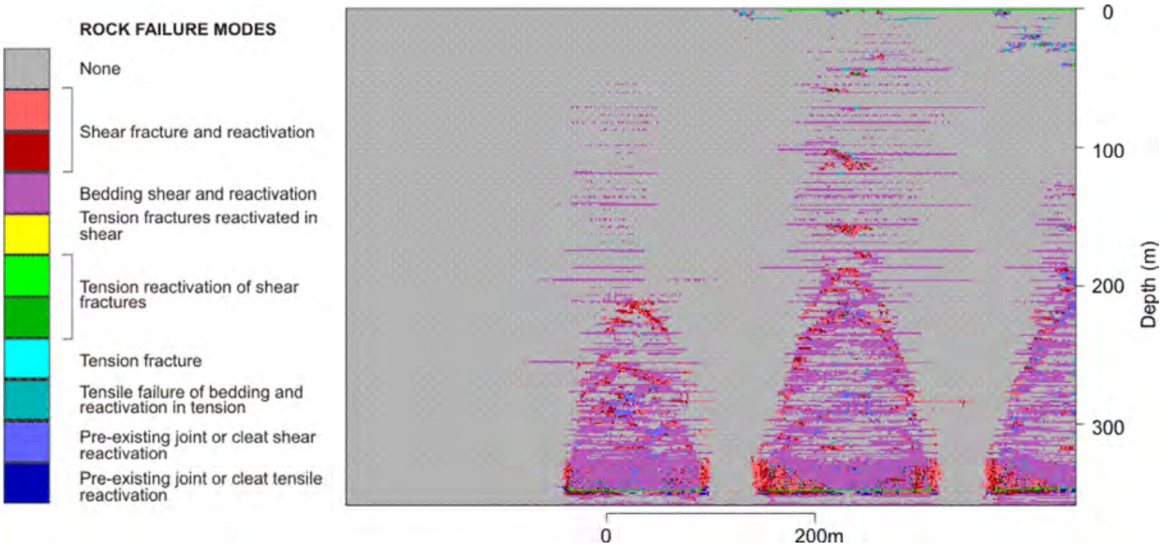

Figure 11: Modelled Rock Fracture Development for the Hue Hue Case (3m extraction)

The SCT model is complex and information provided in the EIS is limited. A more comprehensive description of the SCT model is available in (Gale, 2011) where it was used to predict excessive subsidence experiences at Tahmoor Colliery. Results from Gale (2011) show that:

- SCT Model results can be influenced by strength, lithology, horizontal stress, variations in the frequency of bedding and jointing, joint stiffness and joint friction.
- In some cases variation of these impacts can result in a subsidence prediction varying by a factor of 2.

This discussion is not meant to imply that actual subsidence at W2CP will be or is likely to be twice that predicted. However this study does indicate that the SCT model is sensitive to a significant number of input parameters. Therefore the SCT model is likely to be sensitive to the correlations used in EIS modelling, such as the sonic velocity-UCS correlation, and the other site correlations, such as Youngs Modulus and in-situ stress. The sensitivity of these parameters has not been reported in the EIS and therefore the potential error of the SCT model, and by implication the IPM, is unknown.

Additional limitations include:

- SCT models are 2D representations and therefore do not capture the 3D effects of topography, in-situ stress, pillar shape or changes in material properties.
- The models are based on extrapolation of a limited number of UCS tests (3 boreholes), inferred in-situ stress direction and site-wide correlations of Young's Modulus and in-situ stress magnitude.
- The models are based on simplified failure criteria based on a constant proportion of inferred UCS.
- The models do not provide estimates of sensitivity to input parameters at W2CP apart from two additional analyses to examine concurrent changes to extraction height and pillar width.

These limitations are to some extent acknowledged by SCT who state within the EIS:

- "Numerical modelling is site specific and, in itself, cannot generate subsidence predictions across the entire mining area".
- "The use of a low friction angle and adoption of yield pillar design…. does not account for all potential long-term moisture impacts".
- "In the unlikely event that evidence of non-yielding was to emerge, additional modelling and impact assessment would be carried out and appropriate remediation measures put in place".

7.4. Chain Pillar Performance

Based on geological evidence and geometric considerations MSEC considers the following site specific factors to be significant with respect to subsidence prediction:

- The variation and magnitude of the depth of cover.
- The height of extraction.
- The variation in strength of the units bounding the target seam.

Individually the seam height and variation in depth of cover do not present significant challenges in terms of subsidence prediction. However the variation in strength in combination with these factors does present some potential issues.

The design philosophy as presented by MSEC, SCT and the EIS generally is an expectation that the chain pillars will fail increasing overlying subsidence and presumably locally reducing associated tilts and strains.

This assumption is based on:

- The interpreted strengths within boreholes as documented in the Geology Report (Figures 10.1 and 10.2 of Appendix C).
- Estimation of pillar strength using the empirical Mark-Bieniawski (1995) method.
- An assumed reduction in pillar area due to an expectation of yield, stress fracturing and caving in the vicinity of the pillar.
- An assumed pyramid shaped stress distribution around the yielded pillar.
- Modifications to the SCT 2D model to capture 3D behaviour due to "cut throughs" through pillars.

These assumptions are generally referred to 'worst case' conditions and have been used to set mine plan geometry such that all pillars would be expected to 'fail' sometime after one, two and three longwalls have been extracted, depending on location. Failure was confirmed in all three SCT site specific numerical predictions and the MSEC IPM was subsequently calibrated to mimic this response in terms of the magnitude of additional subsidence over pillars and the timing with respect to number of longwalls extracted.

The current subsidence prediction, therefore, is reliant upon pillar collapse which may or may not represent 'worst-case' conditions in terms of tilt and strain. In fact pillar failure may not occur in many areas due to better than 'worst case' conditions as evidenced by:

- Predicted variation in roof conditions ranging from an expectation of "compressive failure in both primary and secondary roof" to "no compressive failure" as shown in the Geological Report Figure 10.1 (Appendix C).
- Predicted variation in floor conditions ranging from a UCS of less than 15MPa to greater than 40 MPa, as shown in Geological Report Figure 10.2 (Appendix C).

The approach taken has, in effect, used an empirical predictive tool (the IPM) to extrapolate the results from three theoretical idealised profiles across the entire site. Given that the SCT model has been shown to be sensitive to many of input parameters and that these parameters have been estimated, the lack of information concerning the sensitivity of this approach is therefore of significant concern.

It is noted that concern over the likely impacts should the chain pillars not collapse is raised by both the PAC (Reference 3) and Dr Bruce Hebblewhite.

7.5. Management Strategy

The current management strategy is understood to encompass an "adaptive management plan" comprising:

- Undertake an initial stage of mining where a limited (one or two) number of longwalls are extracted in the north-east of the site in the first instance.
- Conduct a variety of survey and monitoring exercises to collect relevant and sufficient data to enable the IPM and SCT models to be verified.
- Consider changes to the mine plan to mitigate any issues arising from survey or model verification.

There are several potential issues associated with this approach, namely:

- The type and extent of survey must be sufficient to clearly measure the extent and nature of mining induced impacts including pillar stability changes in permeability, rate of subsidence development and height and extent of fracturing.
- The first longwalls may or may not be a reliable indicator of future longwall performance as they with lower extraction height and therefore may not initiate pillar yield as predicted. This would make model calibration difficult as the conditions under where pillar yield will occur may remain unknown.
- Some monitoring elements, such as groundwater wells, may be subject to external influences (such as abstraction) making interpretation of mining influence difficult to substantiate.

7.6. Findings

The predicted impacts due to W2CP are, in general terms:

- Subsidence up to 2.6m with less subsidence predicted in residential areas to the east and more subsidence within forested areas to the west, Figure 5.
- Tilts up to 15mm/m concentrated above the edges of the panels and over forested areas, Figure 6.
- Tensile strains up to 4mm/m concentrated near the edge of panels, Figure 7. About 99% of these strains are expected to be less than 2.5 mm/m, Figure 7.
- Compressive strains up to 5.5 m/m concentrated about 50m inside the panel edges, Figure 8. About 99% expected to be less than 3.3 mm/m.
- Far field movements up to ~60 mm horizontally at a distance of around 1km from mining diminishing to less than 25 mm at a distance of 2 km.
- The expected number and severity of impacts across the 245 properties within the area affected by the predicted subsidence are:
  - 83% of properties being unaffected;
  - 12% requiring very minor to minor repair;
  - 5% requiring substantial to extensive repair, and
  - <0.5% requiring a complete rebuild (ie. about 1 property)

In summary we conclude that:

- Based on our discussions with W2CP, we understand that something like 4 to 5 panels would need to be extracted before a full model calibration exercise could be undertaken.
- The reliability and accuracy of the SCT method is unknown as:
  - There is a reliance on extrapolated inputs to which the method has been shown to be sensitive.
  - The model is calibrated to site-specific data and not to a small number of measurements from other sites.
  - The sensitivity to most input parameters is not presented.
- Due to the empirical nature of the method the IPM is only as reliable as the data to which is it calibrated, in this case the SCT model results. Therefore the reliability and accuracy of the IPM is in doubt.

  This is to some extent recognised by MSEC who in the EIS state:

  "*A thorough calibration…will only be achieved after subsidence monitoring data is obtained and analysed".*
- The use of one predictive model to calibrate another is generally unwise and not widely regarded as best practice.

- The IPM is stated as being conservative and likely to over predict impacts. The evidence for this conservatism and the expected magnitude with respect to W2CP are not provided. Indeed all indications are that the model development is centred around matching expected conditions and not exceeding or over-predicting them.
- There is a reliance on pillar compression after extraction resulting in a smoother subsidence profile. However, the basis for this assumption appears to conflict the Geological Report (Appendix C), where significant variation in both roof and floor conditions is expected across the site.
- The EIS acknowledges that pillar compression may not occur but does not quantify the impacts or changes in impact should this not occur.
- First longwall will prove that this pillar compression assumption is valid.
- At least 3 longwalls (L1N to L3N) and more likely 4 to 5 longwalls are required before pillar compression theory can be verified.

We accept that these predicted impacts are in agreement with expectations based on measured subsidence impacts elsewhere, and the Newcastle and Southern Coalfields in particular.

We are in general agreement that should the predicted level of subsidence occur, the type distribution and severity of impacts on houses, buildings and infrastructure is likely to be similar to that stated in the EIS.

We do not agree that the prediction represents a conservative estimate of subsidence impacts as all the evidence presented in the EIS suggests the prediction represents the most likely impacts. We consider that the model, calibration and application of the prediction does not provide sufficient guidance as to the sensitivity and reliability of the method and may, therefore, fail the Director General's "reasonable level of confidence" test.

In general we did not find any omissions or evidence to suggest that subsidence due to W2CP is likely to be significantly different to that predicted by the EIS. Our main concern is the lack of certainty around the predictive method and the likely variation in prediction based on observed variations that are already known and potentially those unknown.

8. GROUND & SURFACE WATER

8.1. Introduction

The potential impacts on groundwater and surface water resources arising from the proposed Wallarah 2 longwall coal mine are considered in this section of the report. The assessment is based substantially on material presented in Appendices of the Wallarah 2 EIS, these being:

- Appendix H: Groundwater Management Studies
- Appendix I: Surface Water Impact Assessment.

The assessment considers the methodology and inputs into the groundwater model undertaken by Mackie Environmental Research (MER) reported in Appendix H.

The prime outputs of the groundwater modelling pertain to the following:

1. The rate at which water flows into the mine, which the miners then have to deal with.
2. The impact of the mine on groundwater levels.

Point 2 above has particular relevance for the local area in regard to water levels in the Yarramalong and Dooralong Valleys and the availability of water in the Wyong River downstream of the proposed mine which is used as part of the water supply to the Wyong and Gosford Local Government Areas. The water intake point on the Wyong River is managed by the Central Coast Water Corporation (CCWC).

Further, activities in both of the valleys such as turf farming and equestrian properties rely on water supply from the local groundwater systems either by collecting the water in dam and/or pumping water from bores.

8.2. The critical importance of extreme events in relation to water resources

8.2.1. Overview

Firstly, we note that the assessments in the Wallarah 2 EIS in relation to groundwater impacts are made in relation to average rainfall conditions, and the same is true for some of the critical assessments in relation to surface waters. Such assessment in terms of averages warrants very careful consideration. This is particularly so given recent experience on the Central Coast were significant water restrictions were in force.

To that end, the groundwater assessment should consider the variation in inputs to the surface water supply to account for extended dry periods. This is particularly so given that if the EIS prediction of leakage from the alluvial lands is negligible given the recharge from runoff. To illustrate this, the following discussion on the Jilliby Jilliby Creek flows is presented.

8.2.2. The Mine and Jilliby Jilliby Creek Catchment

Figure 12 shows the catchment of Jilliby Jilliby Creek in the Dooralong Valley in relation to the mine footprint. It clearly shows that this catchment is the one most vulnerable to mine impacts.

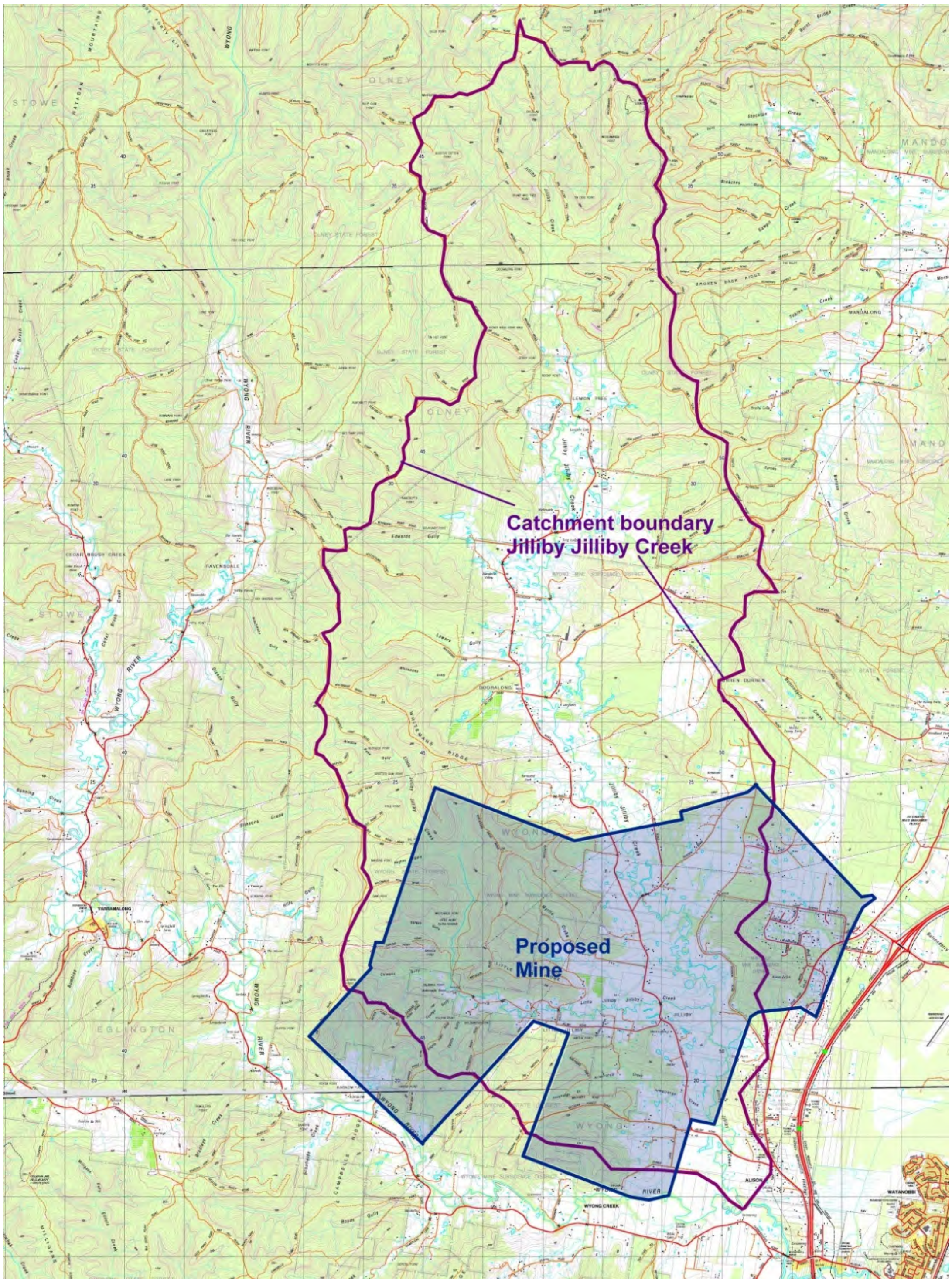

Figure 12: Jilliby Jilliby catchment complete

One of the facets of this catchment is that just downstream of where it joins the Wyong River is the main pump station from which water is pumped to either Mardi Dam or Mangrove Creek Dam (see Figure 13B). Pumping rates over the past few years are shown in Figure 13A.

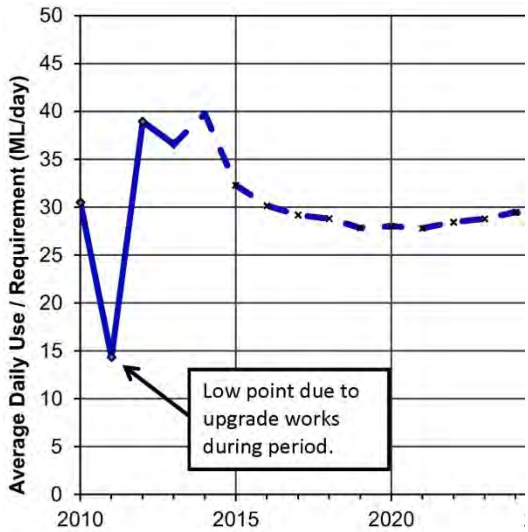

Figure 13A: Pumping rates from Wyong River since 2010 (and projected requirements)

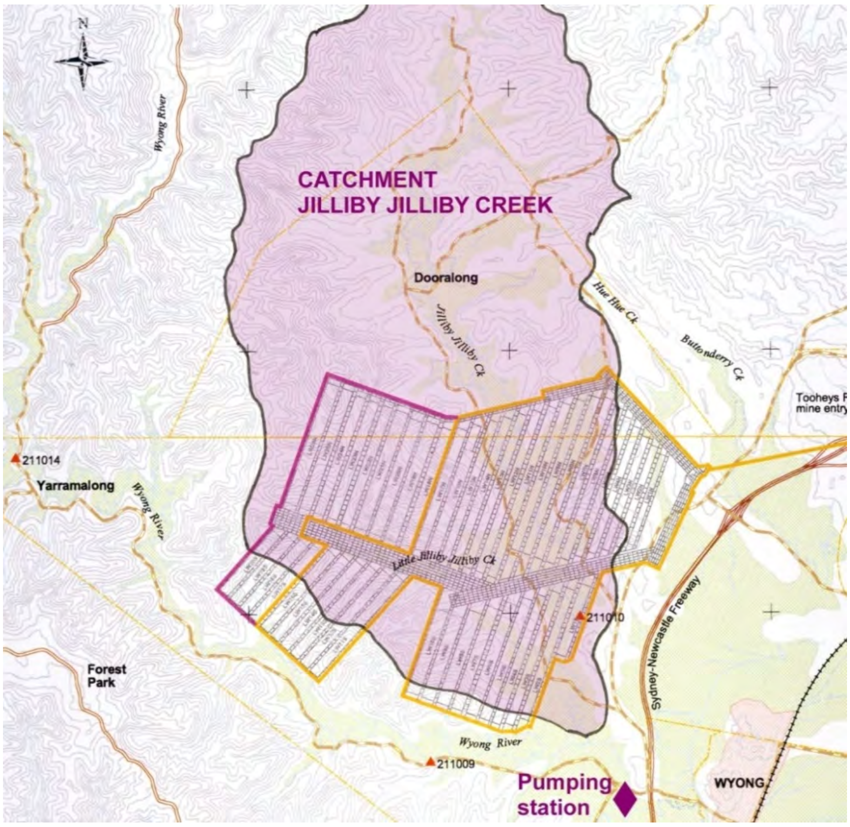

Figure 13B: Location of Wyong River pumping station downstream of confluence of Jilliby Jilliby Creek

8.2.3. Recent Creek Flows

Figure 14 gives the statistical analyses of the flows in Jilliby Jilliby Creek, upstream of the Wyong River, from records since 1972.

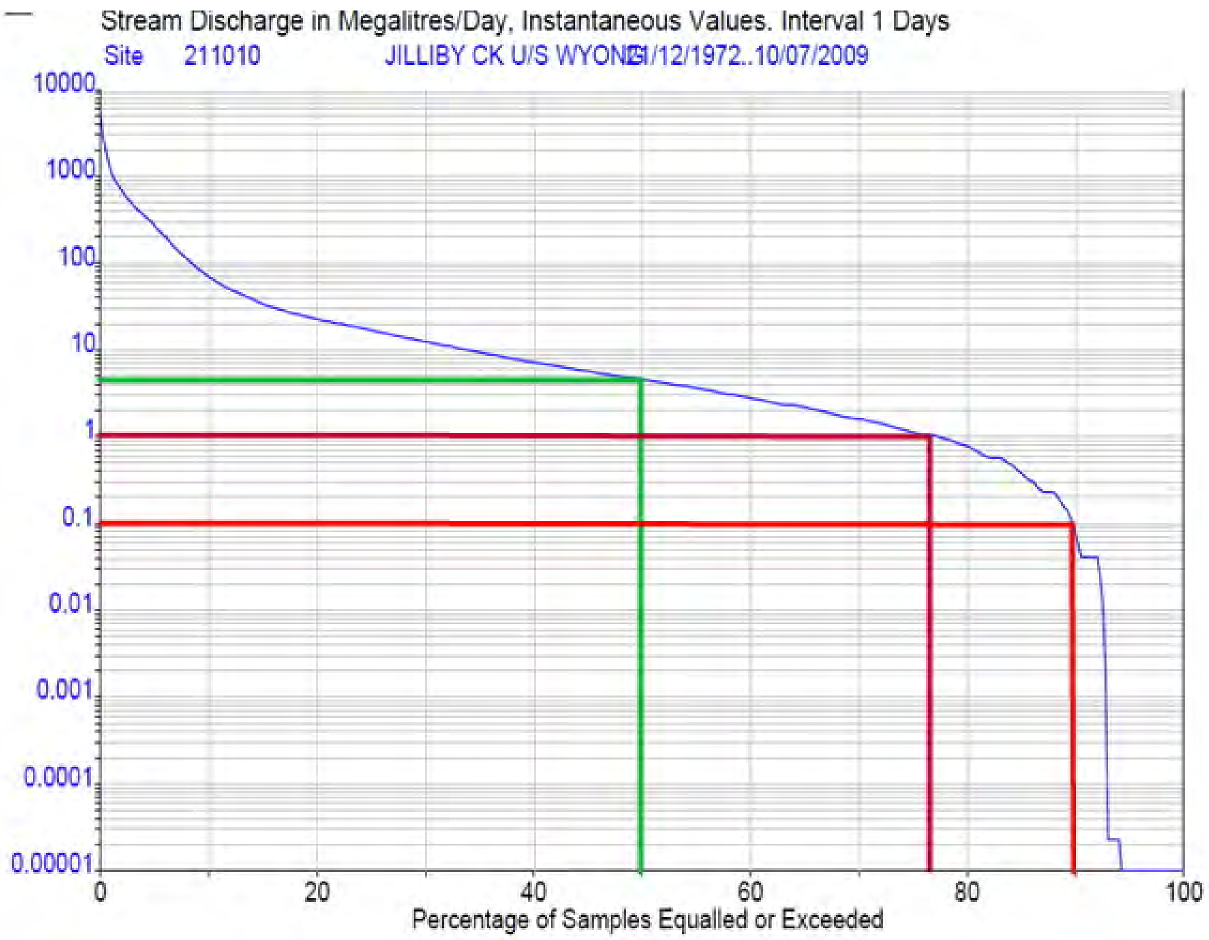

Figure 14: Statistics of flows in Jilliby Jilliby Creek, 1972 – 2013

From the plot above it can be seen that the median flow rate is about 4.5 Megalitres per day (ML/day). However, the flow is less than 1ML/day for 24% of the time of record, and less than 0.1 ML/day for 10% of time.

To put these flow rates into perspective, Figure 15 and Table 4 show that the five longest periods of consecutive days, since 1972, when flows were less than 1 ML/day and 2 ML/day since 1972. It can be seen that for a stretch of 190 days in 1980/81, flows were less than 2ML/day (less than half the average). Sustained periods of flows of less than 2ML/day also occurred for periods of 179, 168, 167 and 135 days. All of these occurred between 1991 and 2006.

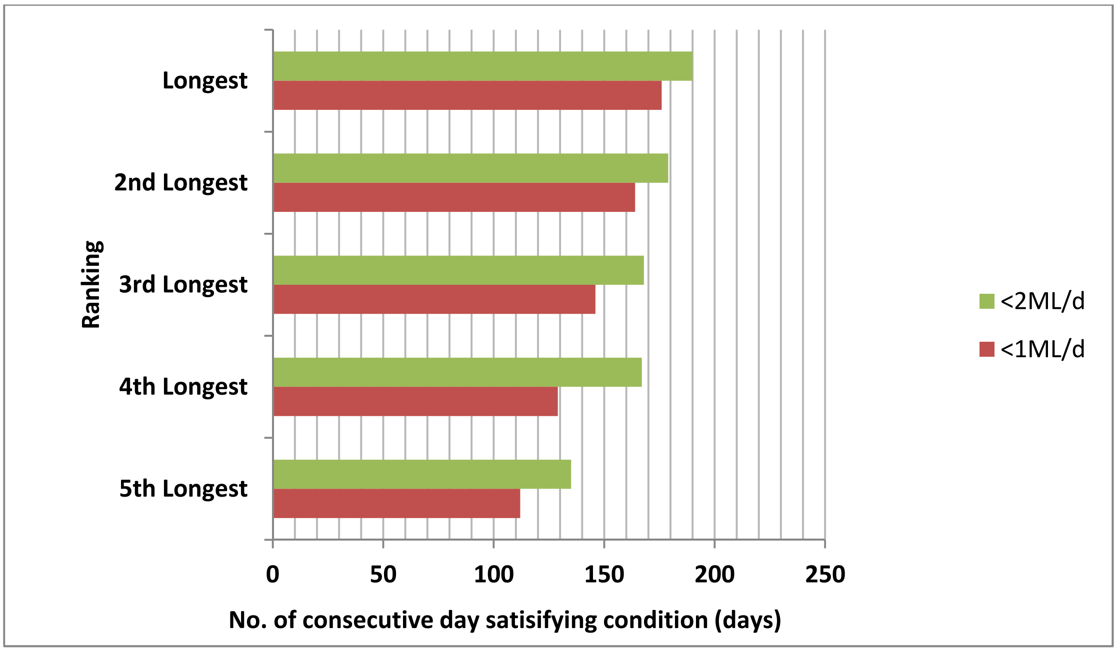

Figure 15: Consecutive days of flow in Jilliby Jilliby Creek less than either 1ML or 2ML per day

The particular periods that are plotted in Figure 15 are summarised in Table 4 below.

TABLE 4
CONSECUTIVE DAYS OF LOW FLOW

RANK	FLOW CONDITION (ML/day)	DAYS	START DATE	END DATE
1	<2	190	31/07/1980	5/02/1981
	<1	176	12/03/2006	3/09/2006
2	<2	179	10/03/2006	4/09/2006
	<1	164	19/10/1997	31/03/1998
3	<2	168	17/04/2004	1/10/2004
	<1	146	8/08/1980	31/12/1980
4	<2	167	17/10/1997	1/04/1998
	<1	129	30/01/1991	7/06/1991
5	<2	135	25/01/1991	8/06/1991
	<1	112	25/11/1982	16/03/1983

8.2.4. Climate

Following from the discussion above, the next important questions are:

- what were the climatic conditions at the time when these sustained periods of low flow occurred; and
- how representative of the full record of local experience area are they?

While the flow records for Jilliby Jilliby Creek from 1972 to now capture the Millennium Drought, they do not capture the more intense droughts of World War 2, and the time of Federation. Figure 16, taken from Appendix H of the EIS, clearly shows how much more severe was the drought of WW2. This means that Figure 16, in all likelihood, does not capture the largest periods for which low flows occurred in the creek. Further, it shows that even short, but intense dry periods such as 1979 to 1981 can significantly impact on the stream flow.

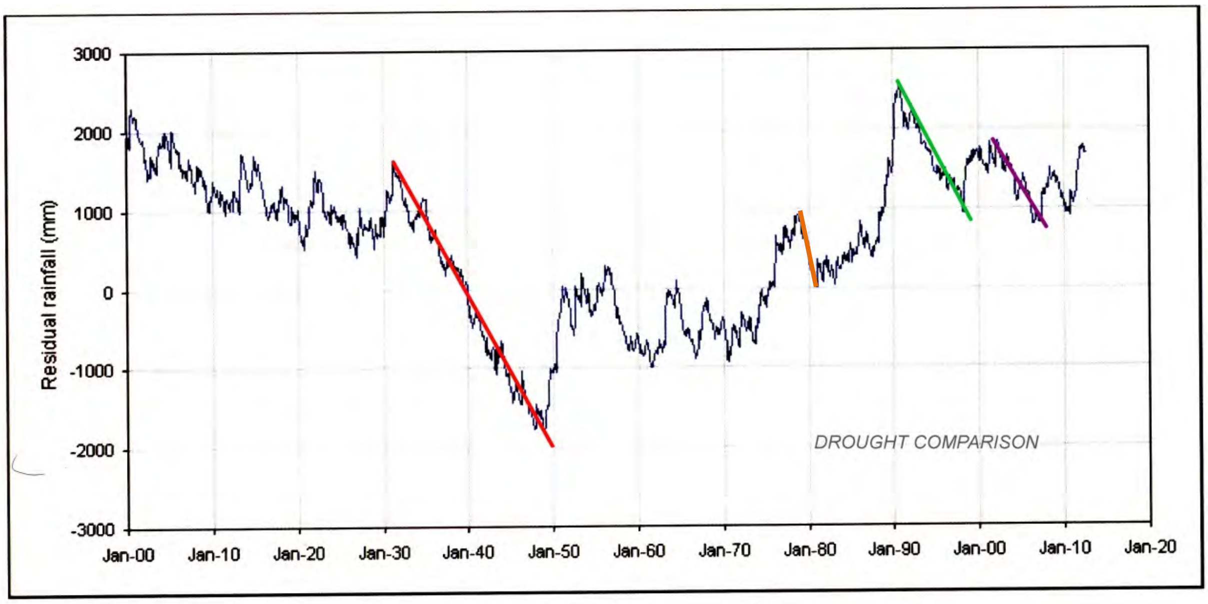

Figure A1: Rainfall residual mass plot for Wyee Gauge 061082 from 1900

Figure 16: Droughts in Wyong are shown by 113 years of rainfall records at Wyee. Downward slopes are periods of below average rain; the steeper the slope the more intense the drought; the longer the downward sloping period the longer the drought.

8.3. Computed Impacts in the EIS on Groundwater and Surface Water

8.3.1. Surface Water Impacts

Based on the 3D groundwater model, the EIS predicts mine inflows as given in Figure 17.

It can be seen that computed inflows reach about 1.5ML/day in Year 6 and are up to 2.5ML/day for 15 to 20 years after about Year 18. The EIS also notes that these calculations do not include flows from fracture zones which are estimated to potentially increase inflows by about 0.5ML/day.

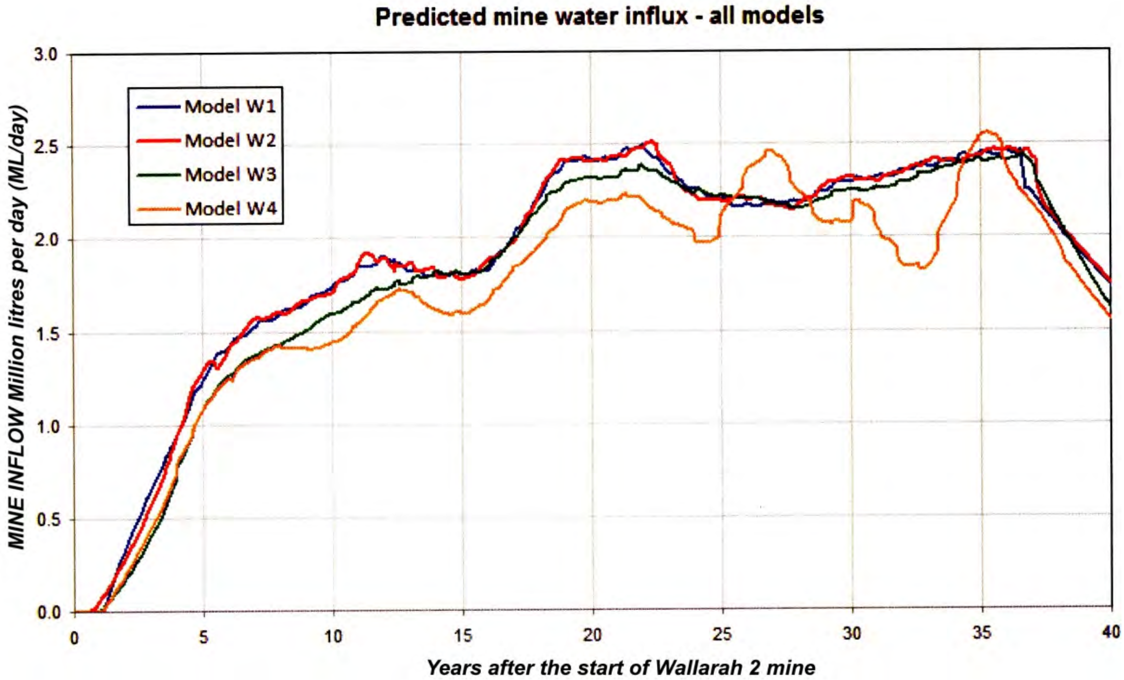

Figure 17: Computed mine inflows as given in the EIS

The EIS does not provide any attempt to reconcile where this water comes from. It implies that it would largely come from water stored in the ground, but this avoids the fact that water stored in the ground comes from somewhere, and is in equilibrium with natural recharge. A valid way to consider this matter is encapsulated in the following quotation from Dr Rick Evans, principal hydrogeologist of Sinclair Knight Merz, viz:

> *"There is no free lunch here. It's very simple – every litre of water your pump out of the ground reduces river flow by the same amount".*

Australian Financial Review,
24 May 2007

While we cannot define precisely what portions of which rivers will be affected, by virtue of Figure 12, it is reasonable to conclude that Jilliby Jilliby Creek is likely to be the dominantly affected stream system. We also cannot say, with confidence, how many years it will take for the impact of underground extraction to reflect in surface flows.

However, it is not a question of if it will occur, it is only a question of how long will it take for the impact to occur. The rate of leakage may be slow if the EIS estimates of Patonga Claystone permeability are correct but much faster if, as discussed in Section 8.9, they are not.

It is valid to compare the data in Figure 16 with the flow records of Jilliby Jilliby Creek.

It is readily seen that 2.5ML/day of mine inflow is more than half the average flow of Jilliby Jilliby Creek and is greater than the flows recorded for 40% of the time since 1972. It is reasonable to assume that the periods of low flow in the creek (see Figure 14) may be longer in future under climatic conditions similar to those experienced since 1972.

This matter of overall water balance is incorrectly addressed in the EIS. On page 86 of Appendix I is the misleading statement that:

> *"It is possible that undermining of Jilliby Jilliby Creek may generate some additional groundwater storage which would be sourced from regional rainfall recharge, as well as surface runoff. The diverted water volume would represent less than 1% of the total licensed extraction volume for the area".*

The inference from this statement is that the flow loss in Jilliby Jilliby Creek is of no consequence. But page (iii) of the same Appendix states that the flow loss may be 0.74 ML/day[1].

For 20% of the time since 1972, the flows in Jilliby Jilliby Creek have been less than 0.74ML/day and that a loss of this magnitude will substantially change the low flow characteristics of Jilliby Jilliby Creek. As discussed below, this will be associated with a substantial change to the groundwater system in Dooralong Valley.

A similar level of baseflow loss was also reported in Section 5.4 of the PAC report (Reference 3) when some cognisance was given to the sensitivity of the modelling to variation in the permeability of the rock mass. In this case a value of 1ML/day was found which represents 24% of the flow record since 1972.

[1] The document states 270ML per year, which is 0.74ML/day.

8.3.2. Groundwater Impacts

Figure E17 of Appendix H of the EIS gives calculations of the groundwater pressure regime around the mine under natural conditions, at the end of mining (Year 38). In this form the plots do not provide guidance on near surface flow lines that illustrate the flow path. The discussion and figures below set out to present the data from the EIS in a practical form to illustrate the impact of creating a groundwater sink in the form of the underground mine.

Figure 18 is an annotated version of part of the EIS plot of natural groundwater conditions above the mining area. To interpret the plot 'equipotential lines' have been annotated onto the EIS data. Equipotential lines indicate the level the water in a well will rise to which on the Figures below is benchmarked against the height above sea level (AHD). So in the case below the equipotential lines show the level water would rise to in a well open only at the bottom, whose bottom is placed on that equipotential line.

Three imaginary wells have also been annotated onto the two figures below, Wells A, B and C. These have been selected to illustrate the results of the MER modelling on the level of water that would appear in a very deep, a mid-range and a shallow bores in the Dooralong Valley.

The water level in the well is shown by the blue column for each well. It can be seen that the two wells (B and C) on the 20m equipotential line rise to the same level, namely RL20 m.

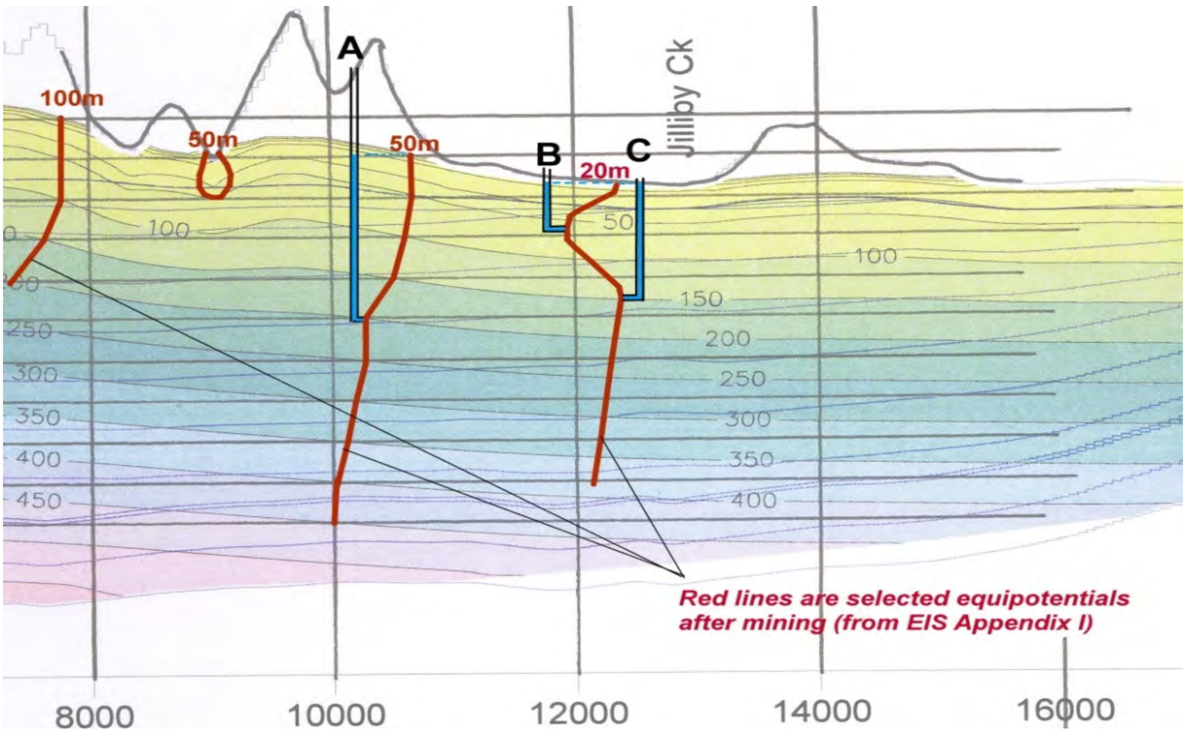

Figure 18: Pre-mining groundwater regime from Figure E17 of Appendix H of the EIS

Figure 19 is the prediction in the EIS of the groundwater regime at completion of mining. Again, selected equipotential lines and the three imaginary wells are annotated onto the figure. The water levels in these wells predicted at the end of mining are again shown by the blue columns. The drop in level for each well is shown by the orange column and as written on the figure. It can be seen that:

- the water level in Well A drops 48m;
- the water level in Well C drops 100m; and
- the water level in the mid-range, 70m deep, Well B drops 12m.

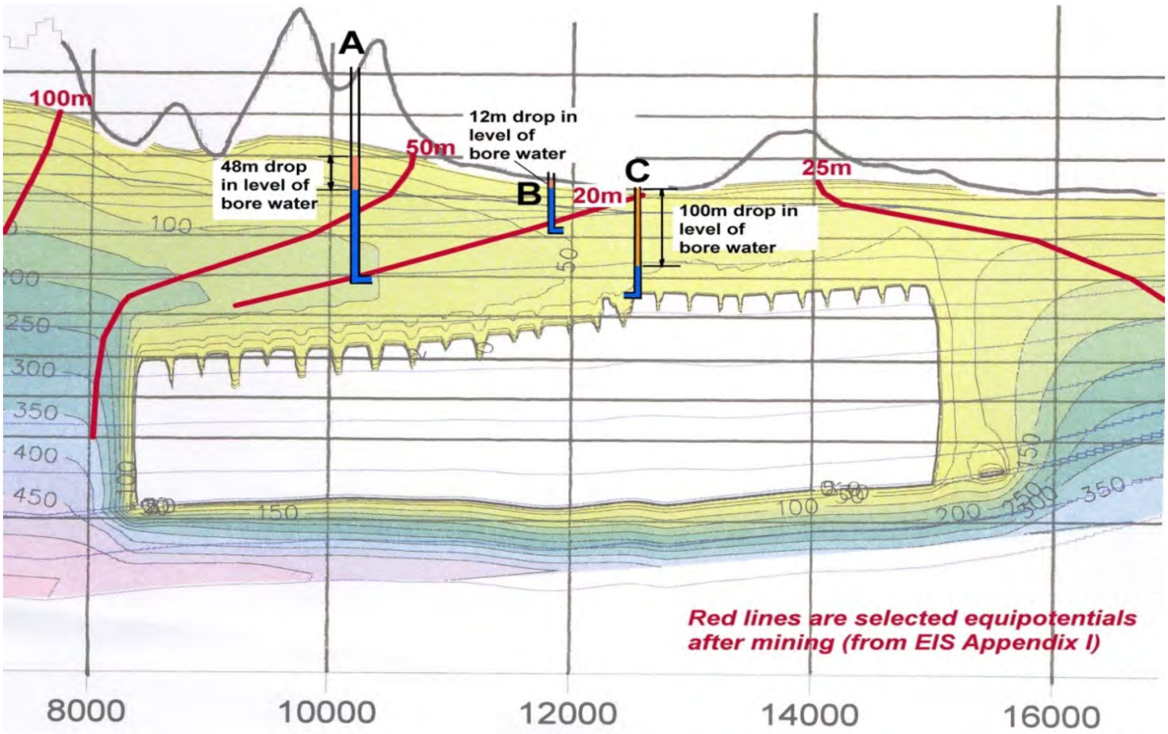

Figure 19: Prediction in the EIS of the groundwater regime at completion of mining

Water level drops in the wells annotated above are substantial and indicate significant changes to the groundwater regime. These pressure drops within the rock must reflect in pressure decreases within the shallow alluvium within the Dooralong Valley, and these decreases, in turn, cause the decrease in base flows to Jilliby Jilliby Creek that are discussed earlier.

It is therefore clear from the modelling results presented in the EIS that there will be very substantial changes to the groundwater regime above the area of the proposed mine.

8.4. Comments on the Groundwater Modelling in the EIS

8.4.1. The Accuracy of Groundwater Models

The validity of any hydrogeological model, notwithstanding its extent, sophistication and cost, depends entirely on:

1. The accuracy of the permeability and storativity parameters for the ground strata.
2. The boundary conditions, including recharge from the surface and around the perimeter of the model.
3. Whether the model properly simulates three dimensional behaviour.

Numerical models always contain a significant degree of uncertainty because of uncertainties in respect of items 1 and 2 listed above, and inherent limitations of the methods of analysis within item 3 above.

In the case of the model run by MER for the W2CP (Appendix H) project, the findings are almost completely dictated by two input parameters, namely:

(a) the assumed permeabilities for the natural strata prior to mine extraction, and in the Confined Zone that is deemed not affected by mining, and

(b) the thickness of the two zones whose permeabilities are increased by mining, namely, the zone directly above extraction (220m assumed by MER) and the Surface Zone (Forster 1995 Figure 1) where there is increased vertical permeability[2].

These facets are discussed in further detail below. However, given the dependence on these key parameters the groundwater model for Wallarah 2 should have been run for a range of assumptions for the assumed permeabilities (point (a) above) and extent of fracturing above the longwall (point (b) above), thereby giving ranges of:

- mine inflows,
- change of flow directions above the area of mining,
- downward loss of water from the alluvium of Dooralong Valley,
- probable drops in bore levels within Dooralong Valley, and
- decrease in base flow to Jilliby Jilliby Creek.

However, only one set of figures covering the all of the factors above has been given in the EIS. This prevents an understanding of the probabilities of the mine impacts on groundwater and stream flows.

[2] This zone has been studied in some detail in the Southern Coalfields and was the cause for loss of water in the Cataract River and the Woronora Rivulet.

8.4.2. Specific matters in respect to the groundwater model

There have not been substantial changes to the assumptions that were adopted by MER in their work presented in the original EIS (2010), compared with those presented in Appendix H of the EIS (September 2012). This is confirmed by a statement in paragraph E4 of Appendix H, namely,

> *"The 2012 model is identified as model W3. This model is very similar to the previously reported model W1 (MER, 2010)."*

The only significant change in respect to assumed permeability values (hydraulic conductivity) is a change for "the Terrigal Formation in hilly terrain".

The following issues represent the uncertainties in the parameters adopted in the model. There are always such uncertainties and it is for this reason that a range of assumptions should have been presented in the EIS to allow proper evaluation of the risks to groundwater and surface waters.

8.4.2.1. Permeability (hydraulic conductivity) assumptions

Firstly, the hydraulic conductivity, or permeability is a measure of how quickly water will flow through a medium, in this case the distance water will flow through the rock in a given time (e.g. meters per second or meters per day). To assess this, MER took samples of solid rock from the exploration bores for the W2CP and considered how fast the water could flow through the rock itself.

In adopting these permeability values, MER makes the assumption that there are no fractures such as joints in the rocks of the Narrabeen Formation below the weathered near surface environment through which water may flow. .

The concept that groundwater flow through rock masses is normally dominated by fracture flow, and not substance (core) flow, is so well established in the civil engineering, building construction tunnelling and mining professions that it does not warrant any testimony. Consequently, MER to a large degree, have based their selection of rock permeabilities on laboratory tests on small (50mm diameter) intact core samples. All field permeability testing that has been done for dams, tunnels, basement excavations and coal mines in the Sydney Basin over the past 80 years was unnecessary if core permeability was the relevant measure.

The vast experience of groundwater flow in rock, down to depths of at least 500 m, demonstrates that it is fracture permeability that matters and not core permeability. There are many references to support this contention with many being cited in the following recent publication:

> *A method of estimating bulk potential permeability in fractured-rock aquifers using field-derived fracture data and type curves*, Mandala, Mabee, Boutt and Cooke, Hydrogeology Journal, Volume 21, Number 2, March 2013.

The MER assumption as to the absence of fractures within the bulk of the Narrabeen sequence is also in contradiction to findings of a paper by Cook (2009):

> *"The bores intersected Terrigal Formation with a preserved thickness of up to 145m in the LGA. Extensive geological and geophysical bore logging delineated aquifers and enabled stratigraphic correlation within and between borefield…………. Aggregate yields greater than 15 L/s were recorded from multi-layered aquifers in several bores.*
>
> *Networks of nested multi-level hardrock and alluvial monitoring bores installed in the borefields revealed direct and indirect hydraulic connection between multi-layered hardrock aquifers with varying degrees of artificially induced vertical leakage from the overlying valley-fill systems during pumping."*

The permeability values adopted for the Wallarah 2 model are given in Table 5 (taken from Appendix G of the EIS).

TABLE 5
NARRABEEN FORMATION (PRE-MINING) PERMEABILITY (HYDRAULIC CONDUCTIVITY) VALUES ADOPTED BY MER FOR THE WALLARAH 2 MODFLOW MODEL

UNIT	HORIZONTAL		VERTICAL	
	m/day	m/sec	m/day	m/sec
Terrigal Formation	2.1×10^{-5}	2.4×10^{-10}	3.6×10^{-6}	4.2×10^{-11}
Patonga Claystone	1.8×10^{-5}	2.0×10^{-10}	3.8×10^{-6}	4.3×10^{-11}
Tuggerah Formation	3.1×10^{-5}	3.5×10^{-10}	1.5×10^{-6}	1.7×10^{-11}
Munmorah Conglomerate	3.4×10^{-5}	3.9×10^{-10}	2.3×10^{-6}	2.6×10^{-11}
Dooralong Shale	2.0×10^{-5}	2.3×10^{-10}	2.7×10^{-6}	3.1×10^{-11}
LOG MEAN		2.7×10^{-10}		3.0×10^{-11}

Now, if we compare an analysis of the field measurements from Coffey Partners International for the Wyong area and the Pacific Power at Dooralong with the MER work for the Ulan Mine the following log mean values for the Narrabeen Formation are found.

Wyong and Dooralong (Coffey)	3.37×10^{-9} m/sec
Ulan (MER)	4.69×10^{-7} m/sec

It can be seen from the above data that on average the vertical permeability values adopted by MER for the Wallarah 2 model are 100 times lower than values suggested by the Coffey field testing.

The values adopted by MER apply to ground that has not been disturbed by subsidence effects and are used by MER in the so-called Constrained Zone that is considered to exist from 220m above the extraction level to the weathered portion of the Narrabeen Formation. Therefore, in essence, MER assumes that there will remain a 150m to 300m thick layer of rock with a very low vertical permeability even after mining is completed.

The input of permeability values and assumption on the constrained zone dictate the findings of the model.

This assumption that there will be a Constrained Zone of unaffected permeability more than 220m above the level of extraction is not supported by experience within the Southern Coalfields and at Ulan. However, the EIS has placed a reliance on the behaviour of the Southern Coalfield to provide a model of subsidence at W2CP. The experience and calculated impact of subsidence on permeability presented in the EIS is discussed further in Section 8.4.2.2 below.

8.4.2.2. Contradictions within the EIS

The assumptions regarding permeability in the MER 3D model are contradicted by calculations given in the MSEC/SCT report in Appendix F to the EIS. The calculations show some disruption of the strata throughout the 350m profile above the level of extraction.

Furthermore, Figures 2.28, 2.34 and 2.48 of Appendix F give the post-mining vertical permeability profiles for:

- the Hue Hue 4 mining thickness case,
- the 'valley' case, and
- the 'forest' case.

These permeability profiles are very different from those adopted in the MER model, upon which groundwater impacts are assessed.

To demonstrate the large differences between what the EIS states as being appropriate permeability ranges, and what has actually been used in the EIS to assess impacts on the groundwater regime, we have plotted, in Figure 20, the parameters used by MER (3D model) against the 'valley' case permeability ranges given in Appendix F.

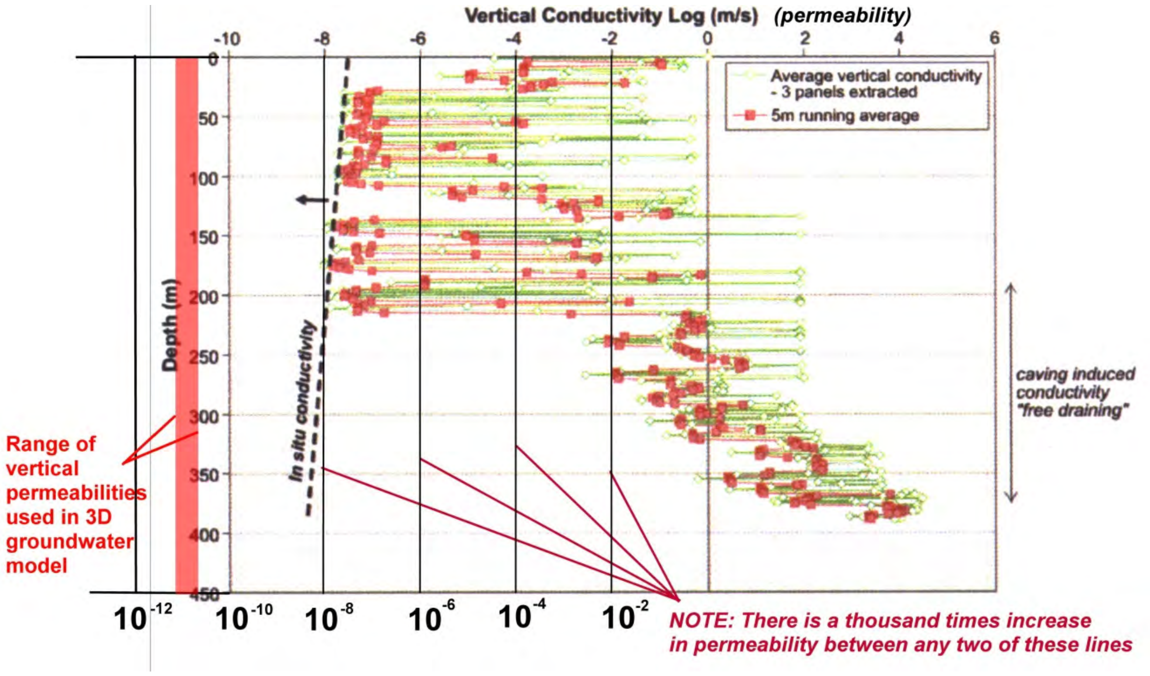

Figure 20 Vertical Permeability values from Appendix F of the EIS versus values used in groundwater impact assessment in Appendix G (After Figure 2.35 Valley Case)

Figure 20 indicates that the hydraulic conductivity values adopted in the MER W2CP model are substantially on the low side of any realistic range of possibilities which have been identified within the EIS itself. If the values provided in Figure 20 were adopted the computed mine inflows, and the rate at which depressurisation progresses through the strata would be substantially higher.

Indirectly MER appear to agree with this assessment. Figure E27a from Appendix I repeated below as Figure 21, shows a distribution plot of vertical (k_v) and horizontal (k_h) conductivity for the Constrained Zone from a synthetically generated randomised distribution.

Interpretation of the data presented in Figure 21 shows that at about 50% of the realisations of vertical permeability have a value equal to, or less permeable than those modelled by MER (about 10^{-11}m/sec or 10^{-6} m/day). However, this indicates that 50% of the potential realisations of permeability are more permeable than those modelled. While it must be acknowledged that the plot below is a probabilistic one, it does show another view that permeability could be higher. The order of increased permeability values shown are:

- 20% of values have a value of k_v up to 10 times greater than those modelled
- 15% of values have a value of k_v up to 100 times greater than those modelled
- 10% of values have a value of k_v up to 1000 times greater than those modelled

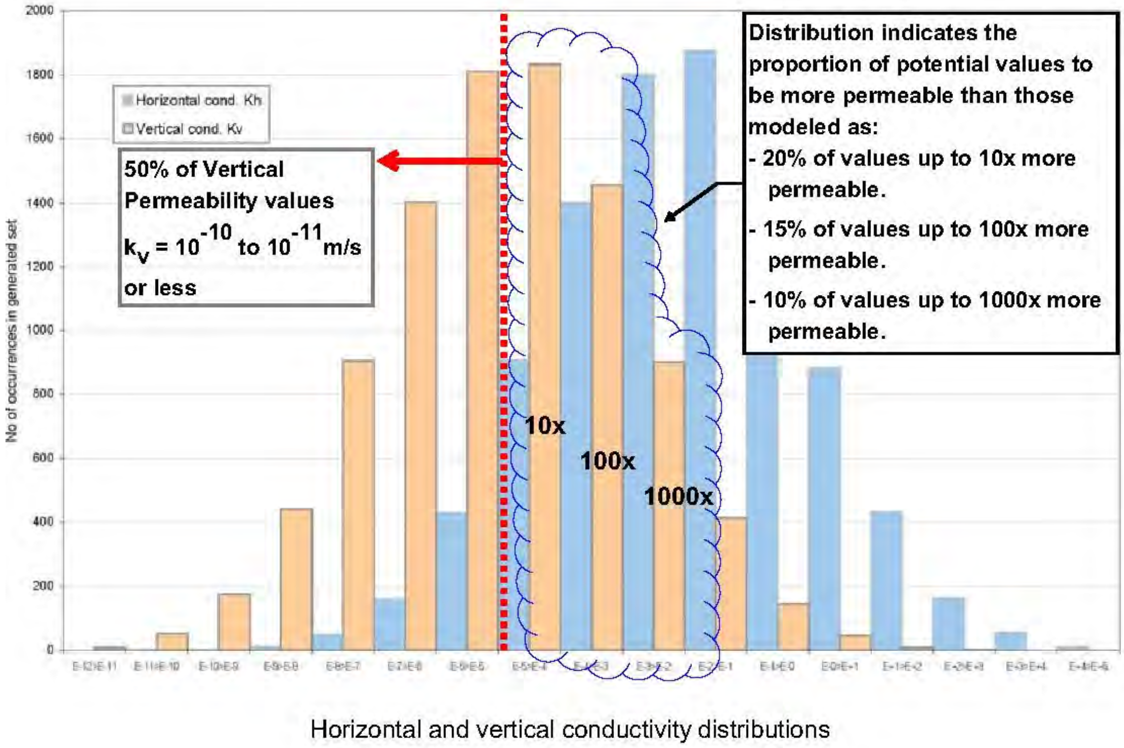

Figure E27a

Figure 21 Distribution of synthetically generated permeability values in the constrained zone by MER – Figure 27a in Appendix H of the EIS

Figure 22 summarises the progression of depressurisation through the strata from the MER model, a process still continuing after 38 years. If MER had adopted the parameters recommended in the previous chapter in same EIS then depressurisation would have been calculated as occurring much faster and to a much greater extent.

Therefore, the flow quantities and extents of depressurisation discussed in Section 8.2, above, must be viewed in the context that they are non-conservative in respect to impacts on groundwater and surface waters. Therefore, the significant impacts actually shown by the MER model, as outlined in Section 8.2, could readily be more adverse, and at the very least warrant assessment with regard to sensitivity and risk.

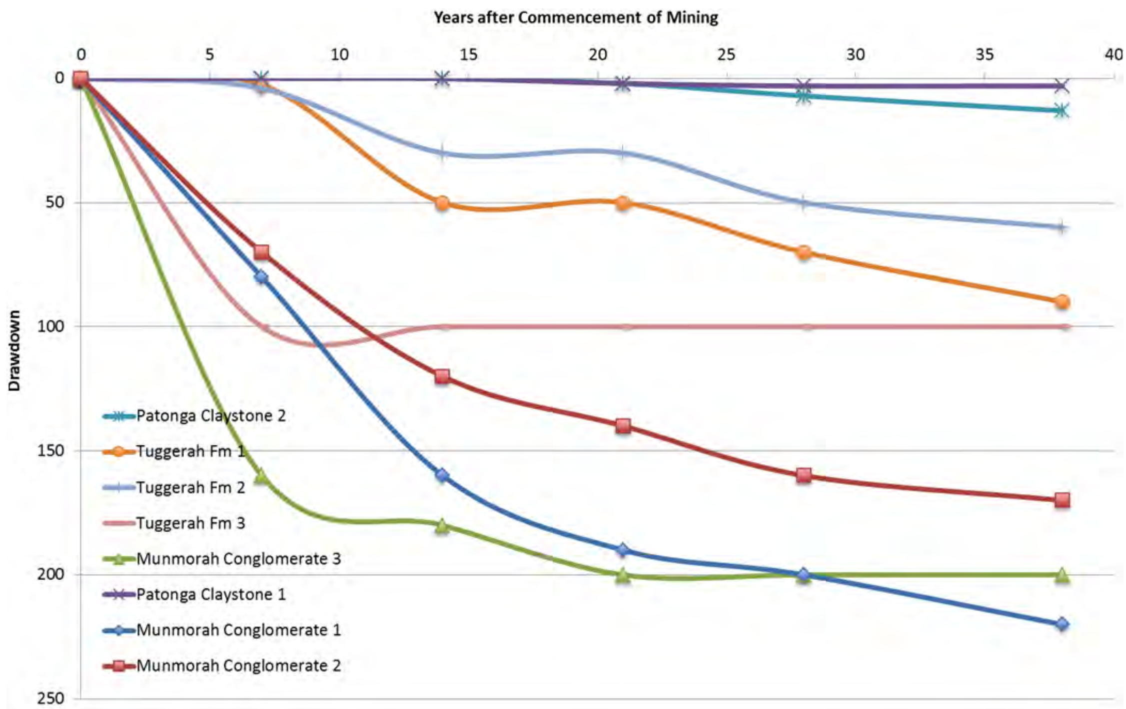

Figure 22 Depressurisation curves extracted from the plots of the MER W2CP model given in Appendix G of the EIS

8.4.2.3. Sampling Methodology

One aspect of the project that has an impact on specialist studies pertains to the makeup of the rock mass that lies between the shallow, alluvial water table and the proposed mine. Studies such as the groundwater modelling rely on the interpretation that the presence of the Patonga Claystone below the alluvium "prevents" water loss from the alluvial layers and the creeks. This is based on the view that no vertical connection occurs to the deeper and apparently more fractured materials in the Tuggerah Formation, the Munmorah Conglomerate and the Dooralong Shale.

The first point to note is that the fracture system in the sedimentary rocks in the Sydney Basin is dominated by sub-horizontal bedding planes and a network of sub-vertical joints. The absence of vertical joints as stated in the EIS is likely to be more of a reflection on the exploration drilling program which exclusively used vertical boreholes, which, by their geometry, are unlikely to intersect such features. Indeed, Mackie notes that:

> *There is potential for groundwater exchange between strata via fractures and micro cracks which introduce secondary permeability if they are connected. However it is extremely difficult to establish the occurrence, frequency and connectivity of these fractures since they are mostly vertical or sub vertical and consequently are less likely to be intersected by exploration boreholes than fractures that occur at shallow angles.*

While we agree that direct connection between the surface alluvial aquifer and the mine is likely to be '*rare*' (in terms of the risk assessment rating in Table 1B), the potential for water to travel via a '*tortuous*' path of vertical joints and bedding planes, albeit ones that are often tight and/or infilled with materials like sand, silt and clay, the likelihood that the tortuous path is present cannot be discounted based on the factual geological information provided and the sampling method of vertical boreholes.

We note that it is not typical for a deep coal mine to undertake a programme of angled cored boreholes, particularly in the initial investigation stages due to the prime interest being at depth with regard to coal quality and stability of the longwalls and main headings. While we understand that W2CP have an extensive database of information on fractures over the project area, the EIS does not indicate how this relates to the near surface rock formations, and in particular the assumed aquatard characteristics of the Patonga Claystone strata.

This oversight goes to the heart of the concern raised by the Director General of Planning about uncertainty and recommendations are made at the Conclusion of this report with this in mind.

8.4.2.4. Sensitivity Checks – Model W4

A single model, W4 has been run by MER to consider sensitivity with regard to permeability. However, inspection of the "scaling" used by MER with regard to vertical and horizontal permeability values, particularly in relation to the layers that actually matter in regard to near surface impacts (Table E3 or Appendix H) again do not appear to reflect the subsidence modelling (SCT 1999 & 2011 as referred to by MER). The factors used to scale the permeability values in the MER "sensitivity model – W4" are repeated in Table 6.

A key parameter in our discussion on groundwater above is the vertical permeability of the Patonga Claystone. Table 6 shows that the sensitivity of this parameter has not been tested.

TABLE 6
PERMEABILITY SCALING FACTORS – MER *SENSITIVITY MODEL W4*

LITHOLOGY	SCALING FACTOR USED BY MER	
	VERTICAL PERMEABILITY (x K_v)	HORIZONTAL PERMEABILITY (x K_h)
Terrigal Formation	1	1
Patonga Claystone	1	10 & 20
Tuggerah Formation	1.1, 2 & 10	60, 100 & 600
Munmorah Conglomerate	100 & 1000	1000 & 6000
Dooralong Shale	90000	148000

8.4.2.5. Absence of critical parameters

MER has properly used the version of MODFLOW that addresses the impact of desaturation in the strata on reducing permeability values. This reduction in permeability has a very important impact on the computed mine inflows and the rate of depressurisation.

There is no information in the EIS, and in particular in Appendix G, that sets out what assumptions have been made in the model in respect to permeability reduction in the desaturated zone in the goaf. Therefore, it is impossible for a measured review to be made of the model results.

In addition to presenting the material parameter assumptions, it would have been proper for the assumptions to be validated against field data from Mandalong Colliery, where there has been substantial depressurisation above the extracted longwalls, viz:

> *Mining of the longwall panels has however resulted in depressurization of the deeper overburden.*
> *Whereas at some depths this may be a temporary depressurization due to bedding parting, at deeper levels the bedrock has probably been permanently depressurized/dewatered when mining intersected a fault and/or goafing provided hydraulic connection with the mine. The alluvium and shallow overburden has however not been impacted with the exception of site BH22, as stated.*
>
> *The data also indicates that the Great Northern Seam to the south of the Mandalong Mine may have been depressurized as a result of mining in the area, but that the deeper Fassifern Seam has not been impacted.*

End of Panel Report
Longwall 12
Mandalong Mine
August 2012

8.5. Borefields

Borefields have been developed for use by the W2CP as a drought contingency measure and we understand there is only limited data on the historical operation and medium to long term yields of these resources.

Borefields are located at:

- Woy Woy
- Somersby
- Mangrove Creek
- Ourimbah
- Mardi.

The yield from these borefields is reported as being:

- Woy Woy - 3.8ML/day
- Ourimbah (Narara) - 1.2ML/day
- Other (remaining) - 3.0ML/day

Notwithstanding the relatively small volume of water reported above, we consider that only the Mardi groundwater bores have any potential to be impacted by the W2CP as they are within about 3km of the southern extent of the mine. The remaining fields are considered too distant to be affected (>6km).

With regard to the Mardi borefield, it actually only comprises one functioning bore, BH15 located at the Mardi Water Treatment Plan site. A second bore, BH16 at Mardi Dam (near Woodbury Park) is understood to no longer be operational. Bore BH15 is understood to extend to a depth of 150m, which is expected to locate the base of the bore in rocks of the Tuggerah Formation, or possibly in the top of the Munmorah Conglomerate. The WGN seam is at about -400mRL to -450mRL in this area (Figure 5 Appendix I) indicating a depth of about 450m to 500m.

Based on predicted piezometric drawdown levels in the EIS (Figures E23 and E26, Appendix I), the location of bore BH15 will not be affected during the period of mine operations. However, some drawdown of up to 5m may occur, based on the EIS after a long period of time (modelling was based on 500 years after mining).

CCWC would need to assess this prediction with regard to the known operation of the bore.

8.6. Findings

The conclusions reached by MER are primarily the result of the input parameters adopted for their numerical modelling. These input parameters are neither consistent with available data from field testing nor the subsidence calibration modelling and do not consider the impact of extended periods of drought conditions on the surface recharge assumed in the modelling. The level of uncertainty is considered to be high and without sufficient sensitivity assessment of the impacts of inputs to the model.

On this basis, the findings from the MER study should be considered as a limited and very likely, unconservative view of potential impacts. This means that, at present, it is not known with an acceptable level confidence what the impacts of the Wallarah 2 longwalls will be on likely groundwater resources, and on groundwater that feeds into the streams of the Dooralong and Yarramalong Valleys.

9. FLOODING

9.1. Introduction

The assessment of flooding impacts of the W2CP is based on material presented in Appendix K by G Herman and Associates (Herman), although this work relies upon information provided in other Appendices in the EIS, viz:

- Appendix G: Subsidence Modelling
- Appendix J: Surface Water Impact Assessment.

As described in Reference 2, the Yarramalong and Dooralong Valleys are well defined and comprise steep valley sides with flat floodplains. As a result, increases in flood levels cause relatively small increases in the overall extent of floods.

The previous EA included assessment of the affect the W2CP on the extent and depth of flood events was undertaken by Environmental Resources Management (ERM) and was included as Appendix C to the 2010 EA. The new assessment presented in the EIS states that the previous flooding assessments were "*fundamental in the development of the current final mine plan assessed in this report".*

However, the flood study by Herman utilised more advanced methods of assessment utilising the TUFLOW software package to allow 2D modelling as compared to the 1D/pseudo 2D modelling undertaken in the earlier studies. This was in line with suggestions from the review panel in 2009.

Herman only assesses flooding for design storms with a 1% and 20% Annual Exceedance Probability (AEP). A 1% AEP implies there is a 1% chance that the design flood will occur, or on average the design flood can be expected to occur once every 100 years.

The 1% AEP flood maps are included in Annex I to Appendix K and are included in the following sections.

The flood maps for the 20% AEP assessment are not present within the EIS document, this being the design flood which is expected, on average to occur every five years.

9.2. Study and Modelling

The study area for the flood assessment includes the areas immediately below the W2CP in the Yarramalong and Dooralong Valleys and in the Hue Hue Creek area and obviously considers flooding due to rainfall across the full catchment areas upstream of the proposed mine. The extent of the study area is shown in Figure 23 and comprises:

- Wyong River upstream of the F3 for a distance of 25.9km.
- Jilliby Jilliby Creek upstream of its confluence with Wyong River for a distance of 20.05km.
- Little Jilliby Jilliby Creek.
- Hue Hue Creek upstream of the F3 for a distance of 5.48km.

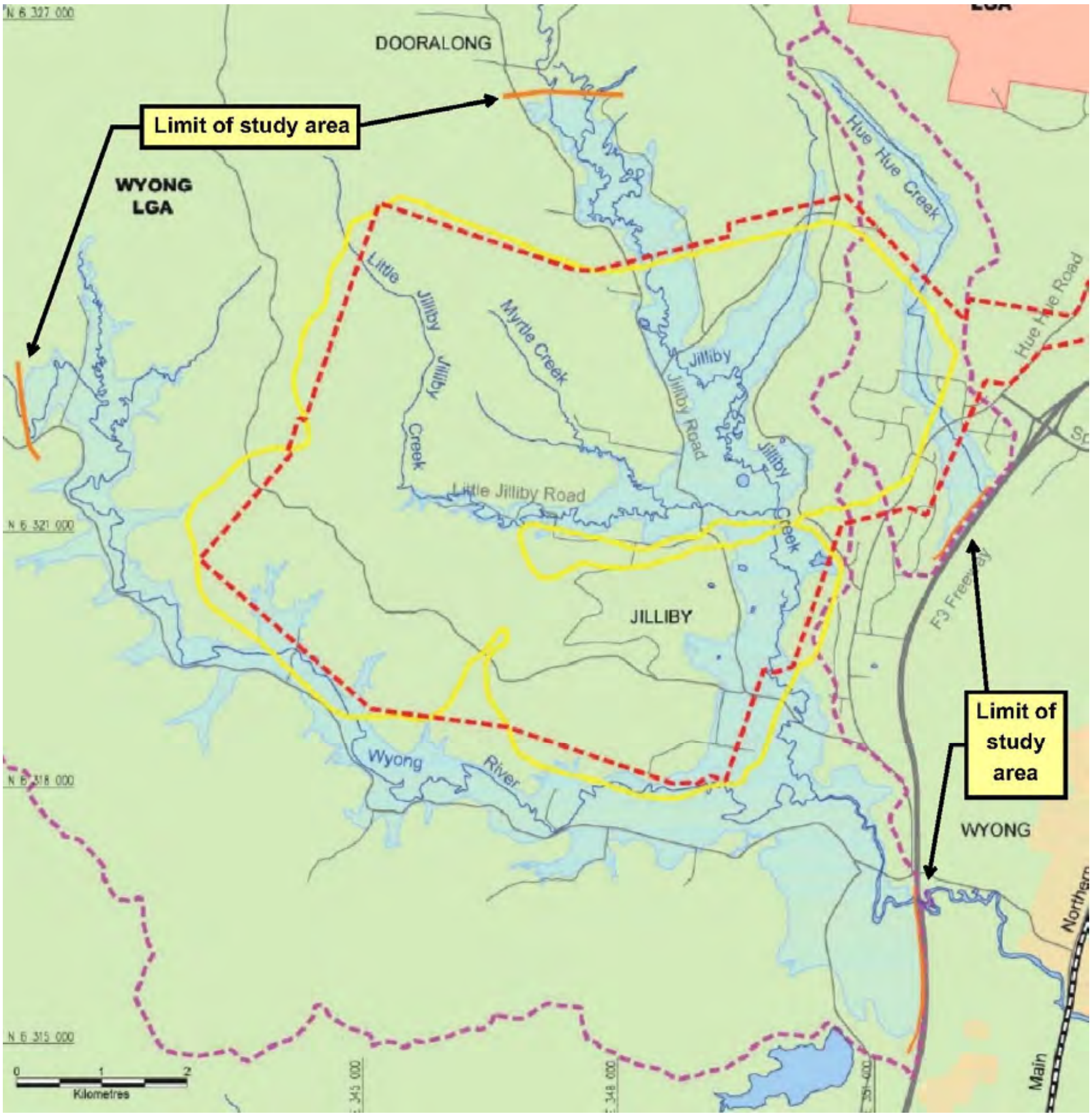

Figure 23: Study Area

As indicated above, the 2D TUFLOW software is able to model secondary flow effects which often occur at stream confluences or the influence of tidal or backwater flows due to high water levels downstream of the study area, such as may occur due to climate change effects. The programme is also able to model the transition between supercritical and subcritical flows. This ability is considered important with subsidence quite possibly producing conditions (i.e. a sharp increase in elevation) that could cause a change in the flow regime. However, it should be noted that TUFLOW cannot model hydraulic jumps.

A further advantage of the TUFLOW model is that it is far more flexible than the modelling software utilised earlier and can be re-calibrated either during the initial work or later such as over the lifetime of the mine if different impacts of flooding are observed to those found from modelling.

A summary of the work conducted in the flood impact assessment is presented below:

- A TUFLOW model was developed to simulate the pre and post mining subsidence flood differences for a 1% AEP flood.
- The assessment considered points of stream construction such as bridges and undertook a process of calibration to ensure the pre mining modelling reflected historical and community records of past flooding.
- Assessed the extent of flooding and level differences due to the project.
- Allowed recommendations on dwellings, access roads and flood hazard risk impacts due to the flooding differences caused by the W2CP.
- Assessed the sensitivity of the results to reasonable changes in the input parameters, in particular Manning roughness coefficients, and due to climate change effects by:
  - Increased storm input to the model by 20% to simulate increased wet periods in the future, and
  - Application of a high tailwater level of 1.1m at the F3 boundary to simulate high lake and/or river water levels.

Further to the above, the following points are noted.

- Sensitivity checks for climate change are described by Herman as simplistic and very conservative. The approach is not considered current best practice (for example a different method will be applied in the upcoming Australian Rainfall and Runoff (AR&R) update). However, the approach is very closely modelled on the NSW legislation requirements, which are conservative. Whilst the modelled climate change results are expected to 'over-engineer' the result there are no adverse effects except possibly higher costs to the project if any pre-emptive works are dictated such as bridge or road access points.
- In general, the model has a low sensitivity to antecedent conditions and downstream boundary condition tail water level and a slightly higher sensitivity to Mannings n and the degree of subsidence.
- Changes to material properties (e.g. Mannings 'n') resulted in slightly reduced peak flows, but increased the peak flood levels by up to 0.15m.

- Changes in the downstream boundary condition tail water level caused virtually no flooding differences beyond 600m upstream of the downstream boundary condition.
- Calibration of the model has been done using the historical stream flow results from within the catchments. However, due to the limited stream flow data in the catchments the model may not be calibrated properly for floods < 2%AEP, due to the absence of records with an AEP less than 0.02. The calibration process was to calibrate the initial/continuing losses, calibrate Mannings ‘n’ and then recalibrate the initial/continuing losses.
- The DTM’s (Digital Terrain Models) used as for input to TUFLOW are from 1996 or more recently. The calibration floods are all from prior to 1996. It is possible with the creek/rivers being subject to dynamic geomorphological changes (see Appendix J to the EIS) that the DTM in the model used could be different in the stream/creek locations for the calibration years, which would be more critical if there was significant curvature/alignment differences between the calibration years and post 1996.
- Whilst it seems logical to select maximum parameters from the AR&R for the IFD calculations as a conservative assumption, this may not be the case, as discussed below.
    - The BOM online service has been used to provide an IFD curve for the project location. When compared with results from Annex B there are up to 10mm/h differences in the 100yr ARI results. The differences are maximum at shorter durations and a minimum at a 72hr duration (0.08mm/h), with, as expected, the results in Annex B always the greater of the two.
    - The 30hr and 12hour durations give the critical floods for the Dooralong/Yarramalong and Hue Hue models respectively.
    - The calibration cannot be confirmed for storms with an ARI greater than 50yrs due to the available historic stream flow data.
    - The Mannings ‘n’ values considered had to be increased over the whole catchment in the calibration process. It is possible that this could be a result of ‘overestimating’ the input rainfall, which would cause the roughness to have to be increased in calibration to give the calibration results. This when combined with the fact that all calibration is done on <50yr ARI storms and that modelling is done for 100yr ARI storms means that the overall catchment roughness may be overestimated (as a portion of the flood plain covered in an 100yr ARI flood is unlikely to have been covered in the <50yr ARI calibration storms), which would attenuate and translate the peak of the hydrograph (potentially underestimating the peak).

Overall, the calibration is considered acceptable and likely to be relatively insensitive to the technical points made above.

Aspects considered beyond the scope for the work presented in Appendix K are:

- Fluvial geomorphology
- Low flow hydrology and river hydraulics
- Sediment transport and deposition.

9.3. Impact of Mining on Flooding

9.3.1. Overview

Results of the flood modelling for the 1% AEP flood event indicate that subsidence from the current W2CP mine plan is likely to result in only minor increases in the depth and extent of flooding compared to current, pre-mining estimates.

A summary of the changes in flood extents and depths as a result of mining subsidence is presented in Tables 8 and 9 below. The reader will also note the introduction of the Flood Impact Category rating in Table 7. A description of what each Impact Category comprises is included in Table 9.

Further to the dwellings described in Table 8, a total of 14 dwellings have no significant change in flood impacts while a total of 49 properties will see a reduction in flood impacts. Most falls in flood level are predicted to be negligible (less than 50 mm fall in flood level). We note that dwelling (D0226) listed as Flood Impact Category E1 is incorrectly assessed, it should be Category E2 based on the values presented in Table 6.2 of Appendix K of the EIS.

Other impacts of the subsidence on flooding such as flood peak flows are anticipated to be slightly reduced with a minor increase in the duration of the peak, although the EIS notes these as being insignificant.

Further, key access roads and some bridges within the Dooralong and Hue Hue valleys will become inaccessible for longer periods as a result of the subsidence.

The reader should note that changes noted are in relation to the 1% AEP event and that the impacts described would only fully come into effect after mining has been completed. Also note that there are minor discrepancies in Appendix K where slightly higher impacts are reported in the executive summary compared to the main body of the report.

TABLE 7
CHANGES TO EXTENT OF FLOODING

AREA	AREA OF ADDITIONAL FLOODING IMPACTS	AREA NO LONGER AFFECTED BY FLOODING
Yarramalong Valley	5.2 Ha	Nil
Dooralong Valley	28.3 Ha	5 Ha
Hue Hue Creek	1.9 Ha	0.8 Ha
Total Areas	35.4 Ha	5.8 Ha

The changes to flooding extents will have an adverse effect on up to 10 properties. The impact is assessed to be up to 5% of additional land area inundated (4 Properties) and up to 20% of additional land area for the remaining 6 properties.

TABLE 8
ADVERSE IMPACTS TO DWELLINGS

DETAIL (IMPACT CATEGORY)	CHANGES TO FLOOD IMPACT	
	YARRAMALONG & DOORALONG VALLEYS	**HUE HUE CREEK**
Dwellings not currently affected by flooding become flood prone[A] (MAJOR – A1)	4 in Total 3 between 4 & 14cm 1 up to 1.27m	1, up to 7cm
Increased Inundation[A] (MAJOR – A2)	1, up to 41cm	None
Increased Inundation[A] (MODERATE – B1 & B2)	7 in Total Increase flood levels by between 6 & 17cm	1, up to 3cm
Reduced Freeboard[B] (MODERATE – B3)	2 in Total Freeboard Levels of between 26 & 28cm	1, Freeboard remaining of 4cm
Increased Inundation[A] (MINOR – C2)	4 in Total Increase flood levels by between 1 & 4cm	None
Reduced Freeboard[B] (MINOR – C1 & C3)	6 in Total Freeboard Levels of between 8 & 48cm	None

[A] Flooding depth above floorboard level.
[B] Remaining amount of freeboard between predicted flood level and floorboard level.

9.3.2. Flood Maps, Dwellings and Property Impacts

A detailed description of the flood study findings can be found in Sections 6.4 to 6.6 of Appendix K. The results are presented in two formats, namely flood maps and tabular format indicating the following:

- Detail on flood levels and freeboard associated with each dwelling for the 1% AEP and 20% AEP are presented in Tables 6.1, 6.2 and 6.3 of Appendix K, although no key is provided as to street addresses associated with the Dwelling ID's.
- Tables 6.4 and 6.5 present a summary of the Impact Category for the changes in the flood status of Dwellings and properties respectively that are a result of the W2CP.

For this report, we have provided a summary of the information from both the flood maps for the 1% AEP. Figure 24 shows an overview of the increased extent of flood water post mining for a 1% AEP flood. Figures 24 and 25 show a detailed view of the Dooralong and Yarramalong Valleys respectively.

Tables 6.4 and 6.5 in Appendix K have been reproduced here as Tables 10 and 11 respectively. The latter two tables described in the second bullet point above are also included as it is useful in outlining the extent of the change at each dwelling and categorise how the detrimental impacts of flooding due to mine subsidence is likely to be treated by WACJV.

Figure 24: Overview of Increased Extent of Flooding (1% AEP) shaded red and areas of reduced flooding shaded green along the fringes of the Dooralong Valley.

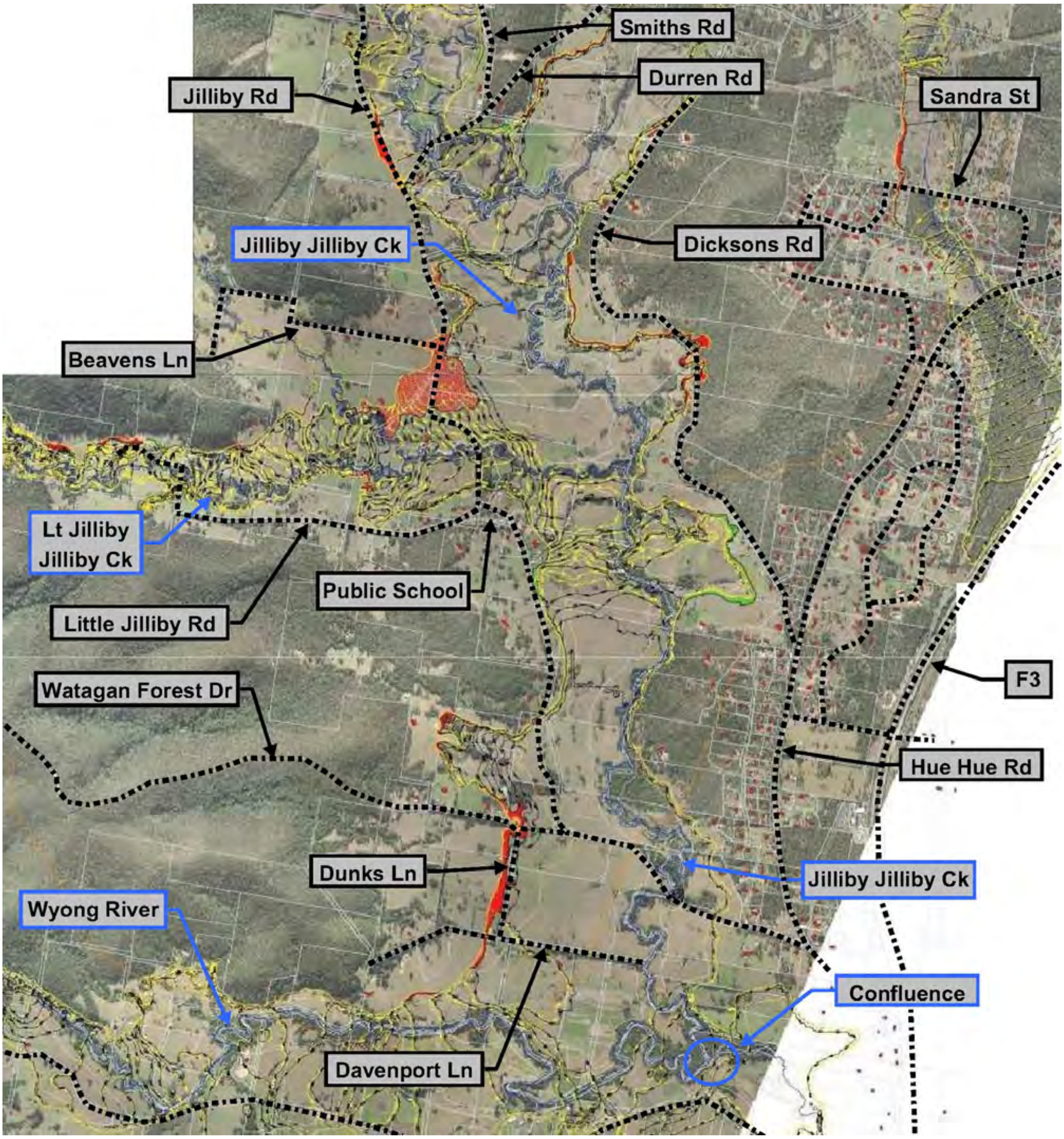

Figure 25: Main Areas of Increased 1% AEP Flooding – Dooralong Valley

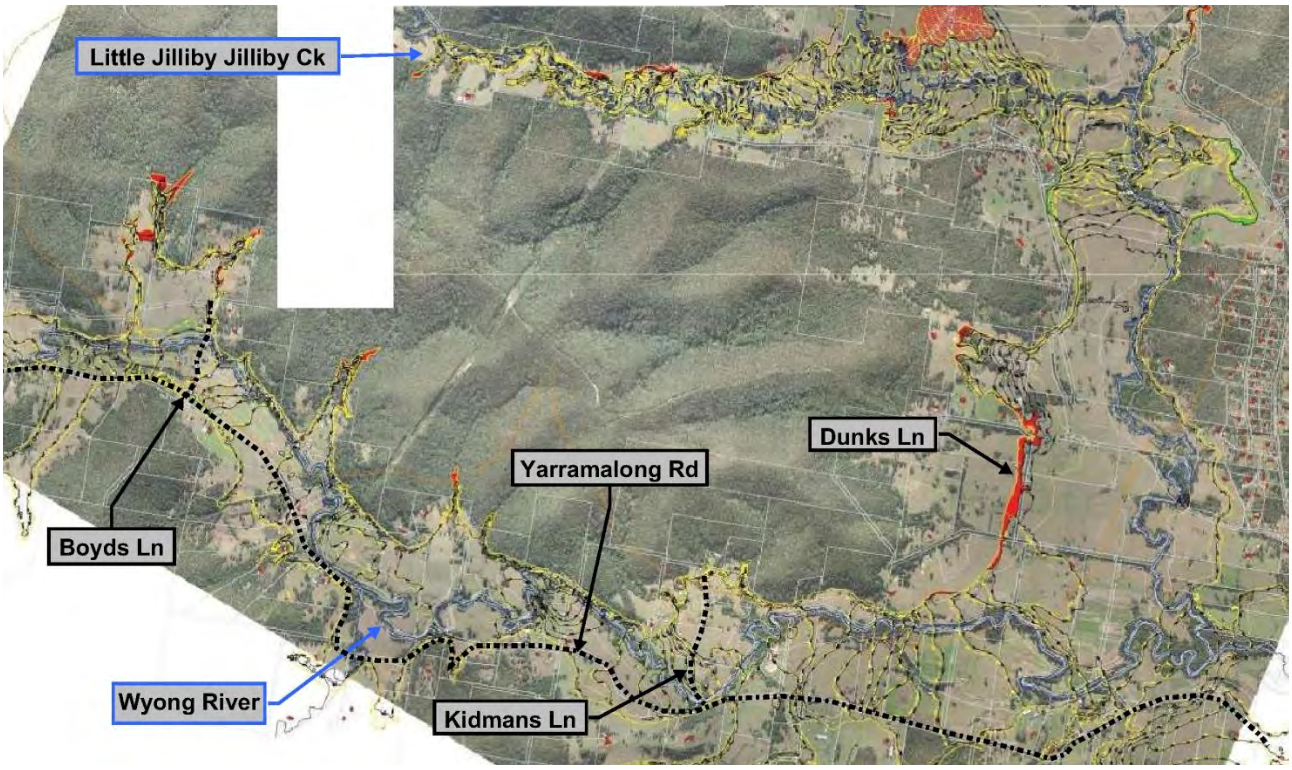

Figure 26: Main areas of increased 1% AEP Flooding – Yarramalong Valley

A minor, but significant point from the aspect of EIS review is that of presentation. It is difficult to interpret with any confidence what the flood levels are on the 1%AEP flood maps included in Annex I to Appendix K nor from the various Figures throughout the text of the EIS. Indeed, the only clearly defined data is that presented in Tables 6.1 to 6.5 of Appendix K with the limitation as to no actual identification of dwelling.

A sample of the current 1% AEP mapping available to Council (from the 2012 Wyong River Flood Catchment Study by BMT WBM) is given as Figure 27 and clearly shows flood levels and depth of flooding.

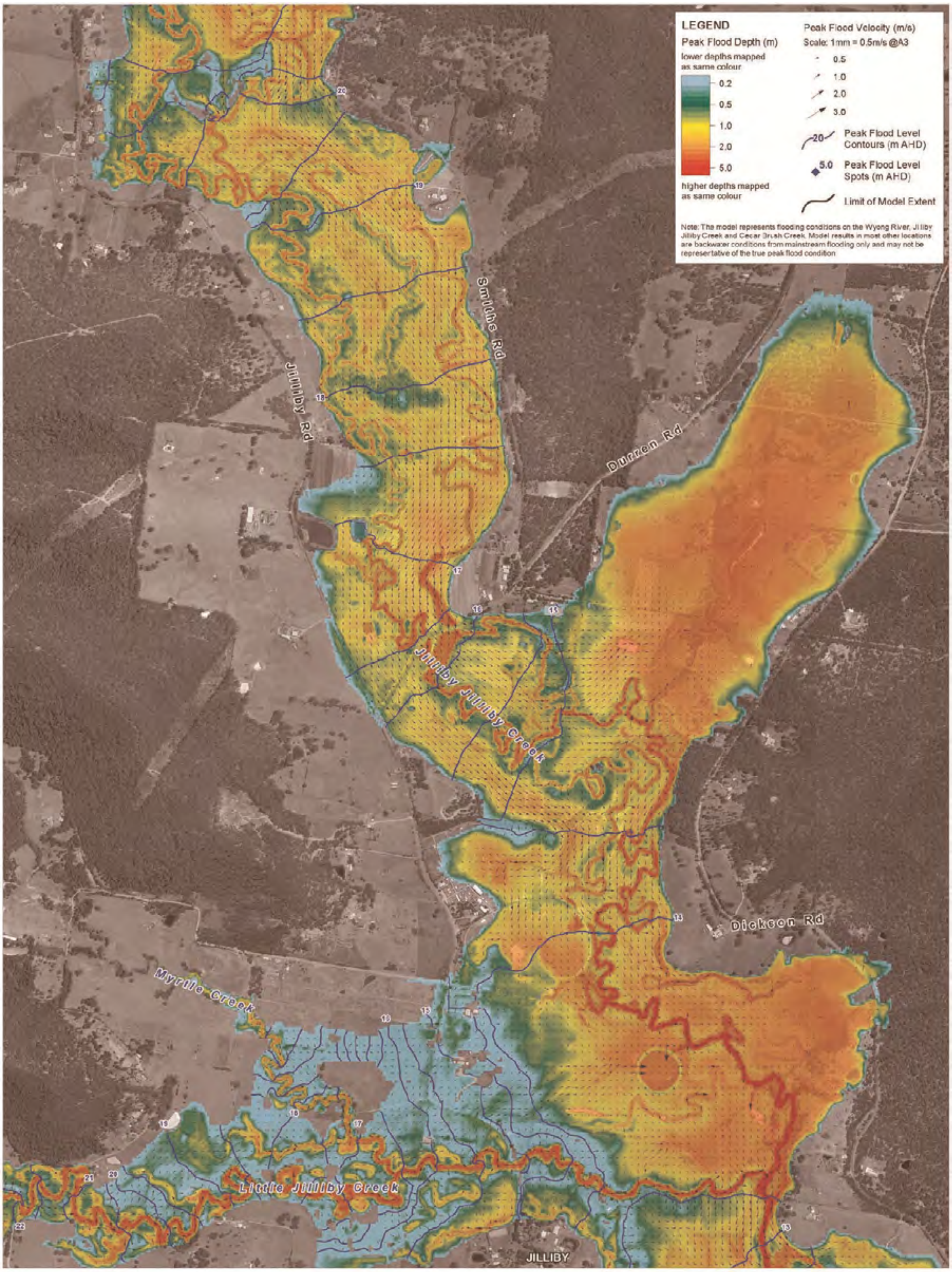

Figure 27: Sample of 1% AEP Mapping for confluence of Jilliby Jilliby and Little Jilliby Jilliby Creeks (2012 Flood Study by BMT WBM).

TABLE 9
FLOOD IMPACT CATEGORIES - DWELLINGS

TABLE 9
FLOOD IMPACT CATEGORIES - DWELLINGS (Continued)

TABLE 9
FLOOD IMPACT CATEGORIES – DWELLINGS (Continued)

Category	Description	Number Affected	Houses Affected	Impacts
E3	Negligible (<0.05 m) reduction in flood levels and/or freeboard after mining for all floods	46	(see Tables 6.2 & 6.3)	No impacts and no significant change
U	Unchanged			
U	No change in flood depths after mining but minor change in ground levels	14	D0006, D0009, D0048, D0106, D0108, D0115, D0170, D0201, D0377, D0384, D0712, D0869, and sheds S0048, S0842	No impacts

TABLE 10
FLOOD IMPACT CATEGORIES – PROPERTIES

Category	Description	Number Affected	Land / Properties Affected	Impacts
L1	Reduction in Flood Extent of 1:100 yr flood (1%) by more than 5% of individual property area after mining.	2	Generally grazing land near property boundary.	Moderate Beneficial Impact.
L2	Reduction in Flood Extent of 1:100 yr flood (1%) by less than 5% of individual property area after mining.	3	Generally grazing land near property boundary.	Minor Beneficial Impact.
L3	Increase in Flood Extent of 1:100 yr flood (1%) by more than 5% but less than 20% of individual property area after mining.	4	Mostly grazing land plus some areas of non-agricultural and uncleared land.	Minor to Moderate Adverse Impact.
L4	Increase in Flood Extent of 1:100 yr flood (1%) by more than 20% of individual property area (or other major effect) after mining.	6	Agricultural land plus one cattle property.	Moderate to Major Adverse Impact.

9.3.3. Access and Low points

Low points on access routes were assessed based on the pre and post mining flood levels considering the NSW Floodplain Development manual (2005) for safe depths for vehicles at specified flow velocities.

A total of thirty low points were identified by Herman. Figure 28 indicates the location of key low points on both primary and secondary access routes. Table 11 summarises the details of the key low points on primary access routes.

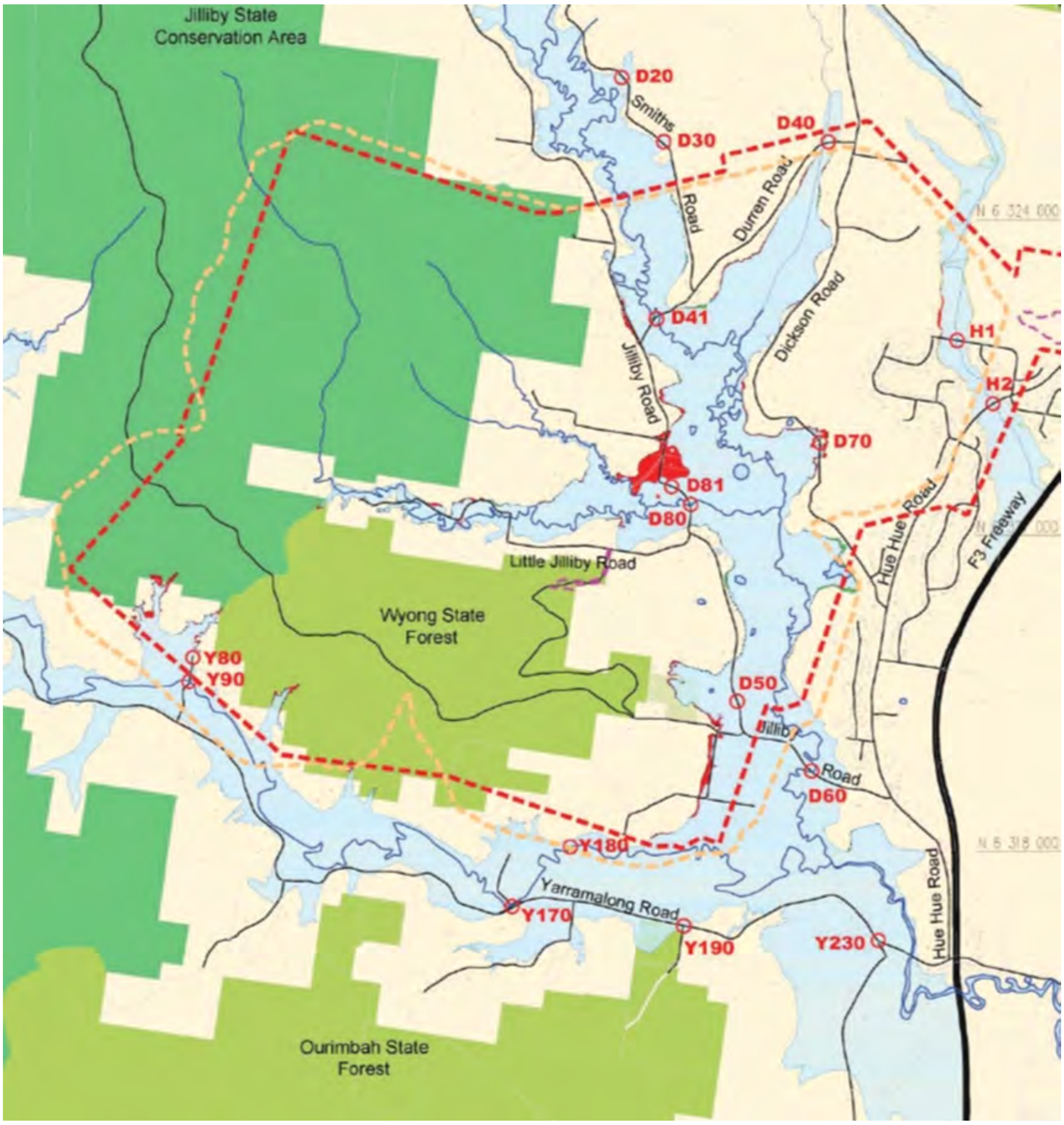

Figure 28: Low points and flood affected roadways (both primary and secondary access routes)

TABLE 11
KEY LOW POINTS – PRIMARY ACCESS ROUTES

Key Low Point ID	Maximum Existing Trafficable RL (m AHD)	Maximum Subsided Trafficable RL (m AHD)	Existing Inundation Duration (hours)		Post-mining Inundation Duration (hours)		Increase in Inundation Duration (hours)	
			1% AEP	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP
D20	20.0	20.0	19	9	19	9	Nil	Nil
D30	19.3	19.3	5	0	5	0	Nil	Nil
D40	18.35	18.35	19	11	19	11	Nil	Nil
D41 (Bridge C)	15.40	14.21	24	24	22	21	Nil	Nil
D50	10.0	8.7	6	0	33	31	27	31
D60 (Bridge A)	7.9	7.9	24	21	24	22	Nil	1
D70	12.45	11.24	15	12	28	25	13	14
D80 (Bridge B)	14.9	13.7	10	0	15	11	5	11
D81	14.7	13.4	11	4	17	10	6	6
Y80	12.6	12.4	71	68	73	69	2	1
Y90 (Bridge 7)	13.06	12.95	62	54	63	55	1	1
Y170 (Bridge 3)	9.84	9.84	50	50	50	49	Nil	Nil
Y180 (Bridge 2)	9.20	9.20	51	50	51	50	Nil	Nil
Y190	9.25	9.25	33	32	33	32	Nil	Nil
Y230	7.85	7.85	10	0	10	0	Nil	Nil

As can be seen from the table above, six locations are expected to be inundated for longer periods as a result of the W2CP subsidence (1% AEP), the increased period over which access will not be possible varies from 1 hour up to a maximum of 27 hours at D50 toward the southern end of Jilliby Road, just north of the intersection with Watagan Forest Drive.

Of the secondary access routes, the maximum reported increase in inundation due to mining is 13 hours at point D70 on Dickson Road.

9.4. Mitigation

9.4.1. Property

As reported above, Herman presents a range of categories against which the impact of flooding induced by mining subsidence may be assessed. Similar to remarks made by ERM in 2009, Herman suggest that it

> "*would be reasonable to expect that mitigation works will be required for dwellings in Category A (Major Impacts) and Category B (Moderate Impacts). However, dwellings in other categories are unlikely to require mitigation works."*

There are a total of 6 dwellings identified as Category A (2 less than the 2010 assessment) and 11 dwellings as Category B.

Mitigating options are discussed in relation to the management measures outlined in the NSW Floodplain management manual (2005) and comprise works that comprise either:

1. Property modification – either of the property itself such as by raising or flood proofing, new controls on the property and infrastructure such as bunds, or outright purchase.
2. Response modification of the population at risk through measures such as evacuation plans.
3. Flood modification measures such as retarding dams, levees, bypass floodways or channel improvements.

Herman has spent some time considering the options above and has made some preliminary suggestions:

i. Minor channel improvements can be made to a short reach of Jilliby Jilliby Creek below the confluence with Little Jilliby Jilliby Creek but this would be to address localised ponding issue and would have little impact on flood levels,

ii. Raise Sandra Street to increase the retarding storage upstream. However, the single dwelling immediately upstream at this location would be further impacted but may limit the requirements for purchase / relocation of properties in the Hue Hue precinct.

iii. Raising or relocating of three timber framed dwellings (ID - D0060 by 0.63m, D0061 by 0.86m & D0237 by 2.02m)

iv. Possible new construction of dwellings of equivalent or superior size, quality and amenity – this option is suggested for all the dwellings identified in the Flood study as being adversely affected by flood changes due to subsidence.

v. Construct grassed earthen levee(s) around dwellings to provide a minimum freeboard of 0.3m. Possible dwellings that this method may suit are D0017, D0058, D0737, D0063 and D0430.

Herman notes that with regard to the voluntary purchase of properties, while a viable option, the mechanism and form of compensation is beyond the scope of their report.

Lastly, Herman notes that WACJV is not responsible for any works pertaining to existing impacts of flooding.

9.4.2. Access

The six, primary access route low points adversely affected by subsidence related flooding can be raised after subsidence has occurred to mitigate the adverse effect. In some instances, the works may require new culvert works to facilitate passage of flood waters past the obstacles.

The impact of "raised" roads does not appear to have been considered as a sensitivity scenario for the flooding assessment and would need to be undertaken if any of these works is to be considered.

9.5. Findings

The results of the flood assessment appear reasonable given the limits of the prediction of subsidence and can be considered as "best practice". However, changes to mine plans can and almost invariably do occur prior to final approval with the associated changes to subsidence. The predicted movement may well be less but could equally be more than currently stated and so the impacts of flooding within the mined areas are also likely to vary.

The discussion on potential flood mitigation measures remain at a feasibility level but are considered appropriate and to constitute "best practice" for this level of appraisal. Detailed assessment will be required if planning approval is given and this must ensure all the Director General's requirements are met.

Notwithstanding the above an ongoing programme of review of subsidence and its impacts on flooding is essential to ensuring flood impacts are correctly assessed and remedial measures undertaken to mitigate flooding.

10. NORMAL STREAM FLOWS

10.1. General

The impact of mining on stream flows in “normal” conditions has been considered by the W2CP and is reported in Appendix J of the EIS. The assessment was undertaken by WRM Water and Environment (WRM) in 2013.

Assessments are driven by a consideration of subsidence along existing creek alignments for the Wyong River, Jilliby Jilliby Creek and Little Jilliby Jilliby Creek. Figures 29 and 30 present the profile along Jilliby Jilliby Creek and Little Jilliby Jilliby Creek respectively. A similar plot for Wyong River has not been produced due to the maximum predicted subsidence being only 150 mm at some locations.

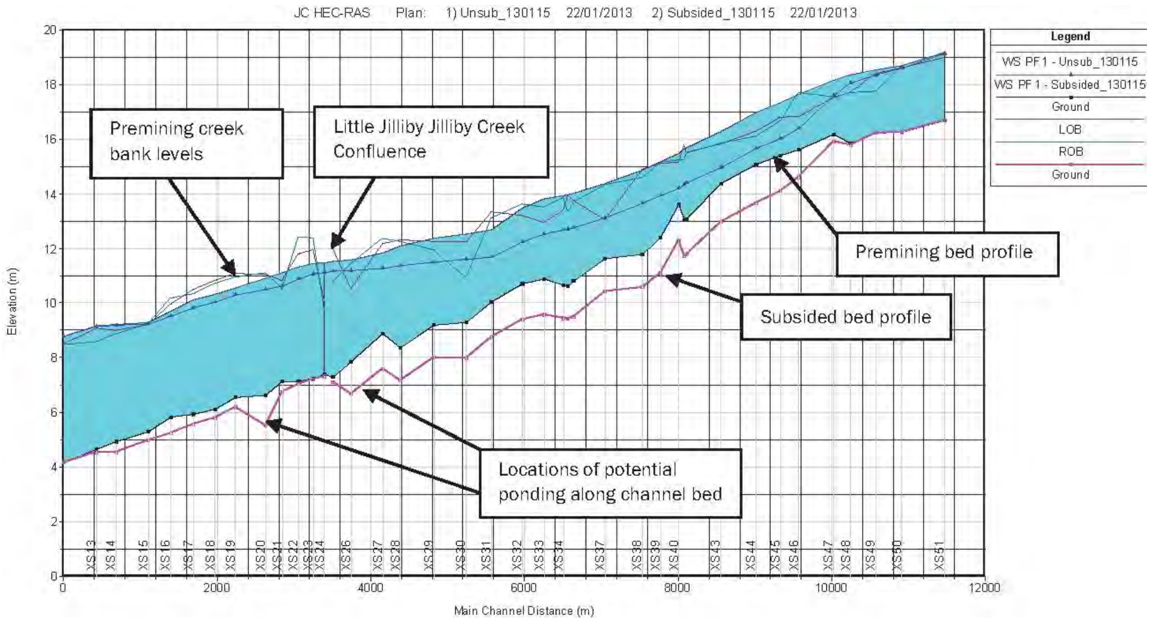

Figure 29: Pre and post mining profiles along Jilliby Jilliby Creek

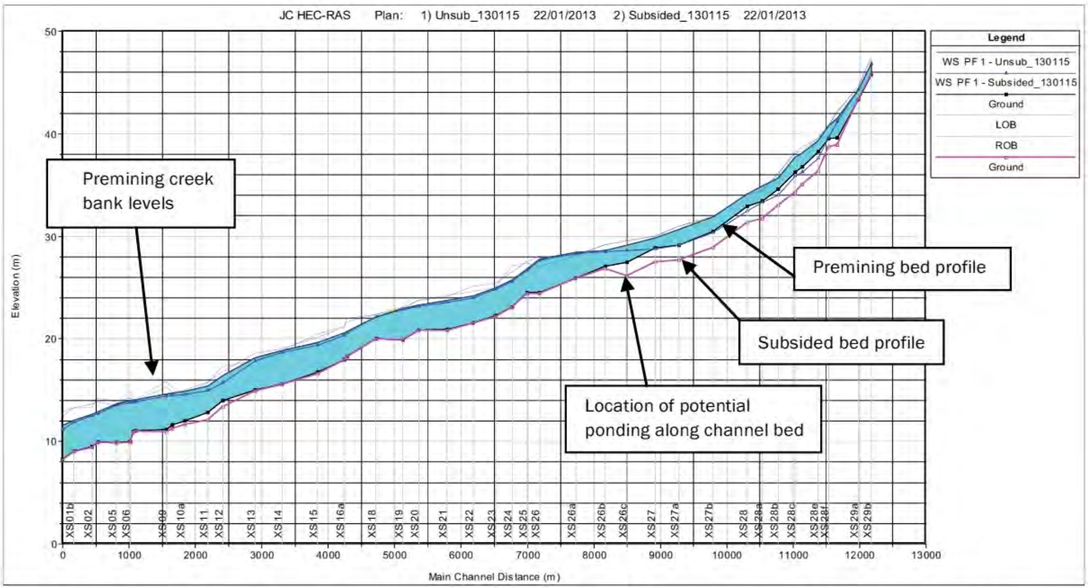

Figure 4.15 Longitudinal Section of Little Jilliby Jilliby Creek Upstream and Downstream of Jilliby Jilliby Creek Confluence, Bed and Water Levels, Pre and Post Subsidence, Bankfull Flow Conditions

Figure 30: Pre and post mining profiles along Little Jilliby Jilliby Creek

Figures 31 and 32 also present the changes in creek flow velocity as a result of subsidence for the Jilliby Jilliby and Little Jilliby Jilliby Creeks respectively. As can be seen, the maximum predicted increase in flow velocity is up to 0.2m/sec in the Jilliby Jilliby Creek and less than 0.1m/sec in the Little Jilliby Jilliby Creek.

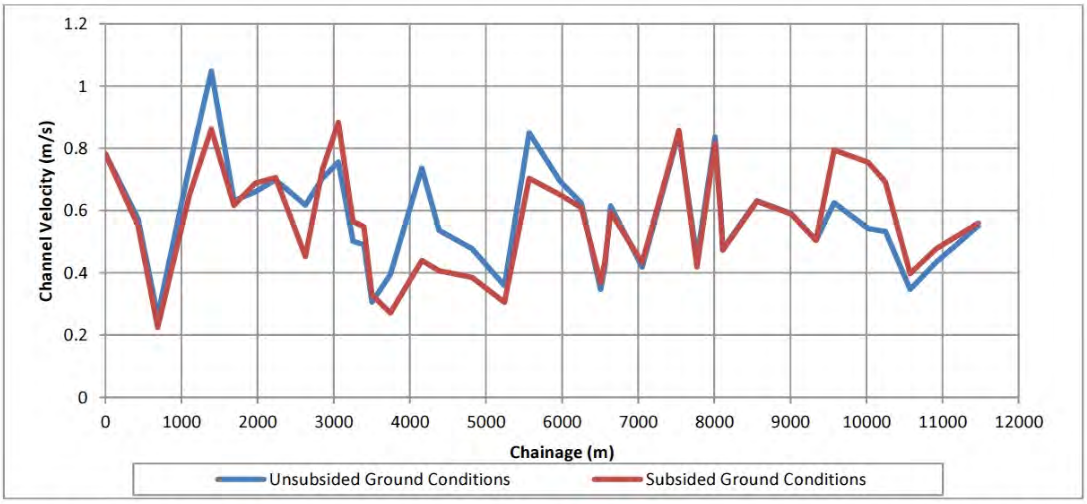

Figure 4.13 Longitudinal Section of Jilliby Jilliby Creek, Velocities, Pre and Post Subsidence, Banl Flow Conditions

Figure 31: Pre and post mining normal stream flow velocity along Jilliby Jilliby Creek

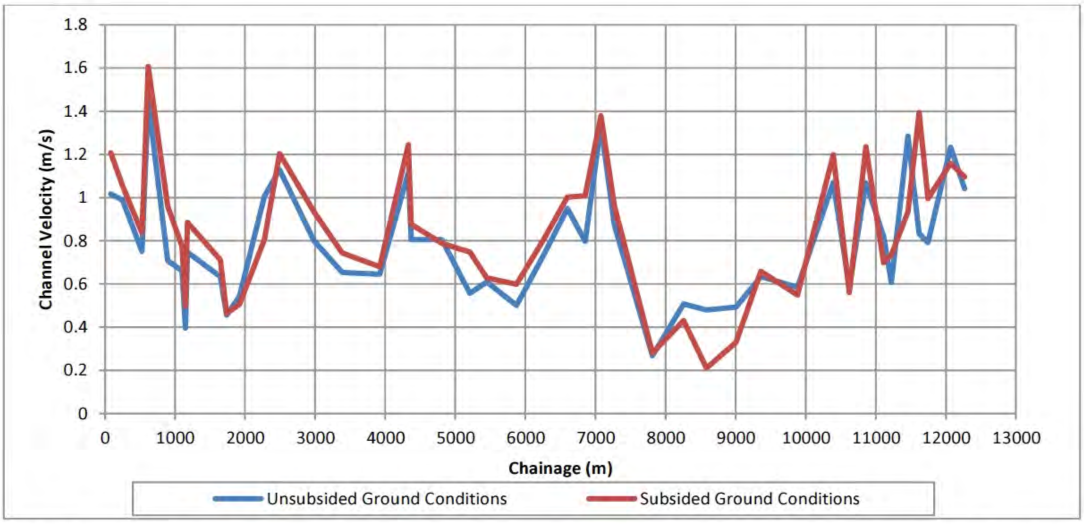

Figure 4.16 **Longitudinal Section of Little Jilliby Jilliby Creek, Velocities, Pre and Post Subsidence, Bankfull Flow Conditions**

Figure 32: Pre and post mining normal stream flow velocity along Little Jilliby Jilliby Creek

The impact of subsidence is considered by the EIS in the following areas.

a. stream levels and localised changes to the level of ponded water

b. flow velocities and impacts on erosion

c. localised widening and narrowing of streams

d. flora and fauna

e. downstream wetlands

f. water quality.

Items a. to c. are discussed in the sections below. The other items are considered outside PSM's area of expertise.

10.2. Loss of Surface Water

Loss of water into the near surface zone is critical to stream flows and the ecology of the streams. The issue of loss of surface water is discussed in Section 8.2 of this report. The reader should note that the assessment of this issue by WRM is governed by the fact that the loss to groundwater reported by MER is taken as the basis for the assessment, ie. "*It was assumed that impacts to baseflow were negligible (MER 2013)".*

10.3. Stream Flows and Ponds

In general terms, subsided areas can result in increased areas or "bowls" where additional water storage can occur along streams. Increased storage capacity can result in depravation of water flows into areas downstream of the "bowl". Where base flows are low or ephemeral this can lead to longer and/or more frequent periods of drying downstream of the pond.

Impacts upstream of any such "bowl" are difficult to interpret off the plots presented in the Figures showing the current and predicted creek longsections above. However, it is likely to be limited to less than say 500m, and in all likelihood less than say 100m.

Based on the creek long section profiles presented in the Figures above and on the EIS, "bowls" where ponding may be predicted to occur are:

1. Negligible along the Wyong River.
2. Up to about 1m depth at two locations along Jilliby Jilliby Creek, one just upstream and the other just downstream of the confluence with Little Jilliby Jilliby Creek.
3. Between about 0.5m and 1m depth along the Little Jilliby Jilliby Creek in the upland forested region toward the head of the creek).
4. Unknown along the Hue Hue Creek.

Following the points above, the potential for dry conditions, solely as a result of upstream ponding to adversely impact native flora and fauna will be minimal but could impact stream edge environments for some short distance downstream of the ponded water. However, WRM make the comment that;

> *"Inspection of the waterway* (Jilliby Jilliby Ck) *indicates that the creek is experiencing active bank erosion under existing conditions",*
>
> And that
>
> *"the main channel drainage system and sediment transport dynamics are unlikely to experience significant adverse impacts due to the project"*

Based on these statements, WRM indicate that the stream beds should readily re-level themselves, via erosion to re-establish a continuous stream bed.

This statement is expected to be correct where the ponds occur in the more silty and sandy alluvial soils along the creeklines, but may be much more limited or restricted if the ponds occur in areas of heavy clay. The timeframe for these changes depends on the soil types and also the flow velocity and frequency where the stream is ephemeral.

If ponds occur in areas underlain by rock, such as may occur in some of the forested areas, these are unlikely to be able to re-establish a continual stream bed and flows will not occur until the pond is overtopped.

Any impacts due to subsidence related ponding should be able to be effectively managed with suitable monitoring and timely response in mitigating any adverse effects. The timing of any inspections and/or testing needs to consider the fact that as subsidence effects travel across the ground surface, the "edge" of the settlement bowl results in localised deformation referred to as either tilt or sometimes travelling strain.

Where the tilt/travelling strain occurs along stream beds/banks, instability due to erosion from increased stream flows can occur. In general, the risk of mining causing an increase in erosion is most likely to occur during "normal" stream flows and smaller, albeit more frequent flood events.

The ability of the mine, locals, Council, or other authority to say what is adverse and what would or could have been expected to occur pre-mining will be nigh on impossible to ascertain and so the question what should be done in terms of mitigation or preventative works. This also impacts on who is responsible for undertaking the works.

10.4. Environmental Flows

The issue of environmental flows is beyond the expertise of PSM and comment on suitable flow volumes and/or frequency is not made.

However, while it is possible that a suitable volume of suitable quality water could be provided to the creek systems for the purpose of environmental flows, say by the W2CP in the form of treated water from that they collect from the underground mine, the benefit of any re-supply to the local waterways will be limited to the immediate stream ecology. The ability for re-supply water to the streams to fully compensate all the alluvium areas and any bores is doubtful, as discussed in Sections 9.2 and 9.3 of this report.

10.5. Mitigation and Management

WRM note that the impacts of the project on surface water resources can be mitigated through implementation of:

- Property Flood Management Plans a water quality monitoring programme for streams in the W2CP area; and
- A stream stability monitoring and management programme.

WRM suggest that the surface water monitoring in streams comprise measurement of pH, EC and TSS and be undertaken on a monthly basis, with an annual "comprehensive" suite of tests. Broadly, this level of testing is likely to be suitable but the detail on what constitutes "comprehensive" is not clear.

With regard to the management of the stream stability and remedial works, WRM propose that works comprise:

- A baseline ground survey of nominated creek cross-sections in areas of expected subsidence prior to undermining as part of the Subsidence Management Plan process.
- Development of specific measurable trigger levels (in consultation with NOW and local landholders) to enable subsidence monitoring to identify any possible unforeseen impacts to the stream system.
- Ongoing monitoring of the stream system prior to, during and after mining beneath the sections of the creek.
- A walkover assessment of key areas, particularly around the confluence of Jilliby Jilliby Creek and Little Jilliby Creek, identifying areas of water ponding, active bed and/or bank erosion and qualitative assessment of the condition of riparian and floodplain vegetation.
- Collection of photographs of creek channel and floodplain conditions.

- Preparation of a report documenting the results of each assessment with recommendations for any mitigation works that may be required. This report will specifically require a Trigger Action Response Plan (TARP) to be prepared to set aside a process for management of any unforseen impacts to the system.

WRM suggest the field assessment be undertaken quarterly and following any significant flow event. They also note that the frequency may be reduced once an area is considered stable in terms of subsidence. Broadly this set of works is appropriate.

However, it is not clear whether this approach is entirely “reactive” or will endeavour to be “pro-active” in nature. We recommend that the WACJV should act to prevent erosion rather than repair it, as this would be best practice.

10.6. Findings

The proposed approach of undertaking detailed baseline studies of the streams in the W2CP area as well as the water quality and ongoing inspection and assessment of the impacts on stream stability and flows is considered appropriate and best practice, provided the approach incorporates a pro-active approach to issues such as stream stability wherever these are identified prior to mining impacts occurring.

If the mine is approved, the issue of assessment of what is adverse, the means of measurement and assessment and mitigation must be carefully and fully detailed to prevent long and potentially futile arguments occurring. To this end, specific and measurable/quantifiable targets must be agreed and established so all parties understand where they stand.

The issue of baseflow loss was presented earlier in this report under Section 8.

11. ADAPTIVE MANAGEMENT AND MONITORING

In recent years a trend has developed for adopting, so-called, Adaptive Management to deal with uncertainties in respect to future impacts on groundwater and surface water systems from mining operations. This developed to the point that adaptive management involved changing the targets that were established in environmental impact statements in response to what actually occurred in the field. This was done in conjunction with the establishment of groundwater monitoring systems and the visual and flow monitoring in creeks and rivers.[3].

The fallacy of this approach was determined by the Land and Environment Court in a recent case (2013) in regard to the proposed expansion of Berrima Colliery. The judges found as follows with respect to Adaptive Management:

> Adaptive management regime
>
> The intention of the Water Management Plan is to provide an adaptive management regime, under which management actions would be modified in response to the results of the monitoring program. Preston CJ held that,
>
> > "in adaptive management, the goal to be achieved is set, so there is no uncertainty as to the outcome and conditions requiring adaptive management do not lack certainty, but rather they establish a regime which would permit changes, within defined parameters, to the way the outcome is achieved."
>
> It follows that it is necessary for there to be precise limits imposed on the cumulative operations of the colliery.

The judges went on to quote Judge Preston in a previous case in relation to the need for implementation of the precautionary principle when there is uncertainty in respect to future environmental impacts. They stated:

> Preston CJ held in *Telstra* at [150], the following, in regard to the precautionary principle and the shifting of the evidentiary burden of proof:
>
> > 'If each of the two conditions precedent or thresholds are satisfied – that is, there is a threat of serious or irreversible environmental damage and there is the requisite degree of scientific uncertainty – the precautionary principle will be activated. At this point, there is a shifting of an evidentiary burden of proof. A decision-maker must assume that the threat of serious or irreversible environmental damage is no longer uncertain but is a reality. The burden of showing that this threat does not in fact exist or is negligible effectively reverts to the proponent of the economic or other development plan, programme or project.'
>
> We are satisfied that the precautionary principle is activated as the risk of significant environmental harm currently remains uncertain,………

[3] For example: responses to cracking of Cataract Creek and Waratah Rivulet in the Southern Coalfields; draining of swamps at Springvale Colliery in the Lithgow area, complete depressurisation of the groundwater systems at Berrima Colliery and Ulan Colliery, and major cliff collapse at Dumbarton Colliery, Nattai North Colliery, Katoomba, Newnes and Baal Bone Colliery

The judges determined that the proposed expansion of Berrima Colliery should not proceed on the basis of Adaptive Management as was proposed by the colliery owners.

We consider that the legal findings summarised above should be taken into account in respect to the proposed Wallarah 2 project, because future impacts on groundwater and surface waters are likely to be substantial to both town water supplies in drought periods, and to agriculture and flora and fauna under even average climatic conditions. Furthermore, there are substantial uncertainties in respect to these impacts, making it possible, and even probable that the impacts will be greater than assessed by the EIS.

12. CONCLUSIONS

12.1. Subsidence

The predicted impacts due to W2CP are, in general terms:

- Subsidence up to 2.6m with less subsidence predicted in residential areas to the east and more subsidence within forested areas to the west.
- Tilts up to 15mm/m concentrated above the edges of the panels and over forested areas.
- Tensile strains up to 4mm/m concentrated near the edge of panels. About 99% of these strains are expected to be less than 2.5 mm/m.
- Compressive strains up to 5.5 m/m concentrated about 50m inside the panel edges. About 99% expected to be less than 3.3 mm/m.
- Far field movements up to ~60 mm horizontally at a distance of around 1km from mining diminishing to less than 25 mm at a distance of 2 km.
- The expected number and severity of impacts across the 245 properties within the area affected by the predicted subsidence are:
  - 83% of properties being unaffected;
  - 12% requiring very minor to minor repair;
  - 5% requiring substantial to extensive repair, and
  - <0.5% requiring a complete rebuild (ie. about 1 property)

In summary we conclude that:

- Based on our discussions with W2CP, we understand that something like 4 to 5 panels would need to be extracted before a full model calibration exercise could be undertaken.
- The reliability and accuracy of the SCT method is unknown as:
  - There is a reliance on extrapolated inputs to which the method has been shown to be sensitive.
  - The model is calibrated to site-specific data, and not to a small number of measurements from other sites.
  - The sensitivity to most input parameters is not presented.
- Due to the empirical nature of the method the Incremental Profile Method (IPM) is only as reliable as the data to which is it calibrated, in this case the SCT model results. Therefore the reliability and accuracy of the IPM is in doubt.

  This is to some extent recognised by MSEC who in the EIS state:

  "*A thorough calibration…will only be achieved after subsidence monitoring data is obtained and analysed".*
- The use of one predictive model to calibrate another is generally unwise and not widely regarded as best practice.

- The IPM is stated as being conservative and likely to over predict impacts. The evidence for this conservatism and the expected magnitude with respect to W2CP are not provided. Indeed all indications are that the model development is centred around matching expected conditions and not exceeding or over-predicting them.
- There is a reliance on pillar compression after extraction resulting in a smoother subsidence profile. However, the basis for this assumption appears to conflict the Geological Report (Appendix C), where significant variation in both roof and floor conditions is expected across the site.
- The EIS acknowledges that pillar compression may not occur but does not quantify the impacts or changes in impact should this not occur.
- First longwall will prove that this pillar compression assumption is valid.
- At least 3 longwalls (L1N to L3N) and more likely 4 to 5 longwalls are required before pillar compression theory can be verified.

We accept that these predicted impacts are in agreement with expectations based on measured subsidence impacts elsewhere, and the Newcastle and Southern Coalfields in particular.

We are in general agreement that should the predicted level of subsidence occur, the type distribution and severity of impacts on houses, buildings and infrastructure is likely to be similar to that stated in the EIS.

We do not agree that the prediction represents a conservative estimate of subsidence impacts as all the evidence presented in the EIS suggests the prediction represents the most likely impacts. We consider that the model, calibration and application of the prediction does not provide sufficient guidance as to the sensitivity and reliability of the method and may, therefore, fail the Director General's "reasonable level of confidence" test.

In general we did not find any omissions or evidence to suggest that subsidence due to W2CP is likely to be significantly different to that predicted by the EIS. Our main concern is the lack of certainty around the predictive method and the likely variation in prediction based on observed variations that are already known and potentially those unknown.

12.2. Groundwater

The conclusions reached by EIS are primarily the result of the input parameters adopted for their numerical modelling. These input parameters are primarily driven by the unsuitable method by which the makeup of the rock and its defects have been sampled and are not consistent with available data or modelling within the EIS. Further, modelling assumes recharge of the water system based on average climatic conditions.

The EIS implies that water inflow to the mine, of up to 2.5ML/day would largely come from water stored in the ground. However, it avoids the fact that water stored in the ground comes from somewhere, and is currently in equilibrium with natural recharge. A valid way to consider this matter is encapsulated in the following quotation from Dr Rick Evans, principal hydrogeologist of Sinclair Knight Merz, viz:

> *"There is no free lunch here. It's very simple – every litre of water your pump out of the ground reduces river flow by the same amount".*

Australian Financial Review,
24 May 2007

Other points to note are:

- We cannot define precisely what portions of which rivers will be affected by leakage losses from the near surface alluvial lands into the deeper rock mass;
- We cannot say, with confidence, how many years it will take for the impact of underground extraction to reflect in surface flows; and
- The EIS states that the mine will not fully recover groundwater pressures for over 500 years.

These points, combined with the uncertainty on the input parameters to the groundwater modelling there is a high probability that leakage losses from the alluvial lands will impact the surface water. Given the high likelihood or even near certainty that climate impacts would be sufficiently severe at some point implies that it may affect visible flows for long periods.

On balance, the findings from the EIS are at the least a limited and probably unconservative view of potential impacts. This means that, at present, it is not known with an acceptable level confidence what the likely impacts of the Wallarah 2 longwalls will be on groundwater resources, and on groundwater that feeds into the streams of the Dooralong and Yarramalong Valleys.

12.3. Surface Water

<u>Flooding</u>

The results of the flood assessment appear reasonable given the limits of the prediction of subsidence and can be considered as "best practice".

The discussion on the impacts of the W2CP on flooding are made in relation to the 1% AEP event (1 in 100 year) and would only fully come into effect after mining has been completed. It is important to note that the assessment of flooding is dependent on the expected subsidence and so any change to mine plans, or the prediction of subsidence through any validation process will result in changes to the extent and impact of flooding.

Results of the flood modelling for the 1% AEP flood event indicate that subsidence from the current W2CP mine plan is likely to result in only relatively minor increases in the depth and extent of flooding compared to current, pre-mining estimates with a total of about 35Ha of additional land becoming affected across the whole W2CP area.

The changes to flooding extents will have an adverse effect on up to 10 properties. The impact is assessed to be up to 5% of additional land area inundated for 4 of these Properties and up to 20% of additional land area for the remaining 6 properties.

In terms of impacts on residential dwellings, a total of 5 properties that were not previously impacted by the 1 in 100 year flood level are now impacted by flood water depths of between 4cm and 1.27m above floor level. These are assessed as being Major impacts in the system of Flood Impact Categories adopted for the W2CP. In addition to these dwellings, a further one dwelling is Categorised as being subject to a Major Impact, in this case the expected 1 in 100 year flood level increase by up to 41cm above current, pre-mining predictions.

In the moderate flood impact category, a total of 8 dwellings will see a rise in the currently predicted inundation levels due to the 1%AEP event by between 3cm and 17cm. A further 3 dwellings will have the level of clearance, or freeboard between the predicted flood level and dwelling floor level reduced to values of between 4cm and 28cm.

Minor impacts are expected to occur to a total of 10 dwellings and comprise increased levels of flooding above floor level by between 1cm and 4cm and reduced levels of freeboard above flood levels.

Further to the dwellings described above, a total of 14 dwellings are expected to have no significant change in flood impacts while a total of 49 properties will see a slight reduction in flood impacts.

Other impacts of the subsidence on flooding are flood peak flows are anticipated to be slightly reduced with a minor increase in the duration of the peak, although the EIS notes these as being insignificant.

Flooding will impact a total of 30 primary and secondary access roads in the project area. Of these, only 6 primary access route low points will be adversely impacted by the mine. Adverse impacts comprise increased duration of flooding of between 1hour and up to 27 hours. The latter time pertains to the crossing (D50) located toward the southern end of Jilliby Road just north of the intersection with Watagan Forest Drive.

Mitigation of the impacts of flooding can readily be undertaken by the WACJV. Detailed plans for each location and/or dwelling are not provided at this stage of the process and are only required after approval has been given.

At this time, the only indication of the extent of potential mitigation is in relation to the Major and Moderate Impact Categories.

Preliminary descriptions of possible mitigation works presented in the EIS comprise:

- Raising or relocating dwellings;
- Raising Sandra Street to increase the upstream flood retarding storage;
- Construction of grassed earthen levees around dwellings to provide a minimum freeboard of 0.3m; and
- Construction of new replacement dwellings.

The purchase of dwellings is mentioned as an option, but is not linked to any dwellings in the EIS, nor is any mechanism or process for such an option canvassed.

In terms of primary access points, the six adversely affected locations can be raised after subsidence has occurred to mitigate the adverse effect. In some instances, the works may require new culvert works to facilitate passage of flood waters past the obstacles. Council must be conscious of the longer term maintenance requirements of any mitigation measures.

The discussion on potential flood mitigation measures remain at a feasibility level but are considered appropriate and to constitute “best practice” for this level of appraisal. Detailed assessment will be required if planning approval is given and this must ensure all the Director General’s requirements are met.

<u>Loss of Surface Water</u>

Loss of surface water from streams in either the Yarramalong and/or the Dooralong Valley will have a direct impact on the availability of water in the Wyong River downstream of the proposed mine which is used as part of the water supply to the Wyong and Gosford Local Government Areas. Further, loss of surface water will also affect businesses such as turf farming and supply of water to local bores.

The assessment of loss of surface water is entirely dependent on the inputs to groundwater modelling and the impacts on groundwater flow by the mine. The EIS concludes that there will be very little impact on leakage from the near surface alluvial lands due to the very low permeability of the rock below the alluvial lands and, that what loss does occur will be readily compensated for by surface recharged.

These statements are based on two assumptions. Firstly, that average climactic conditions prevail and secondly, a favourable view of the permeability of the rock below the alluvial lands. The latter point is discussed above under the topic of groundwater modelling, but suffice to say there is considered to be a high level of uncertainty and a lack of factual evidence to confirm the parameters used.

With regard to the first point above, for the EIS to be relevant, it must also consider the variation in inputs to the surface water supply in extended dry periods. The review in this report considers the flow in Jilliby Jilliby Creek between 1972 and 2013 to illustrate the sensitivity of the stream flow to climate and to small variations in flow volumes, viz:

- The median flow rate in the creek is about 4.5 ML/day.
- Flows of less than 1ML/day occurred for 24% of the time
- Flows of less than 0.1 ML/day for 10% of time.

The predicted water inflow to the mine of up to 2.5ML/day represents more than half of the average flow for Jilliby Jilliby Creek and is greater than the flows recorded for 40% of the time since 1972.

These flows are put into perspective when records of consecutive days, since 1972, where low flows considered. The five longest periods of consecutive days when flow was less than 1 ML/day and 2 ML/day range from 112 up to 190 days. This shows that when dry periods occur, the flow in the creeks can be expected to be at a level that may be readily affected by leakage losses from the alluvial lands.

Further, a review of the climate during this period reveals that while some periods of drought did occur such as the Millennium Drought, it does not include the experience of the more intense droughts of World War 2, and the time of Federation.

Ponding

Current predictions of subsidence indicates three locations where increased bowls of storage in ponds along Jilliby Jilliby Creek (2 No.) and Little Jilliby Jilliby Creek (1 No.) are expected to result in longer and/or more frequent periods of drying downstream and similarly of wetting upstream of the newly created pond.

The expected extent to which the stream and adjacent lands may be impacted upstream and downstream of the pond is difficult to predict, but is not expected to be more than 500m and in all likelihood would be less than say 100m. Given the generally cleared/settled nature of the floodplain areas, the potential for drying conditions to adversely impact native flora and fauna is minimal. Any impacts should be able to be effectively managed with suitable monitoring and timely response in mitigating any adverse effects.

These conditions are expected to prevail until such time as the streams re-establish a continuous stream bed. This is highly likely to occur where the ponds occur in the more silty and sandy alluvial soils along the creeklines, but may be much restricted if the ponds occur in areas of heavy clay. The timeframe for these changes depends on the soil types and also the flow velocity and frequency where the stream is ephemeral.

The potential for ponding in Wyong River is considered negligible under the anticipated subsidence.

Subsidence profiles along the Hue Hue Creek have not been provided and so assessment of impacts of mining have not been made.

Erosion and Environmental Impact

The EIS notes that there is active erosion occurring along the banks of the Jilliby Jilliby Creek, but also that the impacts of the project on surface water resources can be mitigated through implementation of:

- Property Flood Management Plans a water quality monitoring programme for streams in the W2CP area; and
- A stream stability monitoring and management programme.

As with the subsidence and flooding, the W2CP is not required to prepare detailed management plans at this stage of the process but has included some indication on the approach and works within the specialist reports. Broadly the set of works and frequency suggested is considered appropriate but requires a significant amount of detail to allow any worthwhile appraisal to be undertaken of its likely effectiveness. However, it is not clear whether the approach is to be entirely "reactive" in nature, or whether it will include some form of "pro-active" works.

We recommend that the WACJV should endeavour act to prevent erosion rather than repair it where appropriate, as this would be best practice.

The ability of the mine, locals, Council, or other authority to say what is adverse and what would or could have been expected to occur pre-mining will be virtually impossible to ascertain and so the question is what should be done in terms of mitigation or preventative works. This also impacts on who is responsible for undertaking the works. In order to prevent this, and other similar issues from resulting in futile and circular arguments that result in nothing being achieved or done, specific and measurable/quantifiable targets must be agreed and established so all parties understand where they stand if the mine is approved.

12.4. Borefields

Borefields have been developed at Woy Woy, Somersby, Mangrove Creek, Ourimbah and Mardi for use by the CCWC as a drought contingency measure. Of these, only the single, 150m deep bore at Mardi is potentially going to be impacted by the W2CP. This bore is about 3km from the southern extent of the mine.

The Mardi bore is thought to extend into the rock of the Tuggerah Formation, or possibly to the top of the Munmorah Conglomerate. The main coal seam in this location is at a depth of about 450m to 500m.

The EIS predicts piezometric drawdown levels in the location of bore will not occur during the period of mine operations. However, drawdown of up to 5m may occur after a long period of time (500 years after mining).

These predictions appear to assume that nearly all of the water inflow to the mine is from that stored in the ground. Hence the predicted drawdown is expected to represent a worst case. If, as we consider likely, a portion of the water flowing into the mine comes from the alluvial lands above the mine, then the impacts at locations such as the Mardi bore will be less than predicted by the EIS.

12.5. Risk Assessment and Adaptive Management

In terms of groundwater impacts and to a lesser extent surface subsidence, the EIS presents an abridged assessment of the potential impacts and hazards posed by the W2CP. This situation arises as the EIS only considers risks that have been modelled by the specialist consultants and is thereby limited by the specialist assumptions and either lack of or limited sensitivity assessments. This is not considered appropriate at this stage of the assessment where transparency as to the entire gamut of potential impacts should be canvassed.

Further, the consequence rankings at the high end of assessment have been combined and limit the risk assessment process by requiring that severe, long term and/or potentially irreversible impacts must also be wide spread to warrant a high ranking.

In order to begin to allow the impacts of the project to be managed via adaptive management, the understanding of the impacts and risks must be robust and comprehensive, and quantitative in nature, not qualitative as is the case here.

The risk assessment should consider the level of risk associated with all aspects of the W2CP, and in particular those that:

a. Are associated with a high level of severity in terms of consequence,

b. Have a high degree of uncertainty surrounding the assessment/modelling,

c. Have consequences that either may not/cannot be able to be remediated, mitigated or managed once they are observed, or

d. Represent a significant degree of community concern.

The results of a rigorous, qualitative risk assessment could then be considered with respect to acceptable levels of risk, and/or a cost/benefit assessment. The latter of which may, or course result in high consequence impacts with a low risk and/or cost impact being disregarded in the final assessment of the project. However, as stated above, they all need to be considered and presented so an informed judgement/decision can be made.

In terms of the aspects of the project covered in this report, we would recommend the following be subject to a detailed risk assessment process.

1. Ground Water Impacts – test the sensitivity of the baseflow water losses with respect to hydraulic conductivity, level of subsidence induced by mining and environmental factors such as drought.

2. Subsidence Impacts – test the magnitude and location of subsidence effects with respect to items such as variability of the roof conditions of the mine and strength of pillars.

If the impacts of the mine are to be managed via adaptive management then a risk assessment is essential in order for the process to be:

i. Correctly focused; and

ii. Establish realistic and measurable targets.

Following this, and possibly with the assistance of a cost/benefit assessment, for an adaptive management plan to be effective it must be based on targets for monitoring and assessment that are:

- specific;
- measurable; and
- agreed between all parties.

Further, the targets must be accompanied by agreed responses otherwise the management system would be reduced to an impotent and disingenuous process.

Agreed responses may be as minor as “continue to monitor / watch” to potentially leaving coal below the alluvial areas unmined or even as strong as “cease mining”.

13. MANAGEMENT PLAN DEVELOPMENT/APPROVAL CONDITIONS

Measures to mitigate and/or remediate the impacts of subsidence, increased flooding of dwellings and erosion are discussed in the EIS. However, the discussions are relatively general in nature and can only be considered appropriate for the feasibility stage of the project.

The EIS and Regulatory requirements are such that detailed Subsidence Management Plans (SMPs) need only be developed in consultation with landowners, Council and other stakeholders for adversely affected properties and streams after any approval has been granted. This would be expected to invoke the “Adaptive Management” approach for the project, for which there are very significant concerns given the level of uncertainty and lack of a comprehensive risk assessment for the all the possible project impacts.

The following table sets guidance on matters such as monitoring, validation and further assessment requirements, particularly in areas where information is unclear or uncertainty on data and/or impacts is high. The guidance provided below is intended for consideration by approving authorities in the assessment of the EIS and, if applicable the setting of conditions for the approval of the W2CP.

It is possible that approval could be given subject to the satisfaction of conditions prior to commencing mining. In such a scenario it would be expected that the decision of when to assess the conditions or undertake further studies would typically at the discretion of the W2CP as the risk of not meeting any conditions is theirs to evaluate.

TABLE 12
GUIDANCE FOR FURTHER ASSESSMENT / VALIDATION AND MONITORING

ITEM / AREA OF UNCERTAINTY	IMPORTANCE (Low, Medium and High)	MEASURES
Subsidence	High	Accurate measurement of surface subsidence is expected to be undertaken by the mine if and when mining occurs. This must be calibrated against an accurate map of conditions prior to mining. The record must also include detailed survey of all properties, infrastructure and structures that may be affected by subsidence along with comprehensive dilapidation assessments. Agreement with all stakeholders and landowners must be gained as to the extent and infrastructure to be assessed for impact due to subsidence.
Subsidence Model	High	A hold point after an agreed number (possibly 5) of longwalls have been extracted and the SCT and MSEC models validated and recalibrated as necessary.
Subsidence – potential variability in modelling results.	Medium	The influence of UCS – Sonic correlation UCS – modulus correlation and stress regime on the prediction of subsidence must be validated – as is proposed by the EIS.
Subsidence – impact of pillar yielding on subsidence and the ability to validate predictions	Medium	A comparison of impacts with and without the influence of pillar yielding. A program of pillar performance measurement including convergence measurements and extensometer readings.
Mine Plan	Medium	It is likely, or even inevitable that the Mine Plan and layout of longwall panels will change during the life of the mine. This is particularly so after the process of validation of the subsidence modelling has been completed following initial mining of the first longwall panels (minimum of 4). Modification to the Mine Plan and longwall panel layout will alter the extent and location of subsidence and the location of impacts on flooding, access routes and stream flows. A clear process must be setout for the assessment and approval of revised mine plans and must include Council. Assessments of the impacts of Mine Plan change include subsidence magnitude and extent, potential impact on groundwater modelling, impact on flooding and stream flows/ponding.

TABLE 12
GUIDANCE FOR FURTHER ASSESSMENT / VALIDATION AND MONITORING (Cntd)

ITEM / AREA OF UNCERTAINTY	IMPORTANCE (Low, Medium and High)	MEASURES
Sampling of rock mass – impacts on groundwater modelling	High	In order to confirm the EIS assumption and reduce uncertainty on the extent and connectivity (tortuous) of the defect system within the "aquatard" which is relied upon in the modelling factual data should be provided. If this data is not available then within the existing mine database, or other sources additional exploration cored boreholes drilled at an angle to the horizontal plane of say 60° should be implemented. Drilling would need to be undertaken in the Dooralong Valley and in the lower reaches of the Yarramalong Valley to target rocks below the alluvial soils. Drill holes to extend to at least the base of the "constrained zone" from subsidence modelling. The location and number of such holes is not recommended here, but should be of sufficient number to provide confidence in the result when used in conjunction with other available data. These angled holes could also be used to undertake further in-situ permeability testing by means such as Packer or Constant Head testing.
Permeability of Patonga Claystone – impacts on groundwater modelling	High	Specific testing of the permeability of the rock mass below the alluvial soils in the valleys be undertaken to confirm EIS assumptions, or otherwise. The assumptions, and hence impacts of the EIS groundwater modelling must be confirmed prior to mining below any alluvial areas. Testing to be in inclined, cored boreholes. Holes must be logged to allow permeability testing to be carefully targeted to allow assessment of vertical and horizontal defects. Possible methods to test the rock mass permeability comprise; • Packer testing. • In-situ Constant Head testing. • Full scale in-situ pump testing targeting the impacts of dewatering below the Patonga Claystone formation. We acknowledged that these tests are expensive and time consuming and alternate methods may be appropriate. We recommend the former two methods be employed as a first phase of testing. Testing should comprise a suitable number of locations and successful tests to be meaningful. The final number is likely to be subject to the results of the works at the time. A minimum of 6 test holes is suggested.

TABLE 12
GUIDANCE FOR FURTHER ASSESSMENT / VALIDATION AND MONITORING (Cntd)

ITEM / AREA OF UNCERTAINTY	IMPORTANCE (Low, Medium and High)	MEASURES
Impact on Groundwater Levels	High	Should the mine be approved a comprehensive system and regime of groundwater level monitoring must be implemented. This will require a robust system of new and existing monitoring wells and/or piezometers that are able to survive the predicted subsidence impacts. Monitoring points must be read on a frequent basis and compiled into a central database which is not only open for access by Council, but the data must be reviewed and assessed for its 'meaning' on a regular basis. This system should be augmented by measurement of levels and yields from water bores in the valleys.
Impact on Stream Flows	High	Monitoring of streamflow and inputs that influence alluvial lands water table recharge must be ascertained to allow assessment of the impact of groundwater leakage/loss. Aspects that must be monitored include: • Rainfall and runoff across the catchment area for Wyong River and Jilliby Jilliby Creek, • Stream Flows – measured at multiple points along the various streams. As a minimum this must comprise o Jilliby Jilliby Creek upstream of the mine area, upstream and downstream of the confluence with Little Jilliby Jilliby Creek and just upstream of the confluence with Wyong River. o Wyong River upstream of the mine area - say at Duffy's Point, just upstream and downstream of the volcanic intrusion along the southern edge of the mine – say about 500m upstream of Chandlers Creek and about 700/800m upstream of Kidmans Lane, just upstream and downstream of the confluence with Jilliby Jilliby Ck. o Little Jilliby Jilliby Creek just upstream of the confluence with Jilliby Jilliby Creek and say just as the creek enters the upper forested area. These points could also be used to monitor water quality as necessary.

TABLE 12
GUIDANCE FOR FURTHER ASSESSMENT / VALIDATION AND MONITORING (Cntd)

ITEM / AREA OF UNCERTAINTY	IMPORTANCE (Low, Medium and High)	MEASURES
Flood Remediation to Access Roads	Medium	The impact of potential remedial works to access roadways must be understood prior to undertaking such works with regard to the impacts on future flood levels. Models for the 1%AEP and 20% AEP must be developed, assessed and agreed. Further, the method and design of remedial works and the maintenance implications for the future must be understood and agreed with Council.
Stream Stability (and ecology)	Medium	Specific and measurable/quantifiable targets must be agreed and established concerning stream stability and the impacts on erosion (as well as flora and fauna) so all parties understand where they stand if the mine is approved. This is particularly so given the very difficult nature of assessment of what is adverse and what is not as a result of the mine.
Risk Assessment	High	A detailed and comprehensive risk assessment must be undertaken to provide a framework against which reasonable adaptive management programmes can be developed, and assessed.
Adaptive Management	High	<u>Specific</u>, <u>measurable</u> and <u>agreed</u> targets or levels from monitoring **<u>MUST</u>** be established prior to any underground works to allow all stakeholders certainty about what the aims of any adaptive management programme are. These should be based on the results of a comprehensive quantitative risk assessment and possibly cost/benefit assessment. Targets may include loss of stream flows, lowering of water levels/pressures in monitoring bores and levels of subsidence. Further, the targets must be accompanied by agreed responses otherwise the management system would be reduced to an impotent and disingenuous process. Agreed responses may be as minor as “continue to monitor / watch” to as strong as “cease mining” or to quarantine sensitive areas from mining. It may be considered that it is not possible to sufficiently confirm through monitoring the level of streamflow loss. In that case it may be that a proportion of the mine inflow water is deemed to be from streams and an agreed method and distribution of this proportion of mine water is treated and repatriated to streams, users/residents and areas of significant flora.

TABLE 12
GUIDANCE FOR FURTHER ASSESSMENT / VALIDATION AND MONITORING (Cntd)

ITEM / AREA OF UNCERTAINTY	IMPORTANCE (Low, Medium and High)	MEASURES
Independent Impact Monitoring Authority	Medium	An independent body be established to install, monitor and maintain all the groundwater, surface water and surface level impacts of the mine both during and after operation – this is particularly so given the EIS stated length of impact on groundwater and uncertainty on the speed with which pillar yield may impact subsidence. This body must be guaranteed funding to not only establish the monitoring system, but to maintain it as the impacts of subsidence and the long mine life will require significant repairs and timely replacement of equipment and monitoring points/instruments. Indeed, replacement of instrument/monitoring points should not take longer than say 2 months to maintain continuity of measurements. It is also recommend the monitoring authority be given either a direct, or at the least oversight role in the assessment of impacts and on the assessment of compensation for damage/loss or the development of remedial works/measures to control/limit the impacts of the mine – judged against the specific targets of the Adaptive Management Plan – and as such must be able to undertake, or direct the mine to undertake additional investigations and/or assessments with regard to subsidence, groundwater and surface water. The records and recommendations of the authority should be available on the public record.

For and on behalf of
PELLS SULLIVAN MEYNINK

DEREK ANDERSON

REFERENCES

1. Wallarah 2 Coal Project, Environmental Impact Statement, Hansen Bailey dated April 2013.
2. Pells Sullivan Meynink (PSM) report, Wallarah 2 Coal Project, PSM1105.TR1 dated 7 May 2010.
3. Planning Assessment Committee (PAC) Wallarah 2 Coal Project Report, November 2010.
4. NSW Dept of Planning, Major Project Assessment: Wallarah 2 Coal Project (MP 07_0160 - Director Generals Environmental Assessment Report, March 2011.
5. NSW DMR, Guidelines for applications for subsidence management approvals, 2003.
6. Management of longwall coal mining impacts in Sydney's southern drinking water catchments, M. Krogh, Australasian Journal of Environmental Management 2007.
7. Report by Coffey Partners International Z302/2-BZ Coal Operations Australia Ltd, Wyong Groundwater Study, dated 22 December 1998.
8. Report by Pacific Power International, Cooranbong Colliery Life Extension Project Overburden Strata Groundwater Study dated June 1997.
9. Report by Mackie Environmental Research, Ulan Coal Mines Ltd, Continued Operations – Groundwater Assessment dated July 2009.
10. Willey, P., Ditton, S., Thorne, C., Seedsman, R., Appleyard, L., Hanson, G. and Hannan, J. (1993) Improved Recovery of Underground Coal Resources, Compatible with Surface Land Use for Residential Development, NERDDP Project No: 1355.
11. Dr Rick Evans, Principal Hydrogeologist of Sinclair Knight Merz, Australian Financial Review, 24 May 2007.
12. Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW, I.R. Forster, Engineering Geology of the Newcastle-Gosford Region, 1995.
13. A method of estimating bulk potential permeability in fractured-rock aquifers using field-derived fracture data and type curves, Mandala, Mabee, Boutt and Cooke, Hydrogeology Journal, Volume 21, Number 2, March 2013.
14. Geotechnical Engineering of Dams, Rell, MacGregor, Stapledon and Bell, Balkema, 2005.
15. General Discussion on Systematic and Non Systematic Mine Subsidence Ground Movements, MSEC, August 2007.

16. Investigation into Abnormal Increased Subsidence above Longwall Panels at Tahmoor Colliery NSW, Gale, W, Sheppard, I, Proceedings of the 8th Triennial Conference on Mine Subsidence, 2011.

17. Management of Subsidence: State of the Art, Gale, W, 8th Triennial Conference Proceedings, May 2011.